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Space-Based Communications Infrastructure for Developing Countries

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Final Report for Task Order 4

Space-Based Communications Infrastructure for Developing Countries

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List of Acronyms

ACTS	Advanced Communications Technology Satellite
AMSC	American Mobile Satellite Corporation
APA	active phased array
ASIC	application specific integrated circuit
ATDM	asynchronous time division multiplexing
ATM	asynchronous transfer mode
ATPA	active transmit phased array
BER	bit error rate
BISDN	broadband integrated services digital network
BFN	beam forming network
BITNET	packet switched network company
BNDES	National Bank for Economic and Social Development (Brazil)
BPF	band pass filter
BSS	broadcast satellite service
b/s	bits per second
CAD	computer aided design
CAM	computer aided manufacturing
C-band	4 GHz uplink and 6 GHz downlink frequency band
CASC	China Aerospace Corporation
CDMA	code division multiple access
CCIR	International Radiocommunications Consultative Committee
CCITT	Consultative Committee in International Telegraph and Telephony
CCS	common channel signaling
CICESE	Centro de Investigacion Cientifica y de Educacion Superior de Ensenada
CONUS	continental United States
CP	Certificates of Privatization
CPE	customer premises equipment
CPU	central processing unit
DAR	digital audio radio
dBW	decibels referred to Watts
DBS	direct broadcast satellite
DC	direct current
DISA	Defense Information Systems Agency
DoD	Department of Defense
DSCS	Defense Satellite Communications System
DSP	digital signal processor

DTH-TV	direct to home TV
ECCO	Brazilian LEO MSS system
EDI	electronic data interchange
EHF	commercial frequency band at 30/20 GHz; military band at 44/20 GHz
EIRP	effective isotropic radiated power
EMP	electromagnetic pulse
FAX	facsimile
FCC	Federal Communications Commission
FDMA	frequency division multiple access
FEC	forward error correction
FET	field effect transistor
FSS	fixed satellite service
G/T	ratio of antenna gain to system noise temperature
GATT	General Agreement on Tariffs and Trade
GDP	gross domestic product
GEO	geosynchronous earth orbit
GII	global information infrastructure
GNP	gross national product
GOES	weather satellite system operated by NOAA (U. S. Government)
GOS	grade of service
GPS	Global Positioning System
HDTV	high definition television
HEC	header error control
HEMT	high electron mobility transistor
HPA	high power amplifier
IMC	Instituto Mexicano de las Comunicaciones
IN	intelligent network
ISDN	integrated services digital network
ISL	intersatellite link
ISO	International Standards Organization
ITAU	Brazilian Bank
ITU	International Telecommunications Union
Ka-band	30 GHz uplink and 20 GHz downlink frequency band
kg	kilogram
Ku-band	14 GHz uplink and 12 GHz downlink frequency band
kW	kilo Watts
LAN	local area network
L-band	1.6 GHz band
LCC	life cycle cost

LDR	low data rate (up to 19.2 kb/s channels)
LEO	low earth orbit
LL	Lincoln Laboratories (MIT)
LMDS	local microwave distribution service
LNA	low noise amplifier
Mb/s	megabits per second
MDR	medium data rate (up to 1.5 Mb/s channels)
MEO	middle altitude earth orbit
MESFET	metal semiconductor FET
MHP	magneto hydrodynamic pulse
MHz	mega Hertz
Milstar	Military strategic, tactical, and relay satellite
MMDS	multichannel microwave distribution system
MMIC	monolithic microwave integrated circuit
MSS	mobile satellite service
NAFTA	North American Free Trade Agreement
NASA	National Aeronautics and Space Administration
NCS	network control station
NGO	non geosynchronous orbit
NII	national information infrastructure
NIST	National Institute of Standards and Technology
OAM	operations and maintenance
OBP	on board processing
OFND	national development fund bonds (Brazil)
OSI	open systems interconnection
PAS5	PanAmSat 5
PanAmSat	Pan American Satellite
PBX	Public Business Exchange
PC	personal computer
PEMEX	Petroles Mexico
plc	partnership limited corporation
POTS	plain old telephone service
PPP	purchasing power parity
PRC	People's Republic of China
PRI	Institutional Revolutionary Party
PSN	packet switched network
PSTN	public switched telephone network
QOS	quality of service
R&D	research and development
RMB	(Chinese $)

rms	root mean square
ROI	return on investment
RTX	rural telephone exchange
rx	receive
SCT	Secretaria de Communicaciones y Transportes
SCPC	single channel per carrier
SDH	synchronous digital hierarchy
SGLS	space ground link standard
SHF	military frequency band at X-band (8 GHz)
SNC	Secretaria Nacional das Comunicacoes (of Brazil)
SONET	synchronous optical network
SOW	statement of work
SprintNet	Sprint's packet switched network
SS/L	Space Systems/LORAL
SSPA	solid state power amplifier
STM-n	synchronous transport module, level n
SVP	satellite virtual packet
T1	1.544 Mb/s circuit
T3	44.736 Mb/s circuit
TAB	the after burst
TASI	time assignment by speech interpolation
TDRSS	Tracking and Data Relay Satellite System
TE	terminal equipment
TELEPAC	Mexico's packet switched network
TELMEX	Telefonos de Mexico
TDM	Time-Division Multiplexing
TDMA	time division multiple access
TT&C	telemetry, tracking, and command
tx	transmit
TYMNET	packet switched network company SprintNet
TV	television
TVA	Brazilian TV Station (Grupo Abril)
TVRO	TV receive only
TWTA	traveling wave tube amplifier
UHF	300 MHz to 1 GHz frequency band
UNI	user-network interface
U.S.	United States (of America)
VAN	value added network
VC	virtual channel
VCI	virtual channel identifier

VP	virtual path
VPI	virtual path identifier
VSAT	very small aperture terminal
W/G	waveguide
X.25	Packet switching protocol
X-band	7.90 to 8.40 GHz uplink; 7.25 to 7.75 GHz downlink

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Abstract

This study examines the potential use of satellites to augment the telecommunications infrastructure of developing countries with advanced satellites. The study investigated the potential market for using satellites in developing countries, the role of satellites in the national information infrastructure (NII), the technical feasibility of augmenting NIIs with satellites, and the national financial conditions necessary for procuring satellite systems. In addition, the study examined several technical areas including use of on-board processing, use of intersatellite links, frequency of operation, use of multibeam and active antennas,, and use of advanced satellite technologies. The marketing portion of the study focused on three case studies — China, Brazil, and Mexico, These cases represent countries in various stages of telecommunications industry development. The study concludes by defining the needs of developing countries for satellites, and recommends steps that both industry and NASA can take to improve the competitiveness of U.S. satellite manufacturing.

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Section 1

Executive Summary

The executive summary is organized as follows:

1.1 Background

Satellites have the potential to play a significant role in the developing nations by providing fast implementation of modern communications capability. Some applications of conventional technology are already underway in the eastern bloc nations and former CIS states, as well as in Brazil and China. These make use of existing satellites and consequently have relatively low cash flow.

The question is whether new technology satellites using multiple beam antennas, on-board processing and switching, FEC coding, etc. can offer significant advantages. Significantly higher cash flow is involved since procurement and launch of new satellites is included. However, if more subscribers are served, there may be a net reduction in user cost.

Developed nations are in the process of advancing to fiber and fiber standards. With this has come wideband service offering at T1, T3, and even higher rates such as the Metropolitan Fiber Service offerings. BERs less than 10^{-12} can support ATM/BISDN. Such advancements are regarded as essential for continued economic growth.

On the other hand, the developing countries are caught in a dilemma. They need compatible information bridges to developed nations in order to stimulate and maintain growth. However, their communications infrastructure is antiquated and incompatible with the new standards. Wideband services are rare or not available at all. Though these are recognized as needed, their economic base is often insufficient to justify wide scale fiber installation. In addition, industrial growth tends to be centered in economic and communication islands with little need for communications to areas in between. Consequently, traffic is insufficient to justify fiber and the population too poor to support large scale renovation.

Satellites could prove to be a cost effective transition technology for developing countries. They have an intrinsic national view, and could be a more economical means of interconnecting communication islands. In addition, such technologies can easily accommodate new standards (with appropriate error control). Typically, a new satellite system can be implemented in 2 to 3 years, enabling rapid emplacement of a new infrastructure for institutional and industrial support. And with a national view, the same could provide global coverage for educational and governmental support. Potential scenarios for a satellite-based communications infrastructure include:

Hubbed VSATs. Conventional hubbed VSATs are used by business and government. This is not fiber compatible, is poor for voice and regular communications, but is inexpensive and effective for occasional use service.

Hubless VSATs. Voice and other interactive hubless VSAT technology (such as the SPAR SCPC terminals) are (1) still not fiber compatible; (2) restricted in data rate; (3) expensive on a cost/bit basis; but (4) inexpensive and effective for occasional use service.

New technology satellites (lower rate ATM, BISDN) are fiber compatible, are service compatible, but have high initial expenses.

Hybrid systems (VSAT & ATM/BISDN) have the following features: (1) they are fiber and service compatible for those who need it; (2) they have economic advantages for both large and small users; but (3) they have complexity and reliability issues.

1.2 Statement of Work

This task order examines the potential market for satellite technology among developing nations, and assesses its cost effectiveness and affordability. To address these issues, Space systems/LORAL shall perform the following subtasks for NASA/LeRC to the best effort within contract resources.

Task 1. Market analysis:

a. Forecast the demand (need) for conventional (telephony, data, and video) and new (multi-media, movies on demand, interactive TV, direct broadcast, etc.) communications services by advanced satellites in the developing nations.

b. From this forecast, estimate potential revenues and determine if a potential return on investment can be positive.

c. If the return on investment isn't positive, determine what kind and size of government subsidy would make it positive. This subsidy could bootstrap the startup problem which would stimulate the economy and eventually pay for the subsidy in increased tax revenues.

d. Are the developing countries in a "catch 22" situation (need satellites for economic growth but have insufficient economic base for the first satellite?)

e. Develop estimates of quality of service (QOS) (required BERs, availability, etc.) for different communication services.

f. Determine if there is any relationship between market needs and regional climates (i.e., wet, dry).

Task 2. Technical feasibility of national infrastructure augmentation via satellites.

a. Determine if a national infrastructure augmentation (such as the Mexican Morelos or Solidaridad) is technically feasible for large geographic areas such as Brazil, China, or the Philippines. (Assess in terms of sufficient capacity, quality of service, etc.)

b. Determine the potential for: (1) conventional VSAT technology; (2) voice and interactive VSAT technology; (3) hybrid technology when applied to large geographic areas.

c. Determine if the Solidaridad concept is universally applicable (for Brazil, China, or Philippines for example)? Determine whether a large geographic area raises technical and economic issues. Compare Solidaridad with Morelos and Brazilsat for capacity and economics.

Task 3. Determine if on board processing is a net benefit or handicap.

For example, on-board processing would enable service cross-strapping on demand and beam interconnectivity on demand. In addition regeneration improves links and save power. However, a mass and power penalty comes with the required equipment. The alternative hub service may be less expensive, but remote-to-remote communications is not possible without a double hop.

Task 4. Choice of frequency band of operation (C, Ku, and Ka-bands)

a. Determine what frequency bands are favored in different regions of the world in terms of interference from existing terrestrial or VSAT systems.

b. Determine the impact of rain attenuation in different regions of the world. Can quality of service objectives be met.

c. Determine which regions are more favorable for different technologies.

Task 5. Use of multiple beam and active antenna technology

a. Determine if multiple beam antenna technology is necessary or would a shaped antenna coverage suffice. For example multibeam coverage is often necessary for Ka-band due to the need for high gain antennas to combat rain fades and the need for wide geographic coverage. Arid areas may be suitable for simple coverage in Ku or Ka-bands if there is a significant market.

b. Determine if there a net benefit from the use of active antenna technology such as the active transmit phased array. For example the increased complexity of the active antenna is offset by its superior reproducibility and adjustability which reduce manufacturing and testing expenses. In addition, one antenna design can be used for multiple applications, thus reducing development expense. The user benefits from having the flexibility to change beam coverage shapes during service.

Task 6. Use of intersatellite links

a. Determine if inter satellite links (with multiple satellites) be necessary for large geographic areas (such as Brazil, Canada, or the former CIS.

b. Determine the cost-benefit tradeoff of intersatellite links.

Task 7. Financial Analysis:

a. Determine the initial cost of a national infrastructure augmentation for large geographic areas (such as Brazil, China, or others) versus system capacity.

b. Determine how a cash rich (e.g. Singapore) and cash poor (e.g. Philippines) nation might approach financing an advanced technology satellite system.

c. Evaluate the impact of large annual inflation rates (such as 1,000% in Brazil).

d. Compare the Mexican systems with Brazilsat, PhillipineSat, and/or Solidaridad for cost and revenues versus system capacity.

Task 8. Reporting:

a. An initial telephone or video teleconference shall be held approximately two weeks after the award date to determine the relative scope and emphasis among the subtasks.

b. A final report and briefing shall be presented approximately six months after award of contract. The final briefing shall be held at NASA Lewis Research Center in Cleveland or via video conference if mutually agreeable.

1.3 Organization of Report

Table 1-1 gives the organization of this Final Report by section. The first section is the Executive Summary which contains an overview of the results. Section 2 gives the role of satellites in the national and global information infrastructure. Sections 3, 4, and 5 give market case studies for China, Brazil, and Mexico. Section 6 summarizes the market analysis for developing countries. Section 7 discusses the technical feasibility of NII augmentation via satellites. Section 8 presents a financial analysis for developing countries, Section 9 presents our conclusions, and Section 10 lists the references.

The appendices discuss specialized topics that apply to satellites for developing countries. Appendix A discusses the use of on-board processing; Appendix B discusses the choice of frequency band of operation; Appendix C discusses the use of multiple beam and active antenna technologies; Appendix D discusses the use of intersatellite links; and, Appendix E contains a discussion of technologies to enable low cost satellite communications.

Table 1–1. Organization of the Final Report

Section	Contents	SOW Subtask
1.	Executive Summary	–
2.	Role of Satellites in the NII and GII	1
3.	Case Study – China	1
4.	Case Study – Brazil	1
5.	Case Study – Mexico	1
6.	Market Analysis for Developing Countries	1
7.	Technical Feasibility of NII Augmentation via Satellites	2
8.	Financial Analysis for Developing Countries	7
9.	Conclusions	–
10.	References	–
A.	Use of On Board Processing	3
B.	Choice of Frequency Band of Operation	4
C.	Use of Multiple Beam and Active Antenna Technology	5
D.	Use of Intersatellite Links	6
E.	Technologies to Enable Low Cost Satellite Communications	–

Table 1-2 is a compliance matrix which tells where to find the answers to the Statement of Work tasks (from subsection 1.2) in this Final Report.

Table 1–2. Compliance Matrix

SOW Task	Contents	Report Section(s)
1.	Market Analysis	6 (also 3, 4, 5)
a.	Demand for conventional and new services	6.3
b.	Potential revenues	8.1
c.	Need for government subsidies	8.2
d.	Need satellites to pay for economic growth?	8.3
e.	Estimates of quality of service	6.3.3
f.	Relationship between market and climate	6.3.4.3
2.	Technical feasibility	7 (also 2, E)
a.	Feasibility for large geographic areas	7.1
b.	Potential for conventional, interactive, and hybrid VSAT technology.	7.2
c.	Is Solidaridad concept universally applicable?	7.3
3.	Is on-board processing a net benefit?	A.6 (A)
4.	Choice of frequency band of operation	B
a.	Interference from terrestrial and VSAT systems	B.2
b.	Impact of rain attenuation	B.2
c.	Which regions are favorable for different technologies.	B.4
5.	Use of multiple beam and active antenna technology.	C
a.	Is multiple beam technology necessary?	C.4
b.	Net benefit from use of active antenna technology	C.4
6.	Use of intersatellite links	D
a.	Necessity for intersatellite links for large geographic areas	D.2
b.	Cost - benefit tradeoff	D.2
7.	Financial analysis	8
a.	Initial cost of national infrastructure augmentation	8.4
b.	Financing for cash rich and cash poor countries	8.5
c.	Impact of large annual inflation rates	8.6
d.	Compare Mexican systems with others for cost and revenues versus system capacity.	8.7

1.4 Summary of Results

The summary of results is divided into five parts: (1) market analysis; (2) technology assessments; (3) technical feasibility of NII augmentation via satellites; (4) financial analysis; and (5) recommendations.

1.4.1 Market Analysis

Over the next ten years, the geostationary market will still be dominated by conventional C-band and Ku-band transponder satellites. Emerging markets that justify the expenditure of internal R&D monies are in technologies that compete in the DBS and MSS markets.

From the standpoint of the overall satellite market, developing nations represent less than one-quarter of the total market, and while significant, it is questionable whether any manufacture would be willing to invest large sums of R&D to develop unique satellite hardware for that market. However, the satellite market in the Asian-Pacific region is growing, and companies may want to approach this region as a niche market and develop technologies for this specific region.

It is unlikely that developing countries have the foreign capital necessary to develop unique satellite technology themselves. It would seem more prudent for them to use existing technology, perhaps extended a bit, and maintain overall compatibility with satellites developed in the West. Furthermore, they can leverage off the West's development of new technology.

This compatibility with the West extends to the quality of service (QOS) developing countries will establish within their own networks. As developing countries interconnect into the world telecommunications infrastructure, they will be under pressure to have compatible service quality in order to conduct business. Therefore, the developing countries will likely impose ITU standards on their telecommunications systems.

1.4.2 Technical Feasibility of NII Augmentation via Satellites

Developing countries each want to improve their individual nation's basic telecommunication services (telephone, television, and narrowband data). We call these conventional services. To completely wire large countries such as China and Brazil would require large investments in both time and money that many developing countries lack. Therefore, developing countries will use wireless systems to supply basic telephone service and narrowband data, broadcast and cable systems for television services, and VSAT networks for large private data networks. For interconnecting telephone exchanges or where widespread distribution of TV is desired, developing countries will use satellites to augment their telecommunications infrastructure.

Today, China, India, Brazil, Mexico, and the Philippines each augment their telecommunications infrastructure with satellites. China currently uses satellites of similar design as Solidaridad, but with less power, to augment their terrestrial telecommunications infrastructure. These satellite primarily carry public switched telephone network (PSTN) services, broadcast television and radio signals, and private VSAT data networks. In this way, satellites such as Solidaridad can augment the telecommunications infrastructure of a large country.

For developing countries, conventional VSAT networks are best suited to meeting the needs of private business customers and rural telephone exchange interconnectivity. Conventional satellites provide the best near-term cost-benefit for these applications, but as the capacity demands of the rural areas rise, the incorporation of technologies that increase the capacity of PSTN services could improve the cost-effectiveness of satellites. At the point where the demand for PSTN capacity exceeds the capability of conventional satellites, transition to a hubless or hybrid VSAT system may become necessary. It is certainly feasible to incorporate switching on board a satellite resulting in a hubless VSAT system. However, the transition to such a system is a key issue that developing countries would have to face. Not all exchanges could transition at once, therefore, older hubbed VSAT systems would have to coexist with newer hubless VSAT networks. This could become very difficult. Furthermore, the terrestrial system may have had the time to install fiber optic systems that could compete with advanced satellites. In summary, hubless and hybrid VSAT networks could be used, but developing countries demand conventional VSAT systems and the lower associated costs will dominate their decisions.

1.4.3 Specific Technology Assessments

1.4.3.1 On-board Processing

On board processing (OBP) imposes a burden in terms of mass, power, volume, and thermal impact on the satellite, compared with a bent pipe transponder satellite. This impact is directly related to the data throughput. Thus the impact is considerably more for a multi-gigabit DBS satellite compared to an MSS satellite with several Mb/s throughput.

OBP technology is immature and not generally being used on current satellites, with the exception of experimental satellites such as the NASA ACTS. However, a number of satellite concepts have been proposed (Spaceway, Teledesic, Inmarsat-P), and some are even under construction (Iridium, Odyssey), that need on-board switching and thus incorporate OBP technology. Thus for the proper application, OBP is judged to be a net benefit by the commercial market place. OBP with digital switching and intersatellite links make a good combination for those system architectures that require routing of traffic between satellites (e. g., Iridium, Odyssey, Inmarsat P, and Spaceway).

For telecommunication applications that require switching, OBP and switching on the satellite may be desirable. However, the increased cost of OBP satellite services may preclude their usefulness for developing countries. Although OBP can be used for MSS applications (4.8 kb/s voice to 64 kb/s data services), developmental challenges exist to reduce the cost of OBP for high data rate FSS services (switched fractional T-1 supplied from satellites of several Gb/s capacity).

1.4.3.2 Frequency Band of Operation

For FSS band, the choice is between C, Ku, and Ka-bands. As seen from the summary in **Table 1-3**, the higher frequency bands tend to have more spectrum and orbital slots available, but more expensive technology and higher rain margin. The conclusion is to use the lowest frequency that can supply the service, possibly using both C and Ku-band transponders on the same satellite if more capacity is required. Use of Ka-band would require special circumstances such as need for narrow spot beams and/or large bandwidths for high data rates.

Table 1-3. Advantages and Disadvantages of Different Frequency Bands

Freq. Band	Freq. Range (GHz)	Advantages	Disadvantages
L	1.6	MSS service band (uplinks)	Narrow bandwidth, large antennas.
S	2 – 2.5	MSS service band (downlinks)	Narrow bandwidth, large antennas.
C	4 – 6	FSS band. Mature, low cost technology	Spectrum is crowded. Interference from terrestrial microwave links.
Ku	12 – 14	FSS band. Smaller antennas feasible, or more gain from same size antenna.	Spectrum/orbit is becoming crowded. Limited DBS power allowed. More rain margin needed.
Ku	12 – 17	BSS band. High power DBS service allowed.	Wide orbital slot spacing. More rain margin required.
Ka	20 – 30	Wide bandwidth available (1 GHz to 3 GHz)	Immature, expensive technology. Rain attenuation outages.

Interference from existing communications systems and industrial operations is likely to be less in developing countries. In particular, terrestrial microwave relays may not exist, and thus will not place restrictions on ground terminal locations. Thus a general conclusion is that C-band and Ku-band may be more generally available. However, the situation may change rapidly if the local government decides to open up a frequency band for terrestrial use, such as Ka-band LMDS for TV distribution.

Rain attenuation is different in different regions of the world, particularly the wet tropical areas. Unless satellite EIRP and ground station size is adjusted, quality of service will suffer in these regions. The primary factor to suffer will be the availability of service during times of heavy rain. C-band service will have few problems; Ku-band service will have moderate loss in availability; and Ka-band service will have significant drop in availability (98% availability is likely design point, and will require use of larger terminals). Tropical regions favor C-band and Ku-band services, and while temperate regions favor Ka-band services. High rainfall regions should avoid double hop (conventional) VSAT services at Ku and Ka-bands.

1.4.3.3 Multiple-beam and Active Antennas

For fixed coverage area applications, such as DBS over CONUS or Intelsat-type hemi and zone beams, satellite manufacturers are using shaped beam antennas instead of multiple beam antennas. There are several advantages with shaped beam antenna technology:

- There are much fewer feed horns, and beamforming network complexity is reduced. Thus antenna hardware cost is somewhat reduced.
- The computer program design for the antenna is extremely good, and thus antenna range testing can be eliminated with confidence. This results in a very large savings in manufacturing cost. The multiple beam antenna requires range testing for adjustment of the complex beamforming network.

Multibeam antennas may be necessary for applications which require multiple beams to achieve higher gain, either via fixed or scanning beams. Examples of such services include high data rate point-to-point service, or use of high gain to reduce user terminal size and cost.

Current communication satellite payloads are generally not using active phased array antenna technology due to cost and performance issues. Both low efficiency and thermal dissipation are technical barriers to implementation of transmit phased arrays. Present technology has mass and power penalties. Phased arrays show promise for advanced applications where the flexibility to reconfigure on orbit is a benefit, and in low earth orbits where beamwidths are wider, and gain requirements are less. Satellite manufacturers, together with Government agencies, are spending considerable R&D in developing active antenna technology for use with advanced communications system concepts such as Iridium and Teledesic.

1.4.3.4 Intersatellite Links

The use of multiple satellites may be necessary to cover the geographical area of a large country due to reasons of single satellite capacity and better elevation angle in the sky as viewed from the user locations. The availability of orbital slots, or interference issues, may favor satellites being located even beyond the geographical longitude extent of the country.

In general, intersatellite links are to be avoided since they impose additional mass and power penalties on the satellite, and thus reduce the remaining payload capacity to carry uplink and downlink traffic. However, if there is significant traffic that must be transmitted to/from a neighboring satellite, there is less impact on the satellite to use an intersatellite link versus uplinks and downlinks passing through a ground installation.

The conclusion is that a developing country using conventional satellites does not need ISLs. Any interconnections between satellites can be accomplished via ground links. If advanced satellites are used, ISLs are a better way to carry traffic between satellites, providing their is sufficient traffic. Thus, the use of ISLs depends on the volume of traffic and the existence of satellites with OBP.

If ISLs are chosen as the optimal approach, an optical ISL solution will offer greater mass and power savings over an RF ISL solution. However, optical technology advancement must occur before an optical system is feasible. An RF solution (at 60 GHz) is already flight proven on military missions, and the technology and space qualified components currently exist.

1.4.4 Financial Analysis

The marketing analysis shows that the developing countries primarily need conventional satellite services. Competition within the conventional satellite service market limits profit margins and forces satellite manufacturers to supply the highest capacity satellites at the low-cost. This means that manufacturers, to minimize cost, will evolve existing hardware designs rather than adopt a revolutionary hardware technology. Advanced technology satellites with their associated higher costs can compete within the conventional satellite market place provided that the capacity improvement exceeds the increased cost to obtain that increased capacity. This assumes, of course, that the market does not become saturated with satellite capacity. A saturated market would further drive transponder lease prices down, possibly causing the return on a high-cost satellite to become negative.

In the area of newer or advanced services where the market place is not so competitive, advanced satellites have more financial room to play with. Newer more advanced services have less competition and operators can charge more for these services. As such, the profit margins are higher and satellite manufactures can assume more financial risk to adopt newer hardware technology with the promise of higher payoff (i.e., selling more satellites). Eventually, this service market will also become mature forcing service prices down and squeezing profits. However, for both conventional and advanced services, subsidies should not be required to achieve profitable operations.

The cost of supplying telephone service by conventional satellites is three times that of terrestrial system. A satellite voice grade circuit (VGC) costs $3,000 whereas a terrestrial circuit costs approximately $1,000[1]. This means that countries

[1] Costs include both user terminal equipment and satellite (or terrestrial network) costs. The costs are the total costs that must be recovered by operating revenues of the system.

that want to supply telephone services via satellite must somehow provide a $2,000 subsidy per line or somehow provide for the sharing of terminals.

Developing countries could incrementally buy the satellite capacity they need from Intelsat or regional satellite operators. When their needs exceed the available capacity of regional satellites, they can consider the purchase of a national satellite. In this way, developing countries can supply the capacity a country needs while avoiding large up-front costs. In some instances, however, nations will purchase satellites as a source of revenues by leasing transponders to other countries in the region.

1.4.4 Recommendations

The West will lead the world in developing advanced technology, and it will likely be its own customer for this advanced technology. Where U.S. satellite competitiveness becomes an issue is in the area of conventional bent-pipe satellites. Here competition from Europe, Japan and China will become apparent. To compete, the U.S. must quickly produce low-cost satellites with higher capacities than other satellite manufacturing countries. Price competition has lowered profit margins in the satellite industry forcing it to become more cost conscious and to extract economies from specialization. The recent series of mergers and acquisitions support this trend.

Just as the automotive industry had to reduce the cost of car production through the application of new production techniques (and technology), so must the satellite industry. However, unlike the car industry the satellite industry is a low volume industry. In fact, the sale of a single satellite is comparable to the sale of 5000 cars. Annual sales for a satellite manufacture equal the sale of 15,000 to 20,000 cars. Furthermore, the transportation costs for satellites (i.e., launch and orbit raising) account for almost half of the total satellite costs. Thus, satellites have a very high fixed non-recurring cost to deliver their services. Below, we offer specific recommendations to address U.S. satellite manufacturing competitiveness.

Recommendations for Industry

In the end, lower user costs will make U.S. satellites more competitive on the world market. Lower user costs means lowering the cost per unit capacity. There are three ways to lower the cost per unit capacity; (1) increase the capacity of for a fixed satellite cost, (2) lower the satellite cost, and (3) lower the non-recurring user equipment costs. Since satellites are low volume production items, development costs are spread over only a few units. One way to lower the costs for satellites is to invest in both technologies and industrial techniques that lower the development costs of satellites. This could include computer-aided design software and techniques specific to the satellite industry, development simulation techniques that permit the testing of satellites designs prior to hardware development, and supporting industrial techniques that minimize the time and labor required to develop and produce new satellite designs.

Recommendations for Industry and NASA

The second way to lower the cost per unit capacity is to increase the capacity of satellites where the cost of these satellites remains relatively fixed. This means that any new technologies that increase the capacity must be able to be produced with the same cost of materials and labor as for previous satellite systems. Alternately, if the new higher capacity payload costs more to produce, it must save costs somewhere else in the satellite. There are many possible technologies that can increase the capacity of satellites as listed in Appendix E, but for developing countries the technologies that increase capacity must increase the capacity of satellite to carry conventional services (i.e., voice, TV and narrowband data) In addition, any payload that incorporates these new technologies to increase capacity must maintain reasonable compatibility with the country's terrestrial systems. High power, satellites, on-board thin route switching payloads, multiple beam satellites are some of the technologies that may accomplish this goal.

A third way to reduce user costs is to lower the user equipment costs. Lower user costs generally means smaller, simpler terminals. Higher satellite RF power and satellites with larger satellite G/Ts will directly result in smaller terminals. High efficiency solar cells, high voltage buses, high power output multiplexers, high power RF amplifiers, low noise receivers, and high gain antennas can all improve user link margins and reduce terminal size. Both large scale integration of satellite modems and high efficiency RF amplifiers would simplify user terminals and improve their reliability.

In addition to lower costs, users must have easy access to the information infrastructure and that network must assure the privacy of their information. In particular, industry and NASA need to adopt standards for the interoperability of satellites and terrestrial systems, and they need to establish methods and standards for the authentication and privacy of user data.

Recommendations for NASA

NASA faces the challenge of supporting the U.S. satellite industry and while protecting the proprietary rights of individual U.S. companies. We recommend that NASA support both the development of advanced satellite production tools and techniques and the development of low-cost high capacity satellite designs, but at the precompetitive stage. For example, in the area of satellite production processes, we recommend NASA :

- Develop general simulation software libraries that are available to U.S. satellite manufacturers

- Develop a CAD/CAM workstation skeleton that U.S. manufacturers could build upon using their own proprietary software and processes
- Collect a single satellite market data repository that supplies information of the activities and technologies of international satellite manufacturers
- Investigate high risk precompetitive technologies for improving satellite capacity. High risk technologies are technologies that industry cannot afford to fund with their own R&D funds.

In taking these steps, NASA can continue to preserve US competitiveness in the international satellite market place and directly support the growth of the U.S. satellite industry well into the next century.

Section 2

Role of Satellites in the NII and GII

This section seeks to look into the future and to predict the role of satellites in the communications infrastructure of the world. Current terminology refers to the national information infrastructure (NII) and the global information infrastructure (GII). The result is a general picture of the future telecommunications environment and the role of communication satellites. The next three section (Sections 3-6) will focus on market analysis for developing countries. This section is organized as follows:

2.1 Introduction

This is a time of rapid change in the telecommunications industry. Technology advances such as fiber optics and digital processors have enabled greatly reduced cost and much wider bandwidth communications. The increased computer power available from microprocessors enables use of the CDMA and TDMA multiple access schemes for economic bandwidth sharing. New protocols such as BISDN and ATM increase the effectiveness of communication channels by allowing simultaneous transport of voice, data, and video information from multiple users.

These technology advances have changed the regulatory paradigm. Communications is no longer a "natural" monopoly. Many different business entities can economically compete for the same user services, as witnessed by the current explosive growth in cellular traffic and the beginning competition for the cable television market by direct broadcast satellite (DBS). New services such as GPS (global positioning satellite) have "escaped" from their regulatory agency (DoD) and are the basis of a booming industry. Other potential communication "solutions" such as the Globalstar and Iridium mobile satellite services are in process of construction and deployment. Many other ideas such as Teledesic are "standing in the wings" waiting for regulatory approval and financial market funding in order to proceed. The United States and other countries of the world are trying to change their regulatory structures to allow new communication service flexibility.

Defining the role of satellites in developed or developing countries is particularly difficult in the current telecommunications environment. Many communication services of the future have not yet even been defined, and there is no history of use patterns for the digital communication network now being implemented worldwide. The problem is to gain an understanding of the trends and discontinuities – technological, lifestyle, regulatory, demographic, and geopolitical – that are transforming the current communications boundaries and creating new business opportunities.

Customers are notoriously lacking in foresight. In 1980, how many were asking for fax machines, pagers, cellular telephones, personal computers with printers and local area networks, handheld global navigation systems, and a host of other products that are common today? What range of benefits will consumers value in the products of tomorrow? The market projection of this section seeks to address those communication needs that current customers can't yet articulate, but would love to have satisfied. The situation is illustrated in **Figure 2-1** [1].

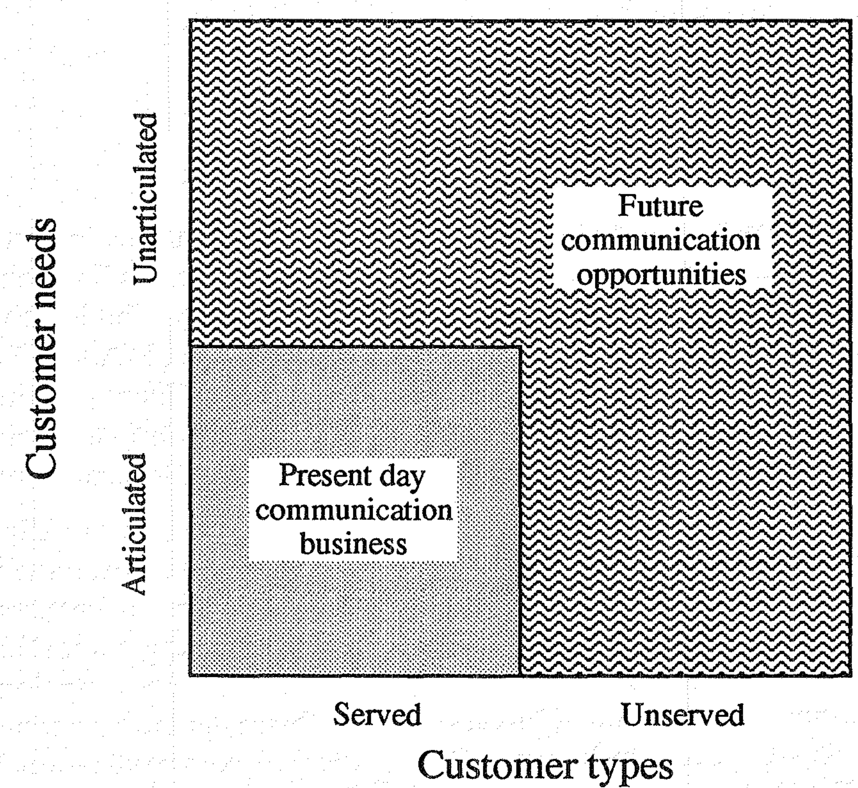


Figure 2-1: Future Opportunities for Communication Services

2.2 Definition of NII and GII

The information infrastructure is defined in a general sense as "the facilities and services that enable efficient and affordable creation and dissemination of useful information". The "information highway" analogy is best made with the entire transportation infrastructure including all roads (interstate, urban, and rural), plus railroads, ships, and airplanes. Our current NII (national information infrastructure) consists of the PSTN (public switched telephone network), satellites, fiber optic cables, cellular systems, microwave links, and radio and television broadcast stations, plus switches, computer terminals, data banks, telephones, cameras, etc. The GII (global information infrastructure) extends to encompass the world, interconnecting other nation's NIIs.

Vice President Gore [2] identified five principles for the NII which will be built and maintained by the private sector:

1. Encourage private investment
2. Promote competition
3. Create a flexible regulatory framework that can keep place with rapid technological and market changes
4. Provide open access to the network for all information providers
5. Ensure universal service

Table 2-1 lists personal services by location provided – mobile, home, or work. **Table 2-2** contains a listing of potential NII/GII services [3]. The services are in seven general areas: manufacturing, electronic commerce, health, education, environment, library, and government services.

Table 2-1: Personal services as a function of location

Mobile	Home	Work
Voice	Voice	Voice
FAX	FAX	FAX
PC access and networking	PC access and networking	PC access and networking
Video wristwatch (interactive)	Video phone	Video phone
—	Community networking	Community networking
Entertainment, video & audio	Entertainment, video & audio	—
Mobile office	Work at home	—
—	Shop at home	—
—	Interactive video	—
Paging	—	—
Location and positioning	—	—

Table 2-2: NII and GII Services

<u>Manufacturing</u>

Electronic data interchange
- electronic inventory
- automated ordering, shipping, delivery, assembly, tracking of parts, assemblies, and final products

Distributed CAD/CAM

Teleconferencing, video phone

Training, interactive video

Supercomputer access

Electronic solicitations, bidding

Access to planning tools
- knowledge bases
- simulation, CAD/CAM tools

<u>Electronic Commerce</u>

Electronic funds transfer
- billing
- payments

Electronic advertising

Electronic sales
- multimedia shop-at-home
- catalogs, product information

Virtual corporation
- integration of manufacturing, distribution, supply, and sales

<u>Health</u>

Electronic data interchange (EDI)
- enrollment, eligibility, billing, claims payment

Physicians data query
- state-of-art therapy
- latest clinical trials

Database access
- diseases, incident rates, demographics

Wideband services
- teleradiology
- telemammography
- other tele-imagery for remote diagnostics and counsel

Table 2-2 (cont.): NII and GII Services

<u>Education</u>

Life long learning
- retraining, specialization, literacy, professional development, etc.

Remote instruction
- broadcast

Interactive classroom
- tele-education for specialty instruction: gifted students, handicapped students, specialty instruction to rural students.

Teacher resource materials
- lesson plans
- simulations, animations, specialty graphics
- peer bulletin boards
- electronic mail

Database access

Library access

Multimedia "help"

Collaborative research
- information bulletin boards

<u>Environment</u>

Integrated environmental monitoring
- assessments of economic impact of floods, drought, insect infestations, plant diseases.
- weather monitoring, prediction, reporting, warning

Database support

<u>Libraries</u>

Electronic publishing and conversion
- Store and share knowledge, history, culture

Interoperability standards between networks
- Help provide information equity for the public (universal access)
- Sources of free (or inexpensive) digital information

Copyright management

Archival
- Collection of information beyond traditional libraries: publishers, research organizations, universities, commercial enterprises.

Navigation and retrieval tools

<u>Government Services</u>

Integrated access to government information and services

Electronic tax and benefit transfers

Electronic data interchange (EDI)
- electronic processing of procurements, contracting, payments.

Interoperable Federal, state, local government data communications
- intergovernmental tax filing, reporting, payments, processing.
- national law enforcement, public safety network

Analogous to the OSI model, the NII (or GII) can be considered in three parts:

1. Physical layer which consists of facilities such as cables, transmitters, receivers, satellites, ground terminals, computer terminals, telephones, etc.
2. Services layer which consists of interfaces, directories, indexes, electronic mail, security, search, retrieval, EDI, billing, etc.
3. Applications layer which represents knowledge and processing such as CAD/CAM, electronic commerce, health care, education, digital libraries, entertainment, home shopping, government programs, etc.

A significant issue is the idea of universal service in the NII. The United States government has traditionally required the regulated telephone companies to provide subsidies to encourage universal coverage for telephone service. The subsidy has been from business to residential, and from long distance to local calls. The new universal service proposed by Vice President Gore has no agreed upon definition, but must include at least:

- Digital service
- Complete connectivity
- Useful bandwidth
- Adequate terminal and user interface

Cost will rise steeply with type of user equipment and available bandwidth, and could pose an significant obstacle to implementation if imposed by Government. This suggests subsidies are needed in a competitive market.

Interactivity will be a key difference of this future NII digital network from the information infrastructure of today. Mass media (such as television, radio, large circulation newspapers and magazines) necessarily aim at the lowest common denominator to maximize their audience. However, on-line networks such as America Online, CompuServe, the Internet, and Prodigy allow, for a few dollars a month, users to find friends and allies and to obtain information. Users of the future are likely to seek out their own information on selected topics, and to the depth of their personal education. This will be an interactive process with questions and answers, and data assembly from a variety of sources via "personal agent" software operating independently of and preprogrammed by the user.

2.3 Roles of Satellites in the NII and GII

In July - August 1994, an Industry Workshop (facilitated by NASA and DISA) addressed the role of communications satellites in the information infrastructure. This subsection briefly summarizes some of the findings of this workshop. A number of satellite features can be listed:

- Can provide connectivity of everyone, everywhere.
- Enables rapid development and global interconnectivity communications infrastructure at low cost.
- Provides immediate NII development in developing countries.
- Cost is not distance dependent.
- Allows user mobility on land, air, and sea.
- Immune to natural disasters; supplies quick restoration of services.
- Provides high data rate capability.
- Complements and expands utility of existing communications networks.
- Permits simultaneous distribution of information to numerous users.

Figure 2-2 illustrates the roles of satellite today. Clearly satellites are an integral part of the NII and GII. There are presently over 200 commercial communications satellites in orbit, with a current global market valued at $15B annually [4]. **Figure 2-3** shows the communications options available to the residential user today. **Table 2-3** shows the trends in information services.

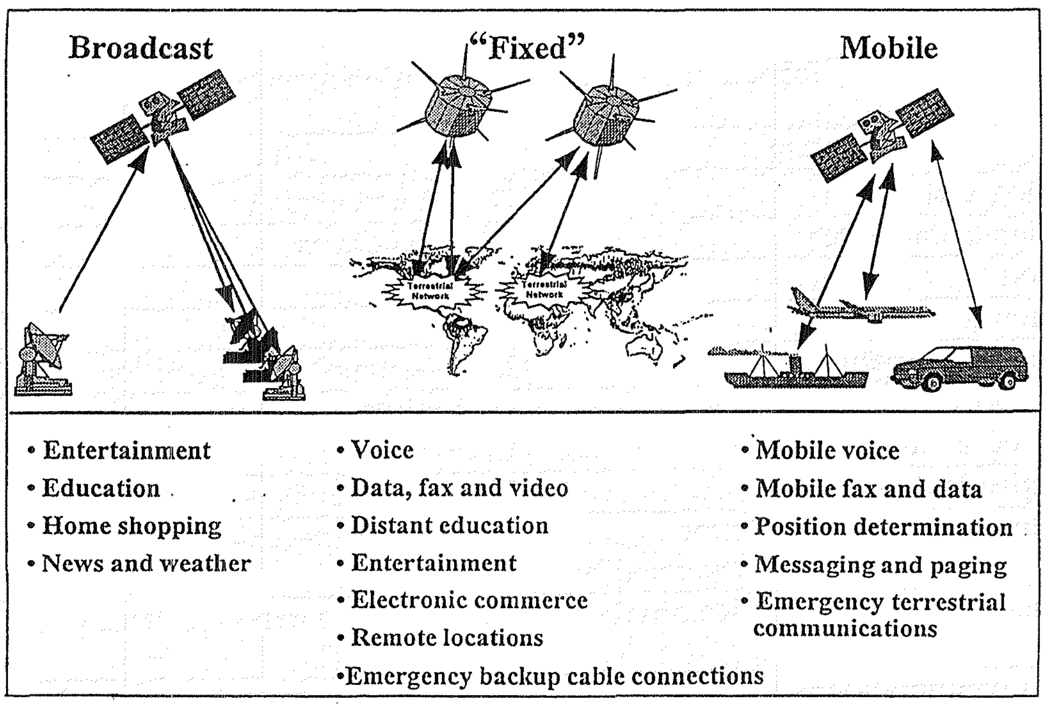


Figure 2-2: Satellites today are an integral part of the NII/GII

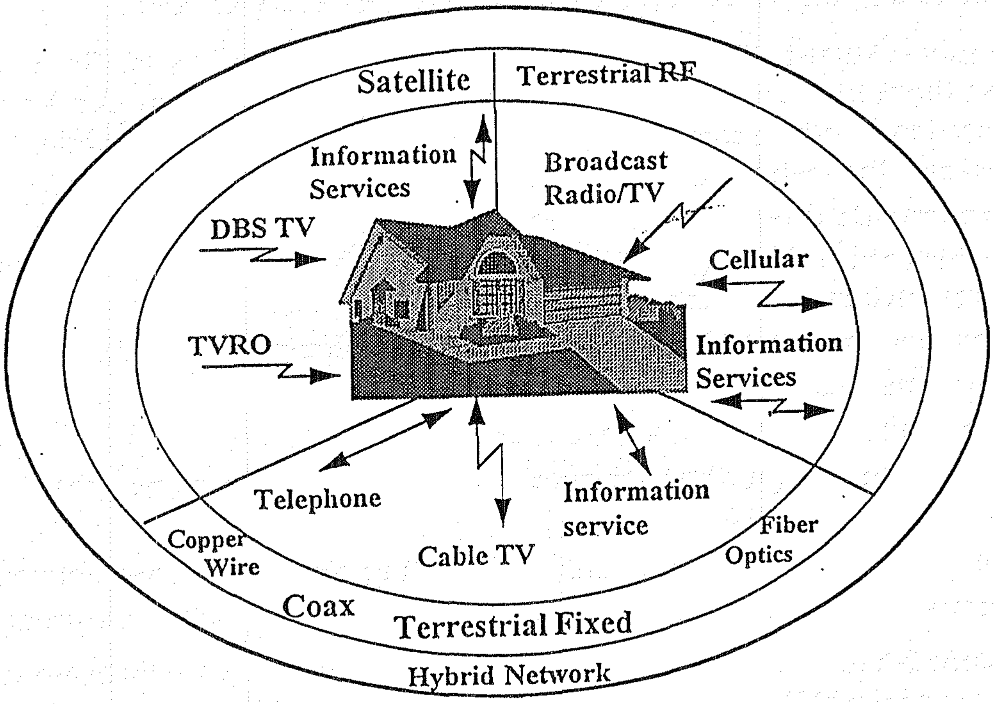


Figure 2-3: Residential information infrastructure is becoming more diverse.

Table 2-3: Trends in information services

Today	Tomorrow
Analog and digital	Digital and analog
Moderate data rates	High data rates
Wired	Wireless
National	Global
Limited competition	Increased global competition
High prices	Low prices
Limited availability	Universal access
Independent services	Integrated services
Modest user expectations for reliability, capacity, privacy, security	High user expectations
Moderate variety of service offerings	Much wider variety of offerings and new services
Good computational power	Dramatically increased computational power

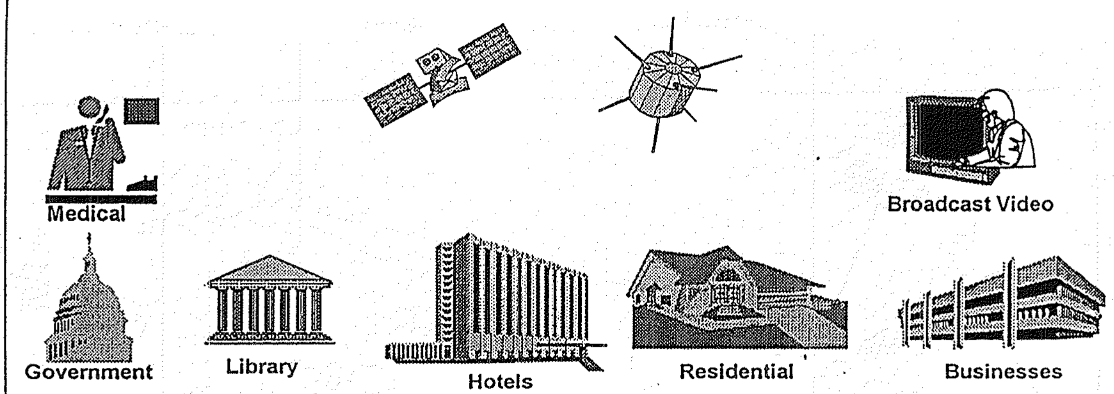
The future roles of satellites can be considered in three categories:

1. Broadcast satellite service (**Figure 2-4**)
2. Fixed satellite service (**Figure 2-5**)
3. Mobile satellite service (**Figure 2-6**)

The figures corresponding to each category list the following information:

- User services provided
- Service characteristics
- Satellite system characteristics required to supply the user services

The listing on the figures provide a rationale for the technologies required by the three different types of satellites. The broadcast satellite (**Figure 2-4**) characteristics include high power, high data rate, regional beams, and many channels. The fixed satellite (**Figure 2-5**) characteristics include flexibility in allocation on demand of coverage, capacity and bandwidth. This implies use of on-board switching, reconfigurable spot beam antennas, and interconnections between satellites. Mobile satellite (**Figure 2-6**) characteristics include connections via gateways to terrestrial mobile and fixed infrastructures, and flexible allocation of resources to users.

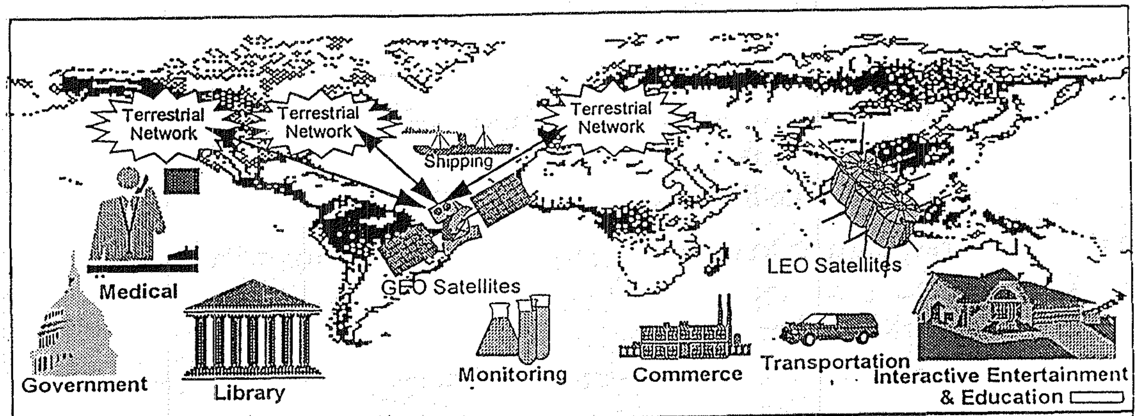


User Services
- Entertainment
- Education
- Library access
- Government services
- Health care
- News & weather
- Home shopping

Service Characteristics
- Video compression
- Competitive prices
- Interoperable with NII /GII
- National/worldwide coverage
- Flexible service configuration
- Interactive service
- Small, low-cost user equipment
- High Definition TV

Satellite System Characteristics
- High data rate
- High output power
- Higher frequency
- High bandwidth
- Large number of channels
- Regional beams

Figure 2-4: Broadcast Satellites: Future User Services and Satellite Characteristics

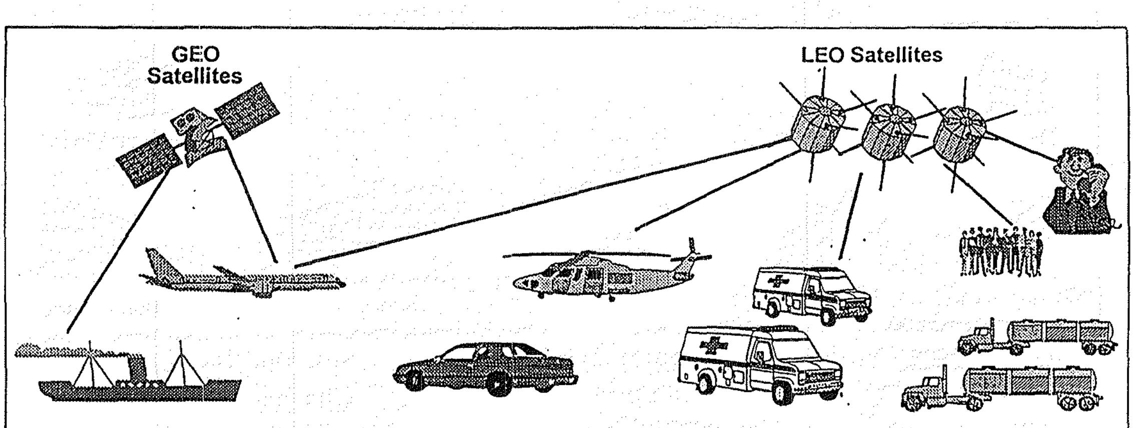


User Services
- Voice, data, fax
- Electronic commerce
- Health care
- Government services
- Library access/ publishing
- Environmental monitoring
- Education
- Telecommuting

Service Characteristics
- Competitive prices
- Interoperable
- Universal access
- Flexible service configuration
- National or international interconnection
- Integrated services
- High quality of service

Satellite System Characteristics
- Flexible allocation of resources on demand: coverage, capacity, bandwidth
- On-board switching
- Spot beam antennas
- Satellite interconnection
- Upgradable for new services

Figure 2-5: "Fixed" Service Satellites: Future User Services and Satellite Characteristics



User Services
- Voice, data, fax
- Messaging and paging
- Image distribution
- Position determination
- News gathering
- Electronic commerce
- Health emergency

Service Characteristics
- Competitive prices
- Interoperable
- National or world wide coverage
- Flexible service configuration
- Adequate quality of service
- Very small user equipment

Satellite System Characteristics
- Gateways to GII and NII
- Flexible allocation of resources on demand; coverage, capacity, and bandwidth
- Upgradable for new services

Figure 2-6: Mobile Service Satellites: Future User Services and Satellite Characteristics

Section 3

Case Study China

This section examines the satellite communications market within the People's Republic of China. This section is organized as follows:

3.1 Market Scope and Distribution

We define the market for satellites to the People's Republic of China (PRC) as the sale of any satellite that can provide communications services to customers within China's borders. Such sales can occur in the following ways:

- direct sale to state-run PRC enterprises,
- direct sale to private-run PRC enterprises,
- sale to regional satellite operators such as AsiaSat or RimSat,
- sale of additional satellites to INTELSAT,
- sale/lease of transponders/capacity, such as PanAmSat.

Currently, all of these methods are used provide satellite communications within the China.

3.2 Market Segmentation

Satellite markets first segment according to ITU service designation; Fixed Satellite Service (FSS), Broadcast Satellite Service (BSS), and Mobile Satellite Service (MSS). The FSS is for geostationary satellite primarily at C and Ku band, the BSS is for geostationary satellites operating primarily at Ku band, and the MSS is for any satellites operating at L-band.

Within each of these ITU segments three primary market segments are of interest for this analysis: (1) conventional satellites; in general, conventional satellites will use both payload designs and technology with long flight histories and do not push the state-of-the-art; (2) State-of-art satellites; state-of-the-art satellites, on the other hand, will either employ new payload designs or implement existing payload designs with new state-of-art technology; and (3) advanced satellites; Finally, advanced satellites employ both new payload designs and state-of-art technology. Because of this they will have a higher risk for development and this higher risk generally translates into higher costs. **Table 3-1** shows examples of the satellite market segments.

Table 3-1. Examples of General Satellite Market Segmentation

Satellite\ITU Segment	Fixed Satellite Service	Broadcast Satellite Service	Mobile Satellite Service
Conventional	• Brazilsat • Morellos • Rimsat	• AsiaSat • APS	• Inmarsat
State-of-Art	• Solidaridad • Intelsat VII/VIII • N-Star	• Primestar • DirectTV	• GlobalStar • Iridium • Inmarsat-P
Advanced	• C/Ku/Ka-band • Multiple Beams • On-board Switching • High data rate	• 15kW versions of PrimeStar	• SpaceWays • Teledesic • ChinaStar

In general, a satellite customer wants to avoid risk unless there is some very large payoff. The payoff for advanced satellites must be capacity/throughput. Since revenues are proportional to the time-bandwidth product that a customer uses the satellite, more bandwidth used more often directly translates into more revenues. We will discuss this more in the financial sections that follow.

3.3 Market Demand Changes and Trends

For now, the overall market segment that we are concerned with is the sale of advanced satellites, as characterized above, that serve the PRC telecommunications market.

3.3.1 Telecommunications Goals and Plans

Many changes are occurring in China that will translate into a demand for satellite capacity over the next fifteen years [8]. The Chinese Government under Deng Xiaoping began a process of reform in the 1970's to marketize the Chinese economy [8]. That process included the establishment of goals (**Table 3-2**) for the Chinese people to be well-off by the year 2000. They also included goals to interconnect more than 70% of the rural villages and to provide television to more than 70% of the households. In addition, the Government has set a goal to interconnect major industries around the country, especially in the interior, and to interconnect the urban (primarily coastal economic regions) areas [32].

Table 3-2. China's Telecommunication Goals [8]

• Interconnection of more than 70% of rural villages
• Provide television to more than 70% of households
• Interconnect major industries around the country
• Interconnect coastal economic regions

We should point out that these goals represent the goals of the state-controlled economy. As China move closer to a market economy and more enterprises become private enterprises, a large "unseen" demand may become a dominate force in China's telecommunications planning. We will discuss this more later. In addition to setting goals, China has defined specific plans for upgrading their telecommunications infrastructure (see **Table 3-3**). Furthermore, they are making significant progress toward achieving their goals and plans.

Table 3-3. China's Telecommunications Plans

• Increase the access line density from 1.63 lines per 100 inhabitants to 5 8 lines per 100 inhabitants (add 48 million lines, 6 million per year, at a cost of $48 6B) [21]
• Increase the number of telephones from 11 M in 1994 to 33 6 million by year 2000
• Interconnect cities and urban centers via fiber-optic cable and digital switching
• Interconnect primary industries (coal, petroleum, railways, and power) and large users via private networks
• Provide rural inter-village connectivity
• MPT to provide a satellite data network backbone for large users
• Television—no plans stated

3.3.2 Current Progress Toward Goals

Although China has made dramatic progress toward achieving their goals, the few statistics available seem to show that they are not achieving the rate of progress they planned. The current line density reported by the ITU shows that they have 8.45 million main [15] lines (twelfth in the world and over seventeen times less than the US) at the end of 1993. In 1992 they added 3.32 million access lines [21], roughly half of the amount planned. Even though this did not make the planned target, the growth is impressive—almost a 40% increase in main lines, see **Table 3-4** and **Figure 3-1**.

Table 3-4. Telephone Access Growth in China [15]

Year (begin)	Main Lines	Lines Added	Average Growth	Cellular Subscrib's	Sub's Added	Average Growth
1990	5,680,400	1,169,900	20.6%	9,805	8,514	86.8%
1991	6,850,300	1,600,300	28.2%	18,319	29,225	159.5%
1992	8,450,600	3,320,000	48.5%	47,544	100,000	210.3%
1993	11,770,600	–	–	–	–	–

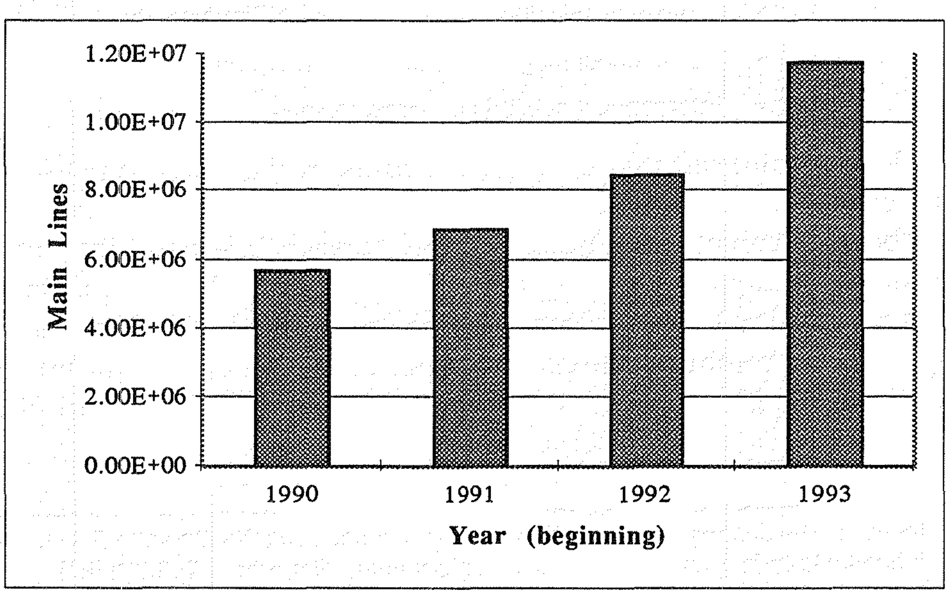


Figure 3-1. Number of Main Lines in China

In addition to main lines, they have added more telephones bringing the telephone penetration from 1 telephone per 133 inhabitants to 1 telephone in 115 inhabitants [32]. Even with this increase, they had a waiting list of 850,000 for telephones with 100,000 in Beijing alone (Beijing population is 6.8 million, 1990) [32].

One of the largest market increases is in the area of cellular subscribers. In 1993, China had 47,544 cellular subscribers, current reports indicate that has climbed to 800,000 subscribers in 1994 with another 300,000 being added in 1995 [2].

As far as connectivity, they have laid 30,000 km of fiber-optic cable in 1993 (cost $230 M) [21], and several large users have established VSAT networks to improve their operations (see **Table 3-5**) [21,39]. They have stated plans to lay a 2000 km fiber optic cable across Tibet where much of the area is above 20,000 (6,000 m) feet in elevation [ref].

Their progress on interconnecting rural villages is largely unknown, but the Chinese Ministry of Electronics has established a new company called Jinfeng (Golden Telephone) to supply telecommunications equipment to the countries

800,000 cellular subscribers. In addition, they have approached SS/L regarding using satellites to provide village public telephone service [2].

Table 3-5. Private VSAT Networks in China [39,42]

- People's Bank of China — established a VSAT network in June of 1991 to provide voice and data between its 300 branches around the country. Upgrades in 1995 will include video telconferencing and video transfer
- Shanghai Securities Exchange — established in 1992 (?) a 1500 site one-way network and a 100 site two-way network for the transmission of trade data
- People's Daily Press — use a VSAT network to connect to 50 regional printing centers throughout China
- China National Offshore Oil Corp. — established a VSAT network in 1993 with two hubs and 20 remote stations to coordinate the drilling operations Ten more remote sites are planned in 1994
- Ministry of water Resources, Foreign Trade, Economic Cooperation, Railway, Meteorological, and Xinhua News Agency are all planning future VSAT networks at Ku-band.

In terms of television, current reports indicate the number of cable television networks increased from 500 in 1992 to 1800 in 1994. In addition, reports indicate that in 1992 STAR-TV reached 4.8 million households. Other reports indicate that between 500 thousand and 1 million 2.4 m-8 m TVROs have been set-up to receive satellite television [21], and this with an official state ban on the individual ownership of satellite antennas! Statistics indicate that overall television penetration in 1995 reached one per five inhabitants, roughly one for every household. As of 1989, 51% of China's urban residents have color television while 4% of the rural residents have color television [8].

3.3.3 Overall Characteristics of the Demand for Telecommunication Services

Any trend in telecommunication changes within China will likely involve the following aspects:

- Business solution
- Combination of rural telephony and remote data access
- Both state and private customers
- Localization of economic activity in east and south, but state push for rural industry to prevent urban migration.

Where the western model for telecommunication access has been based on the social necessity to provide everyone with access to a telephone, China simply doesn't have the money to provide a country with 4.8 times the population of the US with the same level of telephone access. Even if it wanted to, it would cost

China close to $700 billion[1] (twice their GNP) to achieve parity with the US (1 access line per every 1.6 inhabitants). Furthermore, China has a rural population of 863 million [8] scattered over an area roughly the size of the US west and midwest. Much of this terrain is mountainous or desert that makes the development of terrestrial telecommunication systems expensive. For these reasons, China's telecommunications future will largely center around serving business customers. China has no plans to provide telephone service to the general population. Business customers will lead the economic development of China, and as such, they can pay their own way so to speak. Furthermore, most of the businesses are located in China's southern and eastern coastal regions, therefore this will focus the improvement of telecommunications services in these areas.

Currently, a great economic disparity exists between the urban and rural populations of China. The 1990 per capita GNP of urban residents was 3,580 RMB[2], whereas rural residents had a per capita GNP of 686 RMB — over five times less than their urban counter parts [8]. Fearing a mass migration to the cities, the Chinese Government planns to expand rural industries along with the local economies. With over 100 million rural people employed in non-agricultural enterprises [8], any plan to provide an overall telecommunication infrastructure will likely include plans to upgrade the telecommunications access of rural areas as well as urban areas.

As current progress indicates, the Chinese government knew early that many of its industries could not wait for the Government to provide telecommunications service. They had to be able to seek immediate solutions to their need. This has led to the establishment of many VSAT networks that support both private enterprises as well as many state ministries. This trend will likely continue well into the future. In fact, the GNP generated by the private Chinese economy is expected to overtake the GNP generated by the state-run economy in 1995. As this private economy grows, it may become the dominant force in China's telecommunications, market overcoming the force of the official state plans.

The economic domination of the private Chinese economy will also lead to a co-localization of telecommunications services with centers of economic activity. For China this is the eastern and southern coastal regions. With 40% of the population and 15% of the land, this region account for one-half of China's annual

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[1] 700 million lines x $1,000 per line = $700 B

[2] RMB stands for renminbi and is the Chinese currency. Exchange rates int 1990 were approximately 10 RMB to one US dollar, and current exchange rates are 8.45 RMB to the US dollar. However, other references list the Chinese currency as the Yuan. We must point out that the statistics are a conversion from Chinese economic statistics The Chinese had not yet adopted the Western system of national accounts from which a GNP is calculated. The conversion is decribed in reference 8 pages 18 and 19.

GNP and 80% of its trade [8]. Newer economic theories of trade indicate that this localization will likely expand as China move forward economically.

On cannot examine the demand for telecommunications services within China without also looking at the other demands that China faces. Most notably, China must feed 22% of the world's population (1.2 billion) while only 12% of its land is arable (China's land area is rougly the size of the United States). China has a great many demands upon its people and its leaders, telecommunications is just one of them.

3.3.4 Demand for Satellites

Over the next five years, the best way to estimate demand for satellites is by estimating the number of equivalent 36 MHz transponders needed. Beyond that, five to ten years, estimates become more speculative and must be based on perceived demand rather than any specific trend displayed in the market place.

In 1992, the Asia-Pacific region had a capacity of 309 equivalent 36 MHz transponders, and of that China had leased or owned 12 transponders [42]. This represented approximately 4% (12 out of 309) of the available transponders. When China acquires Hong Kong in 1997, they will inherit 24 more transponders, plus they are expected to lease 22 more for a total of 58 transponders. These 58 transponders represents approximately 8% (58 out of 715) of the estimated Asia-Pacific transponder capacity in 1997. This represents a doubling of their capacity in five years. Overall, the region is expected to more than double the satellite capacity by 1997, see **Fig. 3-2, Fig. 3-3** and **Table 3-6** [projected growth in region from ref. 42].

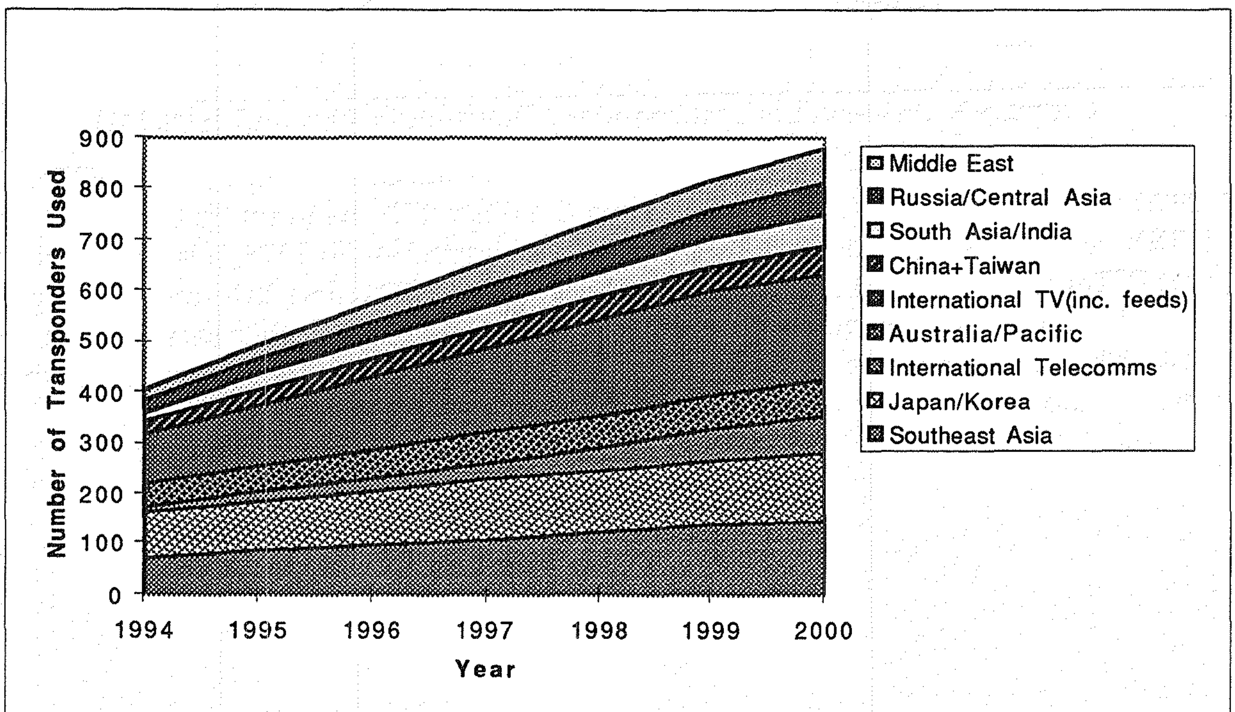

Figure 3-2. Forecast of transponder use in the Asia-Pacific region.

Table 3-6. Forcast for transponder use in the Asia-Pacific Region [42]

Asia-Pacific Trans. Use	1994	1995	1996	1997	1998	1999	2000
China+Taiwan	21	28	34	39	45	50	55
Russia/Central Asia	23	30	37	42	48	54	60
South Asia/India	23	31	37	43	49	56	64
Middle East	17	28	37	45	51	59	67
Australia/Pacific	44	49	55	60	63	66	70
International Telecomms	10	18	26	35	48	62	76
Japan/Korea	95	103	110	117	124	131	138
Southeast Asia	71	85	97	111	122	136	145
International TV(inc. feeds)	100	122	144	166	188	205	205
Total	404	494	577	658	738	819	880

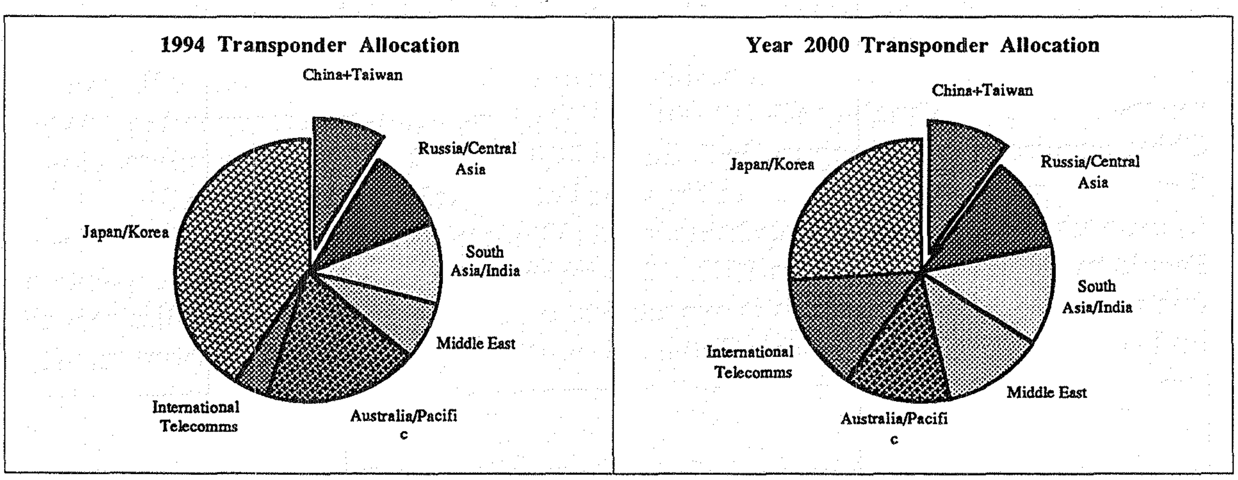

Figure 3-3. Asia-Pacific Transponder Allocation in 1994 and 2000. [42]

Furthermore, Asia-Pacific region used 75% of the capacity in 1992 for PSTN (29%) and broadcast TV (46%) services with the other 25% made up by business (15%), mobile (1%), and other (9%) services, see **Figure 3-4**. In 1997, it is projected that PSTN and broadcast TV services will drop to 61% (28% and 33%, respectively) while business services will use 22%, mobile will use 4%, and other services will use 12%. Thus, in addition to projections of growth in all services, we see an increasing share of the satellite market devoted to business, mobile, and other services.

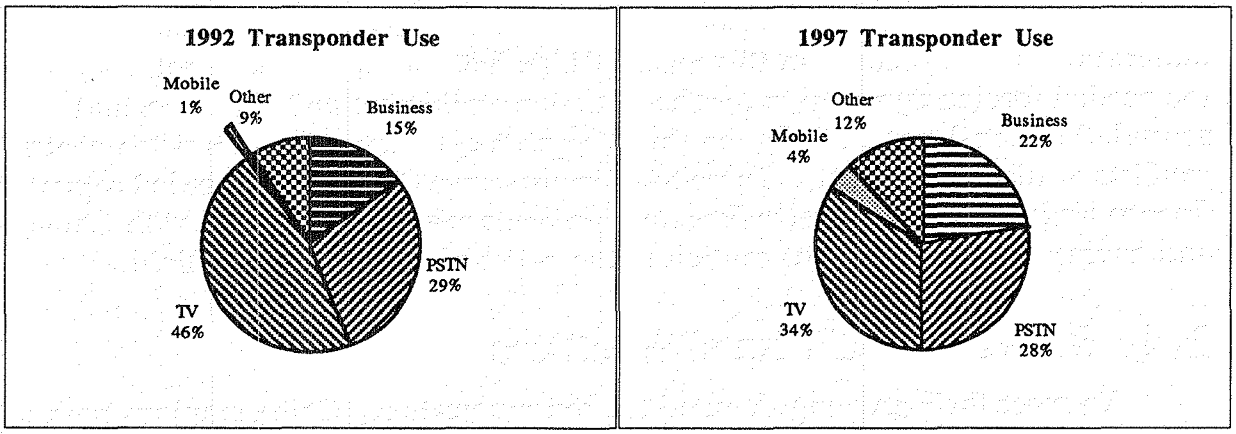

Figure 3-4. Asia-Pacific Transponder Use. 1992 actuals, 1997 projections [42]

3.3.5 Applications for Satellites

In examining China's plans for their telecommunications infrastructure, we see that satellites could aid China in providing rapid connectivity long before the terrestrial systems are in place. We see the following are possible applications for satellites in the near and distant future:

- Provide rural village public telephone access (thin-route traffic)
- Backbone network connectivity for VSAT networks and Value Added Networks (VANs, see glossary)
- Accomodate urban terrestrial traffic overflow
- Immediate inter-city connectivity/trunking prior to terrestrial installation
- Continued access to international telecommunications
- Controlled access DTH-TV (PRC government currently bans DTH-TV—see next section)
- Large trunk interconnection (telephony)
- Expanded broadcast TV distribution

The majority of demand expressed by China is for conventional services, that is telephony, data networking, and broadcast TV distribution. However, we must make the distinction that conventional services does not imply conventional satellites. In fact, the enormity of China's conventional service need may demand the use of very advanced satellites, but used to supply basic services on a wide scale.

3.3.6 Obstacles to Progress

While the promise of China is great, we cannot be blind to the immense obstacles that they face. We cannot forget that China is still primarily a state-run economy, and as Tiananmem Square demonstrates, a country that does not have unlimited freedom—personal or economic.

Financing is a primary obstacle China faces for developing its telecommunications infrastructure. In this regard China has two problems. First, they lack the needed foreign currency to purchase foreign equipment and expertise, and second, their legal system lacks the ability to protect foreign investors when contract conflicts or disputes arise [1]. These two factors starve China of the needed capital to finance large projects. Nevertheless, foreign firms are doing business with China, and having success there, but caution in the midst of optimism is required.

3.4 Survey of China s Satellites

To meet their growing demand for communications, China employs both its own satellites and leases capacity on other satellites.

China is part of the ITU Region 3. The ITU Radio Communication Bureau currently records 21 orbital slot assignments to China. Eight of these assignments have been formally "notified", two of the slots are under coordination, and the remaining thirteen slots have "Advanced Publication" status. The slots are at 87.5°E, 98°E, 103°E, 110°E, and 125°E.

Table 3-7 and **Table 3-8** lists the Chinese satellites (**Table 3-9** indicates the frequency band designations) and their Filing Status (FS). A satellite can have one status of three possible. As satellite may filed as negotiated (N), under coordination (C), and advance publication (A) with the ITU.[3] In addition, China leases transponders from INTELSAT and AsiaSat, and APTSatellite (Asia-Pacific Telecommunications Satellite Co., Ltd.).

[3] "Notified" means that the satellite has been entered into master frequency registry of the ITU Radio Communication Bureau, and that it is protected from interference by international agreement "Under Coordination" means that the satellite has in the process of coordination with other international parties that may have an interest in the particular operating frequency band/orbital slot, and "Advance Publication" means the filing party has the intention of placing a satellite at that location and at that frequency, and that coordination and negotiations other international parties have yet to be undertaken [see reference on ITU regulations.]

Table 3-7. Chinese Owned Satellites

Position	E/W	Stat	Adm	Station	0	1	2	4	5	6	7	8	11	12	13	14
87 50	E	N	CHN	CHINASAT-1				4		6						
87 50	E	N	CHN	DFH-3-0C				4		6						
98 00	E	N	CHN	CHINASAT-3				4		6						
103 00	E	N	CHN	DFH-3-0B				4		6						
103 00	E	N	CHN	STW-2				4		6						
110.50	E	N	CHN	CHINASAT-2				4		6						
125 00	E	N	CHN	DFH-3-0A				4		6						
125 00	E	N	CHN	STW-1				4		6						
115 50	E	C	CHN	DFH-3-OD				4		6				12		14
121 00	E	C	CHN	DFH-3-OE				4		6						
130 00	E	C	CHN	CHINASAT-4				4		6						
75.50	E	A	CHN	CHINASAT-23	0			4		6						
77.00	E	A	CHN	APSTAR-4				4		6				12		14
80 00	E	A	CHN	CHINASAT-31		1	2	4		6						
85 50	E	A	CHN	APSTAR-2 F1				4	5	6				12		14
89 50	E	A	CHN	APSTAR-2 F2				4	5	6				12		14
93 00	E	A	CHN	APSTAR-3				4		6				12		14
98.00	E	A	CHN	CHINASAT-22	0			4		6						
101 50	E	A	CHN	CHINASAT-11									11			14
103 00	E	A	CHN	CHINASAT-21	0			4		6						
105 00	E	A	CHN	FY-2A	0	1	2	C4		C6						
105 50	E	A	CHN	CHINASAT-12									11			14
127 50	E	A	CHN	CHINASAT-24	0			4		6						
131 00	E	A	CHN	APSTAR-1				4		6						
134 00	E	A	CHN	APSTAR-2				4		6				12		14
140 00	E	A	CHN	CHINASAT-32		1	2	4		6						

Table 3-8. Chinese Mobile Satellite Service Filings

Positio	E/W	Sta	Adm	Station	1	2	3	4	5	6	7	8	9
80 00	E	A	CHN	CHINASAT-31									9
140.00	E	A	CHN	CHINASAT-32									9

Table 3-9. FSS and MSS Frequency Bands

FSS BAND	FREQUENCY RANGE
0	< 1 GHz
1	1 215 - 1 710 MHz
2	1 710 - 3 400 MHz
4	3 400 - 4 800 MHz
5	5 000 - 5 925 MHz
6	5 925 - 7 075 MHz
7	7 075 - 7 750 MHz
8	7 900 - 8 500 MHz
11	10,6 - 11,7 GHz
12	11,7 - 12,75 GHz
13	12,75 - 13,99 GHz
14	14,0 - 14,8 GHz
15	14,8 - 15,7 GHz
17	17,3 - 18,1 GHz
18	18,1 - 18,8 GHz
19	18,8 - 19,7 GHz
20	19,7 - 21,4 GHz
>20	21,4 - 30,0 GHz
>30	30,0 - 40,0 GHz
>40	40,0 - 100 GHz
>100	100 - 200 GHz
>200	> 200 GHz

MSS BAND	FREQUENCY RANGE
1	137 - 138 MHz
2	148 - 149 9 MHz
3	149.9 - 150 05 MHz
4	312 - 315 MHz
5	387 - 390 MHz
6	400 15 - 401 MHz
7	1 492 - 1 525 MHz
8	1 525 - 1 559 MHz
9	1 610 - 1 626.5 MHz
10	1 626.5 - 1 660.5 MHz
11	1 675 - 1 710 MHz
12	1 970 - 2 010 MHz
13	2 160 - 2 200 MHz
14	2 483.5 - 2 500 MHz
15	2 500 - 2 520 MHz
16	2 520 - 2 535 MHz
17	2 655 - 2 670 MHz
18	2 670 - 2 690 MHz

China has no current filings for any satellite under the Broadcast Satellite Service. This most likely reflects their ban on DTH-TV. Note, however, AsiaSat does have filings with the ITU for two BSS satellites at 100.5°E and 105.5°E. China's fixed satellites (ChinaSat). also known as DFH and STTW are C-band satellites that are wholly owned and operated by China.

China's first attempt at launching a communications satellite failed in January 1984, but was soon followed by a series of successful launches and successful satellites. Their first satellite was called STTW-1 (some abreviations shorten this to STW) which means Shiyan Tongbu Tongxin Weixing which means "experimental synchronous communications satellite [45]." It was renamed DFH which means Dong Fang Hong, "The Sky is Red".

The first successful launch of an STW-1 (DFH-1) occurred in March 1984. STW-1/DFH-1 has two 49 MHz transponders and generates 23.4 dBW at beam center. STW-2/DFH-2, launched in February 1986, also has two 49 MHz transponders and generates 35.5 dBW at beam center. The launch of DFH-2A1 (ChinaSat-1) in March 1988 began the ChinaSat series. The ChinaSats each have four 50 MHz transponders and generate 36.5 dBW at beam center. December 1988 and February 1990 saw the launch of ChinaSat-2 (DFH-2A2) and ChinaSat-3 (DFH-2A3) [10].

ChinaSat-1 is used by China Central TV in Beijing (transponders A and B) and Yunnan and Sinjiang Television, which share transponder D. Other transponders are used by the military and for telephone traffic (typically, FDMA and SCPC). **Tables 3-10** through **3-15** list the Chinese satellites by program.

Table 3-10. Chinasat-X satellites

Chinasat-X							
No.	Slot	UHF	L	C	Ku	FS	Comments
-1	87 5°E			4/6		N	Previous DFH-2 program
-2	110 5°E			4/6		N	Previous DFH-2 program
-3	98 0°E			4/6		N	Previous DFH-2 program
-4	130 0°E			4/6		C	New position, extends Chinasat service

Table 3-11. Chinasat-1X satellites

Chinasat-1X							
No.	Slot	UHF	L	C	Ku	FS	Comments
-11	101 5°E				11/14	A	New position, uses 11 GHz D/L
-12	105 5°E				11/14	A	New position, uses 11 GHz D/L

Table 3-12. Chinasat-2X satellites

Chinasat-2X							
No.	Slot	UHF	L	C	Ku	FS	Comments
-21	103 0°E	0		4/6		A	Replaces DFH-3-OB, UHF use unknown
-21	98 0°E	0		4/6		A	Replaces Chınasat-3, UHF use unknown.
-23	75 5°E	0		4/6		A	New posıtion, UHF use unknown
-24	127.5°E	0		4/6		A	New Position, UHF use unknown

Table 3-13. Chinasat-3X satellites

Chinasat-3X							
No.	Slot	UHF	L	C	Ku	FS	Comments
-31	80.8°E		1/2	4/6		A	New posıtıon, also an MSS filıng
-32	140.0°E		1/2	4/6		A	New position, also an MSS fılıng

Table 3-14. DFH-OX satellites

DFH-3-OX							
No.	Slot	UHF	L	C	Ku	FS	Comments
-OA	125.0°E			4/6		N	Replaces STW-1
-OB	103.0°E			4/6		N	Replaces STW-2
-OC	87 5°E			4/6		N	Eıther augments or replaces Chınasat-1
-OD	115.5°E			4/6	12/14	C	New posıtıon, with Ku-band payload
-OE	121.0°E			4/6		C	New Positıon

Table 3-15. APStar satellites

APStar-X							
No.	Slot	UHF	L	C	Ku	FS	Comments
-1	131 0°E			4/6		A	Operatıng?
-2	134 0°E			4/6	12/14	A	Exploded 1/26/95, replacement RFQ released
-3	93 0°E			4/6	12/14	A	New posıtıon
-4	77 0°E			4/6	12/14	A	New position
2-F1	85 5°E			4/5/6		A	New Positıon, but wıth 5-6Ghz payload.
2-F2	89 5°E			4/5/6		A	New Posıtıon, but wıth 5-6Ghz payload.

In addition to their own satellites, China also owns partial interests in AsiaSat and APStar. The CITIC owns a 33% interest in AsiaSat, and owns a 57% interest in APStar. The APStar ownership is shared by China Telecommunications Broadcast Satellite Corp. (ChinaSat), China Yuang Wang Corp., and Ever-Victory Company. Each have a 18 3/4 percent share [21]. ChinaSat is an MPT affiliate whereas China Yuang Wang Corp. and Ever-Victroy Company are owned by the Ministry of Defense's Commission on Science, Technology and Industry for National Defense, and by China Aerospace Industries Corp [21].

APStar-1 is operating, but APStar-2 exploded during launch from China on January 25, 1995. This satellite could carry 100 digitally compressed TV channels. Requests for quotes for the APStar-2 replacement have been sent to industry. The specification calls for 8-54 Mhz Ku-band transponders and 26 C-band transponders (2 @ 72 Mhz and 24 @ 36 Mhz) for a total capacity of 1440 MHz. In addition, there is a high-power (120W @ Ku and 60W @ C-band)mode and a low-power mode (100W @ Ku and 50W @ C-band) for each transponder. [21]

Asia Satellite Telecommunications Co., Ltd. (AsiaSat) is owned by Cable and Wireless, plc, China International Trust and Investment Corporation (CITIC), and Hutchison Whampoa Limited. Cable and Wireless, plc is a major subsidiary of Hong Kong Telecommunications, and CITIC was formed in October 1979 by the State Council of the PRC to handle international trade and finance with China. According to the 1991 World Satellite Almanac, in February 1987 CITIC formed a wholly owned subsidiary called CITIC Technology Inc. "to promote the development of technology by linking business expansion with the development of science and technology." This subsidiary (CITICTECH) owns 33% of AsiaSat.

In addition, to the above satellites, China leases additional capacity on a host of other communications satellites.

- PanAmSat— China rents space for television broadcast distribution, this increased following the loss of APStar-2.
- INTELSAT— China rents transponder capacity to for international telephone, telex, and data traffic. In addition, China uses these satellites for domestic services.
- RimSat—joint venture formed to serve Asian region by buying second-hand Gorizont satellites. China currently leases space on Rimsat satellites.

In additon, reports from Via Satellite magazine indicate Deutsch Aerospace (DASA) is preparing a proposal on SinoSat—a joint venture between China Aerospace Corporation (CASC) and the People's Bank of China for their VSAT network [45]. Reuters also reported that the China lost a prototype satellite called "East is Red" in December of 1994. The satellite was a prototype of a satellite that China hopes to begin exporting.

3.5 Market Share and Sales

U.S. manufacturers currently only manufacture AsiaSat, APStar, and INTELSAT. China manufactures and produces their primary domestic satellites (DFH-2, and ChinaSat) themselves.

In addition to the four satellites "Under Coordination", China has filed announcements for 18 satellites with the Radio Communications Bureau of the ITU. In addition, they are currently taking bids from satellite manufacturers for AsiaSat-3. We expect that China will continue to expand conventional C-band and Ku-band access by both increasing the delivery of Chinese satellites, purchasing satellites from other manufacturers, and by purchasing additional capacity on regional satellites. This need is based on the fact that China needs the transponder capacity immediately, and satellites can deliver that capacity now. Therefore, over the next five to seven years, we expect that China's need for conventional C-band and Ku-band satellites will continue at a rate of 1 to 3 satellites per year. This represents a total market of $2.7B, one-half of which could go to U.S. satellite manufactures.

In the longer-term, we expect China to look for more innovative solutions from satellites in the way of providing wireless Central Office interconnection (switch in the sky), and the ability to supply wideband services, specifically in the form of VANs via private VSAT networks, to its larger business customers.

3.6 Conclusions

3.6.1 General Telecommunications Market

The overall the telecommunications infrastructure in China will evolve quite differently than that in the West or U.S. China cannot afford to provide ubiquitous telephone service to the general population. Therefore, telecommunications will develop to serve primarily businesses [6]. China will push forward in all areas of telecommunications infrastructure including satellites. Specifically, they will continue wiring urban areas with fiber-optic cable as well as installing many long-haul fiber-optic cables across the country. We expect them to install an extensive terrestrial wireless (wireless telephone and cellular) systems and interconnect those cellular systems either via fiber-optic lines, microwave trunks, or satellites. The increasing demand for VSAT networks will continue and begin to incorporate newer services (VANs) into these networks as businesses need them.

As China's telecommunications developments becomes led by business, the overall telecommunications landscape in China will fragment. Each business will develop its own telecommunication service, and interconnectivity could become a major problem in the future. In addition to fragmentation, a stratification of services will also develop. The more influential and wealthy business will evolve to using sophisticated systems, whereas the less wealthy businesses will be forced to use less capable and, perhaps, out-of-date systems.

For television services, we expect the official ban on DTH-TV to continue until a solution for controlled access is found, at which time the state will enter into ventures to program and distribute state-controlled programs and approved international programs on a wide-spread basis. In the meantime, the ban will have little effect on either the demand for satellite TVRO systems or their race to procure satellites with a TVRO capability (as evidenced by the APStar-2R proposal). China may view DTH-TV market as a way to generate large revenues in much needed foreign cash. In the area of television distribution, we expect the demand for transponder capacity to continue, especially as international television carriers seek to enter the Chinese market.

In terms of specific satellite services, we expect demand for the following services (in order of demand for satellite capacity):

1. Broadcast TV Distribution
2. Conventional PSTN
3. VSAT Networks
4. Mobile/wireless telephone services.
5. DTH-TV (larger if ban is lifted)

The demand for other services (videophone, multimedia networks, e-mail, etc.) will likely be led by the private VSAT networks. VSAT networks will tie major businesses together and they may be the only ones within China that have the resources to make use of advanced services. These services are just to new to formulate accurate and quantifiable demand statistics.

3.6.2 Satellite Market Evolution

We expect the Chinese satellite markets to evolve in three overlapping phases similar to the satellite market in Japan. They will begin by buying conventional satellites to meets their immediate demands, but begin joint ventures on longer-term projects that involve the transfer of satellite technology and manufacturing to China. During these phases, we expect that China will seek to build up its satellite manufacturing capability so that around 2005, they can begin to export and operate satellites in competition with the West.

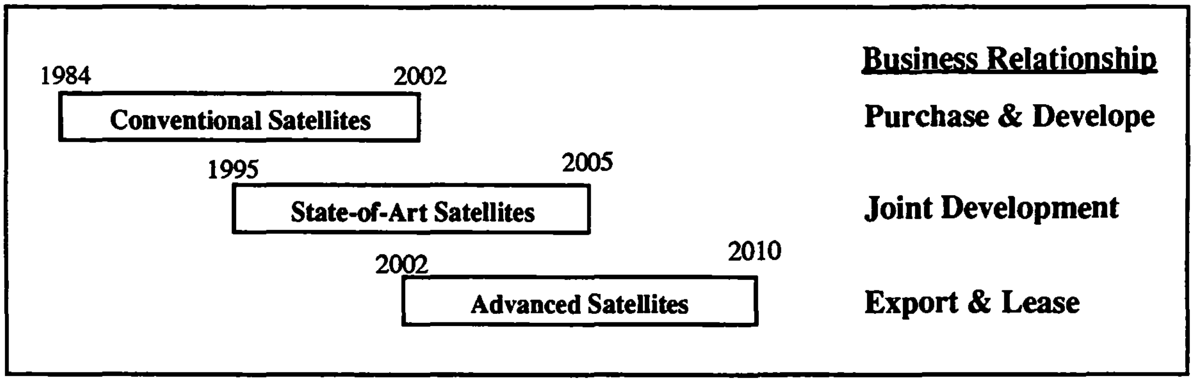

Figure 3-5. China's Satellite Development Plan

Some of the major limitation to China's rate of growth in telecommunications include access to foreign cash, sufficient foreign investment, bureaucratic in-fighting, and competition for resources with other major infrastructure project (e.g., railroads, agricultural reform, etc.).

We expect that the following specific applications will require satellites:

- Rural telephony and remote data networks
- Urban telephone traffic overflow
- Conventional PSTN trunking
- Broadcast TV distribution
- DTH-TV

The first two applications would require a "telephone switch" in the payload of a geostationary satellite to avoid a double-hop delay. This implies the use of an advanced satellite. The remaining applications can use both conventional and advanced satellites. However, the demand for capacity in China is so great that any technology that enhances the capacity beyond conventional satellites could result in large increase in revenues.

3.6.3 U.S. Satellite Market Share and Forecast

What all this means to the satellite industry is the following. In addition to the four satellites "Under Coordination", China has filed announcements for 18 satellites with the Radio Communications Bureau of the ITU. In addition, they are currently taking bids from satellite manufacturers for AsiaSat-3. We expect that China will continue to expand conventional C-band and Ku-band access by both increasing the delivery of Chinese satellites, purchasing satellites from other manufacturers and by purchasing additional capacity on regional satellites. This need is based on the fact that China needs the transponder capacity immediately, and satellites can deliver that capacity now. Therefore, over the next five to seven years, we expect that China's need for conventional C-band and Ku-band satellites will continue at a rate of 1 to 3 satellites per year. This represents a total market of $2.7B, of which one-half we expect should go to US satellite manufactures.

In the longer-term, we expect China to look for more innovative solutions from satellites in the way of providing wireless central office interconnection (switch in the sky), and the ability to supply wideband services to its larger business customers, specifically in the form of VANs via private VSAT networks. The growth of cellular systems in China is staggering, and we expect that they will need some way to interconnect these systems.

Today, China needs to meet an immediate demand for capacity, and that capacity demand can be met with conventional satellites procured from the west. In the future, we expect China to have the goal to become a world competitor in satellites just as they have become a competitor in launch vehicles. Therefore, in parallel with meeting their immediate capacity demands, China will begin to look for ways to obtain a satellite manufacturing capability, and to compete, they will begin to build a satellite manufacturing capable of producing satellites at low cost..

We expect that China will begin to pursue joint ventures for the development of (one or two) advanced satellites. In addition, these procurements will involve large amounts of technology transfer. This shift in emphasis will become first apparent in the types of business relationships the Chinese seek with the West. They will begin to look for more technology licensing arrangements, joint ventures, and parts supply arrangements. In addition, they will look to transfer management techniques and organizational capability into their factories. Following the satisfaction of their immediate needs, we expect that China will begin to develop their own satellite manufacturing capability.

All in all, the satellite future for China looks bright, but we must remember that the U.S. is supplying a future competitor. Now they buy satellites, tomorrow they will technology and know-how, and in the not-to-distant future, they will start selling satellites in the international market place.

Section 4

Case Study—Brazil

Brazil covers a vast geographic area, roughly the size of the U.S. with a population of about 150 million. Brazil has used its two Brazilsat satellites to connect this broad region since 1985. Brazil replaced its original satellites in late 1994 and early 1995, with Brazilsat B1 and B2. This section is organized as follows:

4.1 Current Telecommunications Environment
4.2 Trends in Telecommunications
4.3 Country Overview
4.4 Summary and Conclusions

4.1 Current Telecommunications Environment

The Brazilian telecommunications network is the fifteenth largest in the world. The Ministry of Infrastructure through the Secretaria Nacional das Comunicacoes (SNC) is responsible for planning, coordinating and regulating all telecommunications services. Embratel is Brazil's long distance voice and data carrier with responsibility for satellite communications.

4.1.1 Telephony

The following characterizes the state of Brazils telephone-based telecommunications infrastructure:

- Density of lines - 9 telephones per 100 inhabitants
- Number of main lines - 10,075,924 as of 1/1/92 (annual growth was approximately 6.7-7.1% from 90 to 92)
- Local exchanges - 5305 automatic, 535 semiautomatic as of 1/1/92
- National long distance calls in 1991 - 3,266,801 (average annual growth 1981-1991 = 16.5%)
- International long distance calls in 1991 - 39,302 calls (average annual growth 1981-1991 = 20.0%)

- TELEX subscriber lines - 151,870 ,in 1991
- Video TEX subscribers - 13,700 in 91, 11,532 in 1988
- Cellular subscribers - 6,652 as of 1/92, 1600 as of 1/91, none as of 1/90.

4.1.2 TV and Entertainment

Rede Globo TV is the nations largest broadcast network. Brazil has two large multichannel companies, Grupo Abril's TVA and TV Globo Net Brazil.. So far, multichannel investors both inside and outside the country have centered their attention on the larger cites.

TV Households - 33 million or one for every 4.8 people

Radios - one for every 2.5 people.

Multichannel TV programming - 1.5% of TV set owners As of 2/95 the subscriber breakdown was:

Cable -	242,000
MMDS -	162,000
DTH (C band) -	68,000

In all of Latin America there are 80 million TV households of which almost 10 million have cable and another 3.4 million have other sources of multi-channel programming [1] such as DTH or MMDS.

4.1.3 Data Services

Embartel in partnership with Sprint International, operates the largest data network in Brazil, mainly with satellite circuits. At the end of 1990 AT&T Tridom and Vilares Control of Sao Paulo, a distributor and manufacturer of telecommunications services, signed an agreement to provide VSAT equipment for PRODEMGE, one of the largest data processing companies in Brazil.

4.1.4 Advanced Services

Currently TVA, Brazil and MVS Multivision, Mexico operate DTH services at C-band. TVA is joining other TV companies in the region and Hughes to form DirecTV Latin America. The service will be 60% owned by Hughes, 20% by Televisao of Brazil, and 20% by Cisneros,of Venezuela. The project is estimated to cost $300 million. It is expected to break-even within one year of its expected launch of a Hughes Galaxy III-R satellite in February 1996. The service is estimated to need 1.3 million subscribers to break-even. This service will offer 144 compressed channels via Ku band, split equally between Spanish and Portuguese. The

Portuguese will only be beamed into Brazil. Initial consumer equipment cost is $700 expected to drop to $300-400 within two years, and a monthly charge of $28. There will also be additional pay-per-view services. TVA's C-band service would remain in effect as it is targeted to a base of some 2 million dish owners in Brazil, who are interested in picking up the signals of broadcast networks in that country as well as TVA's pay channel offerings. [2] Competition for this project will be from PAS 5, a PanAmSat satellite, that will also serve Spain and Portugal, and Inkari, a Miami based Sur network.

In the 1997-8 time frame satellite PCS systems such Globalstar, and Iridium will be available.

4.2 Trends in Telecommunications

On average, multichannel TV distribution, wireless, and hardwire systems are growing at a rate of 10% monthly. TVA's monthly sales volume has tripled since the end of 1994. One short term handicap is that most (pan-regional) channels have Spanish language versions, but there are not many with full time Portuguese tracks.

The new President Fernando Henrique Cardoso is about to loosen restrictions on foreign investment, local system advertising, and program production. The Ministry of Communications is in the process of ruling on the act and it is expected that by the second half of this year hardwire licensing will begin for cable TV. Nearly 2000 requests have already been submitted by about 100 companies. So far 15 large markets, mostly state capitals, have not been awarded. The revision of the constitution now underway is likely to end the state monopoly on of voice and data transmission.

Direct-to-home (DTH) co-ventures between American satellite companies and large Brazilian media firms are in the works, see DTH under Satellites below.

> "The development of multichannel television in Sao Paulo and the intense competition now underway there may give an indication of how pay TV will develop in other markets."
>
> Rubens Glasberg, "Bringing Up Brazil,", Multichannel News International, April 1995

4.2.1 Satellites

From early 1970's to the mid-1980s, Brazil used Intelsat's domestic services to establish its earth station network across the country. Brazilsat has been operational since 1985, Recently PanAmSat was authorized to provide services. Brazil also utilizes Intelsat and Inmarsat. Brazilsat A1 was launched in 1985 and A2 was launched in 1986. Brazilsat B1 and B2 were awarded to Hughes in April 1990 for $155 M. They are HS376W spinner type. Brazilsat B2 was launched in March '95.

Table 4-1 BrazilSat A/B

Position:	65° W and 70° W
Mass on orbit	1200 kg
Primary power EOL	799 W
Stabilization	Spin
Expected lifetime	12 years for B1 & B2, (A1 & A2 were 8 years).
Transponders	28 each 10 W TWTA with 4:1 redundancy at C-band 1 ea. at X-band for the military
Flux density/carrier	-82 02 -77 dBW/sq.m.

Table 4-2. Transponders Used for TV on Brazilsat A2 70.0° West

Transponder/polar	TV Station	System
1 / Horizontal	Rede Global TV	PAL
2 / Vertical	SBT TV	PAL
3 / Horizontal	TVE Educativa	PAL
4 / Vertical	Rede Manchete	PAL
5 / Horizontal	Bandierantes	PAL
5 / Vertical	Globosat	PAL
6 / Vertical	Globosat	PAL
6 / Horizontal	TVA / MTV	PAL
7 / Horizontal	TVA	B-MAC
7 / Vertical	Record Network	PAL
8 / Horizontal	Regional Oeste	PAL
10 / Vertical	Globosat	PAL
11 / Horizontal	KTV Horse Racing	B-MAC
10 / Vertical	O.M. Network	PAL
11 / Horizontal	KTV Network	PAL
20 / Honzontal	Globosat	PAL
21 / Vertical	MTV	B-MAC
22 / Vertical	Joven Pan TV	PAL
24 / Vertical	Amazon Sat TV	PAL

VSATs

VSATs provide private network services for commercial and industrial organizations. Earth stations for the A1/A2 series used single channel per carrier (SCPC) two way earth stations with dishes as small as 5 meters, system noise temperature of 150° K and uplink EIRP of 35 to 44 dBW. TV receive only service uses 3 meter earth stations, and TV transmitters use 7.5 meter antennas.

Table 4-3. Total VSAT Terminals in Brazil in 1993

Type	Micro	Small	Medium	Large
International			2	3
Domestic		75	3	
Mobile	131			
TVROs	30	55		
Corporate	1100			
Total VSATs	1261	130	5	3

Banking is one of the largest VSAT end-users in Brazil. Banco Bradesco and ITAU have installed private VSAT networks. Several hundred branch banks, customer site branches, and automatic teller machines are connected via Brazilsat to ITAU massive IBM computer system. VSATs enable branches to open in remote locations where resources are limited.

PRODEMGE is using its VSAT network for data communications between its corporate headquarters in Belo Horizonte and hundreds of state-operated companies such as banks, health organizations, taxation agencies, and public security firms. A total of 900 earth stations are planned for the total system with 360 in operation in 1993.

Direct To Home (DTH)

In February 1995, TVA launched a C-band DTH service offering 11 digitally compressed channels on the Brazilsat B1 satellite, competing with the six analog channels Globo has offered in recent years. There are currently 2,000,000 subscribers to DTH at C-band in Brazil. Plans are currently underway for much larger Ku band services. In March 1995, TVA announced it has teamed up with Hughes for DirecTV service and plans to offer 72 channels in Portuguese. Globo is expected to team with PanAmSat, however, its major effort is cable. There are two other competitors for DBS TV: Inkari, using Intelsat 707, and Nahuelsat, supported by the government of Argentina.

It is estimated that a Ku band installation is around $1000, whereas a hardwired connection in a medium sized city is $176.

4.2.2 Satellite Demand Forecast

From early 1970's to the mid-1980s, Brazil used Intelsat's domestic services to establish its earth station network across the country. Brazilsat has been operational since 1985, Recently PanAmSat was authorized to provide services. Brazilsat B1 and B2 were awarded to Hughes in April 1990 for $155 M. They are HS376W spinner type. Brazilsat B2 was launched in March '95. The Hughes-Promon proposal was chosen over the SPAR-Alcatel's 3-axis craft based on price: $155 M vs. $216M. Since these are basically replacement satellites the next generation has room for marked growth:

- To Ku and Ka bands for added capacity
- 3 axis technology enabling bigger and higher power satellites.
- DBS technology for direct to the home TV and smaller dishes (.5 meter)

This growth will be driven by the demand for more conventional and advanced services, and constrained by the ability to supply end user equipments. VSAT networks will continue to grow and are the backbone for data circuits since the rough terrain makes it difficult to lay cable.

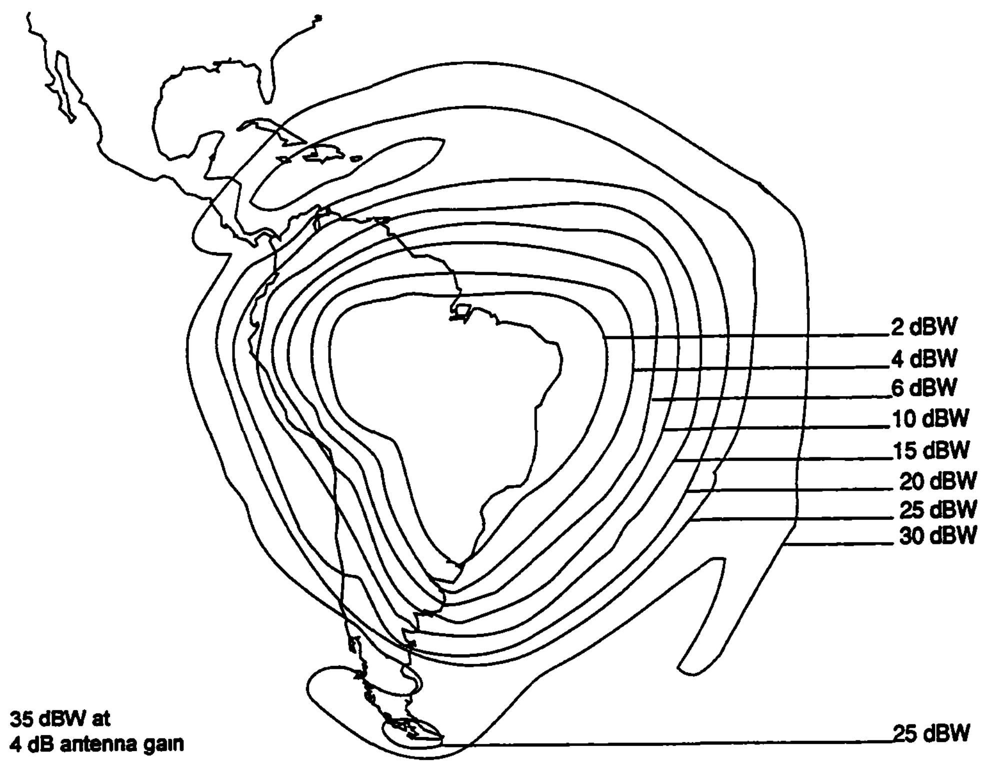

Figure 4-1. Coverage for Brazilsat (A1 and A2) [3]

Brazilsat has just been placed into operation, and will not need to be replaced for at least 10 years (Brazilsat B expected lifetime is 12 years). New services may emerge such as DTH, that may justify another satellite, however it is more likely that this service would be provided by an existing system such as PanAmSat. If a DTH system could be sold to other smaller countries in South America like Argentina, the increased revenues may justify Brazil's procurement of such a system. When they become available, other services like Globalstar or Iridium for personal PCS may also be utilized in the next few years . It is unlikely that Brazil would want sole ownership of such a system, but would want to participate by buying equity shares and gateways for terrestrial access to the PSTN.

4.3 Country Overview

4.3.1 Brazil's Economic Importance

Brazil is the largest and most industrialized country in Latin America. It is the fifth largest nation in the world, about the same size as the continental United States, and occupies 48 percent of the land mass of Latin America (3,287,000 square miles). Brazil is a democratic, intermediate-income developing nation with the ninth largest economy in the world. It has a diversified industrial, agricultural, and services base; a gross domestic product (GDP) of approximately $358 billion (1991) and a wealth of resources, both human and material. Brazil's current economic structure breaks down into roughly 54 percent of GDP from services, 35 percent from industry, and about 11 percent from agriculture.

Principal industries are agriculture (coffee, soybeans, and orange juice), minerals, steel, automobiles, footwear, textiles, capital goods, electronics, and petrochemicals. Brazil has a population of 146 million (1991 census), with a growth rate of 2.5 percent per year. Brazil has become increasingly urbanized, with 72 percent of the population now living in cities; Sao Paulo, Brazil's industrial center, has 17 million inhabitants.

U.S. direct investment in Brazil at year-end 1990 was estimated at about $15 billion, accounting for approximately 32 percent of total foreign direct investment in Brazil.

4.3.2 General Background

Area: slightly smaller than the US

The total area of Brazil is 8,511,965 sq. km with a land area of 8,456,510 sq. km

Population

With an estimated population of 160 million, Brazil is the most populous country in Latin America and ranks sixth in the world. Most of the people live in the south-central area, which includes the industrial cities of Sao Paulo, Rio de Janeiro, and Belo Horizonte. Urban growth has been rapid; by 1984 the urban sector included more than two-thirds of the total population. Increased urbanization has aided economic development but, at the same time, has created serious social and political problems in the major cities.

Total Population (1994 est.):
160 million Annual growth rate (1989): 2.1%.
Population Density:
17.6 per sq. km. (45.6 per sq. mi.).
Ethnic groups:
Portuguese, Italian, German, Japanese, African, Indians, principally Tupi and Guarani linguistic stock.
Religion: Roman Catholic (89%).
Education: Literacy--78% of adult population.
Health:
Infant mortality rate--109/1,000.
Life expectancy--61.3 yrs.
Work force (1989, 62.5 million):
Agriculture--35%.
Industry--25%.
Services--40%.
Trade union membership--about 6 million
Cities (1989):
Capital--Brasilia (pop. 1.8 million)
Other cities--
Sao Paulo (11 million, with 3 million TV households),
Rio de Janeiro (6 million),
Belo Horizonte (2.3 million),
Salvador (2 million), Fortaleza (1.8 million),
Recife (1.4 million),
Porto Alegre (1.4 million),
Curitiba (1 4 million).

Figure 4-2. Brazilian Population Characteristics

Economy

Figure 4-3 lists the major characteristics of the Brazilian economy.

Overall Economy
GDP (1988): $352 billion.
Annual real growth rate (1985-88): 5%.
Per capita GDP (1988): $2,434.
Defense:
2.6% of 1990 government budget.
Natural resources:
Iron ore, manganese, bauxite, nickel, uranium, gemstones, oil.
Agriculture (12% of GDP):
Products--coffee, soybeans, sugarcane, cocoa, rice, beef, corn, oranges, cotton, wheat.
Land--17% arable, cultivable, or pasture.
Industry: Types
--steel, chemicals, petrochemicals, machinery, motor vehicles, consumer durables, cement, lumber, shipbuilding.
Trade (1988):
Exports--$33.8 billion. Major markets--US 26%, Japan 7%, Netherlands 8%, France/Germany 4%, Italy 4%, Argentina 3%.
Imports--$14.7 billion. Major suppliers--US 21%, FRG 10%, Japan 7%, Argentina 5%, France 4%.
Official exchange rate:
Cr 72.3=US$1 (Aug. 1990; changes frequently)
Foreign direct investment and reinvestment in Brazil
Total (registered with Central Bank as of June 1988): $30.7 billion
Sources--US $8.7 billion (28%); FRG $4.8 billion (16%) Japan $2.9 billion (10%) Switzerland $2.9 billion (9%), UK $1 9 billion (6%), Canada $1.4 billion (5%).
Terrain:
Dense forests in northern regions, incl. Amazon Basin; semiarid along northeast coast; mountains, hills, and rolling plains in the southwest (incl Mato Grosso); and coastal strip. Climate: Mostly tropical or semitropical with temperate zone in the south.
Land use:
Irrigated land: 27,000 sq. km (1989 est.)
- forest and woodland: 67%
- meadows and pastures: 9%
- arable land. 7%
- permanent crops. 1%
- other: 6%

Figure 4-3. Brazilian Economic Characteristics

Transportation

Of all the means available for transporting goods within Brazil, the highway system is the most dependable. The Brazilian government has channeled considerable financial resources into improving and extending the road network. Some shipping is done by rail, but the railway system is limited, and much slower than highway transport. The government is trying to remedy deficiencies in the railway system. Coastal shipping is also deficient. Goods shipped between the ports of Santos and Porto Alegre, for example, have traditionally traveled by highway. Air cargo service, domestic and international is excellent; however, congestion does occur in ground handling facilities in Sao Paulo and other large cities.

Air Travel

Brazil has three major airlines, Varig/Cruzeiro, Vasp, and Transbrasil. These companies provide efficient service throughout the country. Brazilian regional airlines provide service to their respective parts of the country. Air taxi services are available at most airports. Scheduled airline fares are comparable to those in Western Europe.

Business people, travelers, and residents spend a good deal of time among the four most important cities -- Sao Paulo, Rio de Janeiro, and Brasilia and Belo Horizonte.

- Sao Paulo is Brazil's center for commerce and manufacturing;
- Rio de Janeiro is important for its service industries and several state companies;
- Brasilia is the seat of government and location of foreign embassies.

An excellent air bridge (or "ponte aerea") service facilitates travel among these three cities. During rush hours, flights between Rio de Janeiro and Sao Paulo leave every 15 minutes from conveniently located downtown airports.

4.3.3 History

From 1889 to 1930, the government was a constitutional democracy with a limited franchise. The presidency alternated between the dominant states of Sao Paulo and Minas Gerais. This period ended with a military coup by Getulio Vargas, who remained as dictator until 1945. From 1945 to 1961, Eurico Dutra, Vargas, Juscelino Kubitschek, and Janio Quadros were the elected presidents. When Quadros resigned in 1961, he was succeeded by Vice President Joao Goulart.

Goulart's years in office were marked by high inflation, economic stagnation, and the increasing influence of radical political philosophies. The armed forces, alarmed by these developments, staged a coup on March 31, 1964. The coup leaders chose as president Army Marshal Humberto Castello Branco, who was elected by the National Congress on April 11, 1964. Castello Branco was followed by retired Army Marshal Arthur da Costa e Silva (1967-69), Gen. Emilio Garrastazu Medici (1969-74), and retired Gen. Ernesto Geisel (1974-79). Geisel began the political liberalization process, known as abertura or "opening," which was carried further by his successor, Gen. Joao Baptista de Oliveira Figueiredo (1979-85). Figueiredo not only permitted the return of politicians exiled or banned during the 1960s and early 1970s but also allowed them to run for state and federal offices in 1982, including the first direct elections for governor since 1966.

However, the electoral college, consisting of all members of Congress and six delegates chosen from each state, continued to choose the president. In January 1985, the electoral college picked Tancredo Neves from the opposition Brazilian Democratic Movement Party (PMDB). However, Tancredo Neves became ill in March and died a month later. His vice president, the former Senator Jose Sarney, who had been acting president since inauguration day, became president upon Neves' death.

Brazil completed its transition to a popularly elected government in 1989, when Fernando Collor de Mello won 53% of the vote in the first direct presidential elections in 29 years.

4.3.4 Global trade

Foreign direct investment and reinvestment in Brazil (registered with Central Bank as of June 1988): $30.7 billion.

Sources--

- US $8.7 billion (28%);
- FRG $4.8 billion (16%)
- Japan $2.9 billion (10%)
- Switzerland $2.9 billion (9%),
- UK $1.9 billion (6%),
- Canada $1.4 billion (5%).

For 1991, Brazil's global trade reached almost $53 billion; $31.6 billion in exports, and $21.0 billion in imports. The United States is Brazil's major trading partner, absorbing approximately 21 percent of Brazil's exports during 1991. The United States imported $6.7 billion from Brazil in 1991, down about 18 percent from $7.9 billion in 1990. U.S. producers supplied $6.2 billion in exports to Brazil in 1991, accounting for about 30 percent of Brazil's total imports. Principal U.S. exports to Brazil are aircraft, chemicals, computers, electronic components, office equipment/parts, coal, telecommunications equipment, and fertilizers. Leading U.S. imports from Brazil are footwear, automotive parts, petroleum products, orange juice concentrate, iron and steel, and coffee.

4.3.5 Trends in Industrial Development

Since World War II, the Brazilian Government has stressed the importance of industrial growth as the key to general economic development. Initially, growth was generated almost exclusively by tariff-protected consumer goods industries such as food processing and textile manufacturing. Gradually, high growth rates were maintained by shifting emphasis to more sophisticated industries, including light capital and consumer durable goods manufacturing. In recent years, a relatively sophisticated capital goods industry emerged and greater emphasis was placed on indigenous technological development.

The evolution of Brazil's industrial sector was orchestrated by the government through a system of incentives for production and export. Industry represents a growing percentage of Brazil's GDP. Economic difficulties, prompted by the oil shock of the early 1970s and Brazil's debt crisis, led the Brazilian Government to pursue a policy of import substitution and export promotion. To foster domestic production, the Brazilian government established incentive programs to stimulate exports and to assist import substitution. However, most of these incentive programs were abandoned as costly and inefficient in recent years.

Geographically, industrial growth in Brazil has been very uneven. It is heavily concentrated in the southeast region, principally the states of Sao Paulo, Rio de Janeiro, and Minas Gerais. Though primarily agricultural, the southern states of Paran , Santa Catarina, and Rio Grande do Sul, are considered a part of the more developed, technologically advanced, dynamic, and productive states in Brazil.

North and central Brazil have great potential for agro-industrial development, but large capital investment will be required. The Government of Brazil has encouraged heavy agro-industry investment in this area. It also has toughened zoning restrictions in the state of Sao Paulo in an attempt to force industry to locate in the north. However, U.S. firms should also be aware that there are restrictions concerning the amount of rural land that foreigners and foreign companies can own. Exceptions to this may be made on a case-by-case basis.

Economic activity in the northeast is primarily agricultural, notwithstanding periodic droughts in the semiarid back lands. The northeast has received considerable aid from the Brazilian Government, including special fiscal incentives designed to promote development of new industries. While establishment of an industrial center and a petrochemical area near Salvador has enhanced economic growth in the state of Bahia, income in the region as a whole still remains well below the national average.

The vast center-west and northern regions account for only 10 percent of Brazil's total population. The most important economic activity in the center-west is open range cattle grazing. Subsistence farming and rubber gathering are predominant in the northern region. Brazil's development plans aim to stimulate activity in agriculture and mining in certain selected areas of the north.

4.3.6 Brazil's Space Program

Brazil has invested about $300 million [4] in a launch infrastructure since 1980. The Alcantara range is in close proximity to the equator, allowing rockets to use less fuel than launch facilities from higher latitudes. Brazil is establishing a tax free space business enterprise zone around the center. Key to Brazil's development efforts is a new domestic small satellite launcher called "VLS". The new launcher is targeted to lift 150 kg into LEO for a price of $6-10 million. Brazil would like to demonstrate the rocket in 1996, but has been held up by the Missile Technology Control Regime (MTCR), an international agreement designed to curb the export of offensive missile components. The Brazilian Space Agency was put under civilian control in 1994, after 20 years of military control of the program.

4.3.7 Role of Government

Under the development policies of previous Brazilian administrations, the government established a tradition of being the dominant force in shaping economic growth by means of planning and management. Its influence was felt not only directly through the day-to-day activities of government entities, but also through governmental wage, price, and credit policies, and subsidy and fiscal incentive programs. While the central government still retains an important economic role, the policies of the current administration focus on reducing the role of the government in economic activities and concentrating government activities on more traditional roles, such as improving public health, safety, and education. As a result, the government is emphasizing creating greater economic opportunities for the private sector through privatization, deregulation, and removal of impediments to competition.

4.3.8 Recent Government Actions

Privatization

Since entering office in March 1990, the Collor Administration has undertaken an effort to implement a sweeping program to privatize state owned companies. The program has broad public support, but got off to a slow start because of opposition from labor and certain vested interests. However, in 1991 with the sale of a major steel mill, the program began to gain momentum. Firms in the steel, transportation equipment, fertilizers, and petrochemicals sectors have been successfully auctioned. There are now more than 20 companies on the list for privatization in sectors including iron and steel, fertilizers, shipping, chemicals, petrochemicals, copper mining, railways and aircraft manufacture.

The scope of the privatization program is limited by provisions of Brazil's 1988 Constitution which establish government monopolies for basic telephone and telegraph services, electric energy production, and petroleum extraction and refining. These constitutional provisions effectively bar privatization of Telebras (telephone company), Electrobras (electric Utility holding company), Petrobras (petroleum company). Constitutional amendments have been introduced to allow privatization in these sectors.

Responsibility for implementation of the privatization program is delegated to the National Bank for Economic and Social Development (BNDES), which contracts for evaluation and sale of state-owned companies via auction. Payment for company shares may be made in seven different currencies: cash (cruzeiros or cruzados novos), agrarian debt bonds, national development fund bonds (OFND), Siderbras debentures, Certificates of Privatization (CP), matured securitized debts, and certain external debt credits and securities.

In an effort to attract more foreign investment, the government has amended the rules for foreign participation. The rules governing privatization limit foreign ownership to 40 percent in the first sale of the state enterprise, but foreign companies can buy up to 49% of the privatized firm during a subsequent resale. Foreign capital invested in a privatization must stay in the Brazil for six years before it can be repatriated.

4.3.9 1988 Constitution

Brazil's current constitution, promulgated on October 5, 1988, enshrines many of the nationalistic features of Brazil's economic and trade policies common during the past several decades. The 1988 constitution includes provisions for government monopolies in key sectors of the economy, such as petroleum extraction and refining, public telecommunications services, and electrical energy generation. The constitution allows for reserved markets and other special treatment for Brazilian firms, and permits limitations on foreign investment and trade in certain goods and services.

As part of its efforts to remove impediments to private sector initiative and foreign investment in the Brazilian economy, the government of President Collor introduced a package of constitutional amendments collectively called the emend o, or "big amendment" to remove government monopolies and correct other provisions causing economic distortions. These amendments were subsequently grouped together into five separate pieces of legislation which are awaiting action by Brazil's congress.

Brazil's 1988 constitution contains certain provisions which pose, or threaten to pose, restrictions on foreign investment. The constitution differentiates between majority Brazilian owned companies -- Brazilian national capital companies (BNCC) -- and Brazilian companies with majority foreign capital, such as subsidiaries of multinational firms. A BNCC must be permanently controlled by individuals domiciled in Brazil (or the Brazilian Government) who retain majority ownership of the firm's voting capital and decision making authority (Article 171.II). Fiscal benefits and preferential treatment in government procurement are granted to BNCCs.

The 1988 constitution provides for government monopolies in petroleum extraction and refining and basic telecommunications services, and restricts foreign participation in health services and mining. The current administration has proposed constitutional amendments to remove these and other restrictions on foreign investment. These proposed amendments will be considered in 1993 as part of a scheduled constitutional plebescite.

4.3.10 Marketing Considerations

Potential exporters to Brazil should take into consideration the vast geographic size of the country as well as the demographics and diversified industrial base of the country. In Brazil, these market factors have traditionally been overshadowed by political-economic uncertainties. However, with the advent of the Collor presidency in 1990, a policy is in effect to stabilize the domestic economy and resolve the external debt issue, as well as to liberalize the market to allow for greater imports. These changes have had a positive effect on market opportunities for American exporters in selected sectors.

With a marketing campaign focused on medium-to-long-term growth, experienced exporters and investors will benefit not only from Brazil's sheer size but, as the market evolves, from the country's increased need for capital equipment and foreign technology. To enter this changing market, it is essential that firms establish a relationship with a well-qualified Brazilian partner. The Brazilian representative should have proven knowledge not only of the sector marketplace but of current government policy. Both U.S. and Brazilian participants must consider competitive financing, distribution support and follow-on service and training, as well as potential market growth.

Government Procurement

Brazilian Government imports (direct and indirect) account for around 20 percent of Brazil's capital goods imports. In part, this is due to the considerable financial backing (domestic and international) given to infrastructure projects such as highway construction, hydroelectric plants, port improvement, subway construction, etc. It is worth noting that the Brazilian Government buys a preponderant share of total imports in at least two product categories -- electric power generation and distribution and telecommunications -- while other imports, such as petroleum are controlled by government monopolies.

In cases of indirect importation, such as purchasing foreign goods through local intermediaries, the government prefers to work through Brazilian firms. This policy is primarily to ensure the government's ease in taking legal action against a supplier if necessary. A Brazilian contractor with a government agency may import duty free in the name of the agency. In this case, the equipment must remain in the country. If the contractor later uses the equipment in Brazil for private purposes, a prorated duty must be paid.

Investment Climate in Brazil

Brazil's basic legislation governing foreign investment has been in place for about 30 years. Under this basic legislation, foreign capital is granted the same treatment as national capital, and foreign investment is encouraged. However, laws, regulations, and policies governing investment were instituted during the past two decades that combined to create a very complex, and in some sectors, restrictive investment climate. To conform with its overall economic objectives of promoting growth and development by fostering economic modernization and greater international competitiveness, the current Brazilian government is implementing reforms aimed at improving the investment climate to attract greater foreign investment and inflows of foreign technology.

Though prior Central Bank approval is required, foreign investors are generally free to invest directly in legitimate ventures in sectors not reserved for Brazilian companies. Government policy discourages or prohibits foreign investment in certain sectors of the economy, such as petroleum production and refining, basic telecommunication services, and most public utilities. Government policy seeks to boost nationally owned development of sectors such as informatics and telecommunications that are perceived to be of "strategic importance" for long-term technological development in Brazil.

TVA received some $35 million from Chase Manhatten in 1994 for about 17% equity. TVA aslo gained Ammerican support of $10 million for initial funding from Warburg Pincus Investors, of new wireless comapany, linking of both TVA and TV Filme (a separate TVA wireless systems comapany).

Entertainment Market

Cinemas in Rio and Sao Paulo show a wide variety of up-to-date foreign films in the original language with Portuguese subtitles. For those who understand Portuguese, theater is lively, especially in Sao Paulo. Music and dance performances are also common is these two cities. Nightclubs for all tastes are plentiful in Rio and Sao Paulo. Discos are found in many of the better hotels. Brasilia, by contrast, is less culturally sophisticated than Rio and Sao Paulo.

Popular culture predominates, with a thriving popular music industry, relatively active cinema, and a highly developed television empire, producing an enormous number of soap operas (telenovelas) that have found a world market. The visual arts, especially painting, are lively, while literature and the theatre, although important, play a less prominent role in this fast-moving, media-oriented society.

In Rio, much of the entertainment is on the beaches. Copacabana covers a 6 kilometer crescent and is the largest and most famous. The beaches of Ipanema and Leblon are more chic. Further along the coast, beaches at Sao Conrado and Barra tend to be less crowded.

Residents escape the pollution of Sao Paulo for a day at the beach with an hour-long drive to Santos or Guaruja on the coast.

Business Etiquette and Cultural Considerations

U.S. business visitors must become accustomed to several business conditions that are specific to Brazil. Compared to the United States, the pace of negotiation is slower and is based much more on personal contact. It is rare for important business deals to be concluded by telephone or letter. Many Brazilian executives do not react favorably to quick and infrequent visits by foreign sales representatives. They prefer a more continuous working relationship. The Brazilian buyer is also concerned with after-sales service provided by the exporter.

The slower pace of business negotiation does not mean that Brazilians are less knowledgeable in terms of industrial technology or modern business practices In fact, one should be as prepared technically when making a call on a Sao Paulo firm as on a Chicago firm. In addition, a U.S. business person is encouraged to learn as much about the Brazilian economic and commercial environment as possible before doing business in that country.

While office hours in Brazil are generally 8:30 a.m. to 5:30 p.m., decision makers begin work later in the morning and stay later in the evening. The best times for calls on a Brazilian executive are between 10 a.m. and noon, and 3 to 5 p.m., although this is less the case for Sao Paulo where appointments are common throughout most of the day. Lunch is usually two hours. It is customary in Brazil to drink coffee during a business appointment.

While many Brazilians may speak English, they may wish to conduct business in Portuguese. The non-Portuguese speaking U.S. executive may need an interpreter on more than 50 percent of business calls. Correspondence and product literature should be in Portuguese, and English is preferred as a substitute over Spanish. Specifications and other technical data should be in the metric system.

4.4 Summary and Conclusions

Brazil has used its two Brazilsat satellites to connect its broad and varying regions since 1985. Brazil replaced its original satellites in late 1994 and early 1995, with Brazilsat B1 and B2. Brazilsat B's expected lifetime is 12 years.

New services may emerge such as DTH-TV, that may justify another satellite. However it is more likely that this service would be provided by an existing system such as PanAmSat. If a DTH system could be sold to other countries in South America such as Argentina, the increases revenues may justify Brazil's procurement of such a system.

When they become available, other services like Globalstar or Iridium for personal PCS may also be utilized in the next few years . Brazil could participate by buying equity shares and gateways for terrestrial access to the PSTN. Brazil is participating in a proposed 12 satellite global mobile telephone system called ECCO. Partners include Telebras of Brazil, Bell Atlantic, and Constellation Communications Inc. of Fairfax VA.

As its telecommunications services and infrastructure grow, satellites will continue to play a role in its infrastructure. Brazil may follow Mexico with its next satellite by utilizing three axis stabilization, able to generate 4kW to 8kW of power. Brazil may also decide to acquire a hybrid satellite that has a mix of FSS, BSS, and MSS capabilities, as well as Ku band transponders. It is less likely that Brazil may acquire excess capacity and lease that to other countries, although there are potential markets in Portugal, Argentina, and other South American Countries such as Paraguay and Chile.

Government policy discourages or prohibits foreign investment in certain sectors of the economy, such as petroleum production and refining, basic telecommunication services, and most public utilities. Thus telecommunications is a monopoly in Brazil and will not soon be private. Satellite Importers have a market but must have a Brazilian partner. The currency and inflation have stabilized but have recently been threatened by the currency crisis in Mexico.

Section 5

Case Study—Mexico

Satellites have been, and will continue to be, a major part of the modernization of the telecommunications infrastructure of Mexico. Mexico is now into their second generation of satellites, exploiting Ku-band and even selling excess capacity to the US. Mexico is leading the emerging nations in terms of developing its telecommunications infrastructure. Like many other nations they are using a mix of equipment to accomplish this goal This section is organized as follows:

5.1 Current Telecommunications Environment
5.2 Trends in Telecommunications
5.3 Country Overview
5.4 Summary and Conclusions

5.1 Current Telecommunications Environment

Mexico has taken significant steps to modernize its telecommunications system. A key element was the privatization in 1990 of the national telephone company, Telefonos de Mexico (TELMEX), which was sold to a consortium of Mexican investors, Southwestern Bell, and France Telcom. This privatization has meant an increased rate of investment in the infrastructure and has improvemend the telephone network. In addition, eight regional companies are providing cellular telephone service to various parts of Mexico, resulting in a dramatic expansion of cellular telephone users. The government has also opened the telecommunications sector to further foreign investment.

5.1.1 Telephony (including cellular)

Figure 5-1 lists the primary telephone-based telecommunications characteritics of Mexico.

Density of lines - 8.8 per 100 inhabitants (1994)
Mexico City has 40% of nations phones and telephone density of 20 per 100 residents
Number of Main Lines
- 1994 < 8 Million
- 1/1992 - 5.8 Million
- 1/1991 - 5.2 Million
- 1/1990 - 4.7 Million

Growth of main lines - 12% annually
Domestic Long Distance Calls
- 1.4 Million in 1993 (5.9 million billed minutes)
- 1.2 Million in 1992

International Calls
- 387,462 in 1993 (2.2 Million billed minutes)
- 351,258 in 1992
- 86,900 in 1991

Public Telephones
- 200,000 in 1994
- 95,328 as of 1/1992

Telex subscriber lines
- 1/1991 - 13,682
- 1/1990 - 17,054

Cellular subscribers
- 1/1995 - 400,000 (estimate)
- 1/1992 - 150,663

Figure 5-1. Mexico's Telephone Characteristics

5.1.2 TV and Entertainment

Mexico is covered by existing broadcast TV (seven channels total) and emerging cable TV. Megacable, for example, has 174,000 subscribers in Mexican franchises covering 960,000 homes. It owns all of the franchises along the 800-mile stretch of Mexico's Pacific coast from Hermosillo to Guadalajara.

TV Sets - 56 million NTSC
Number of broadcast TV channels available:
4 Private channels (2, 4, 5, 9)
3 National (government) channels (7, 10 or 22, 13)
Radios - 21 million

Figure 5-2. Mexico's TV and Entertainment

In all of Latin America there are 80 million TV households, almost 10 million households have cable and another 3.4 million have other sources of multi-channel programming [1] such as DTH-TV or MMDS. It is estimated there are approximately 400,000 total subscribers in Mexico.

Direct to Home (DTH) TV

Currently MVS Multivision of Mexico and TVA of Brazil operate DTH services at C-band. Multivision is joining other TV companies in the region and Hughes to form DirecTV Latin America. The service will be 60% owned by Hughes, 20 % by Cisneros, of Venezuela, and 20% by Televisao of Brazil. The project is estimated to cost $300 million. It is expected to break-even within one year of its expected launch of a Hughes Galaxy III-R satellite in February 1996. The service is estimated to need 1.3 million subscribers to break-even. This service will offer 144 compressed channels via Ku band, split equally between Spanish and Portuguese. The Portuguese will only be beamed into Brazil. Initial consumer equipment cost is $700 expected to drop to $300-400 within two years. In addition, there is a monthly charge of $28, along with additional pay-per-view services. [2]

Competition for this project will be from PAS 5, a PanAmSat satellite, that will also serve Spain and Portugal, and Inkari, a Miami based Sur network.

5.1.3 Data Services

Until now, Mexico's local area network (LAN) interconnectivity needs have been provided through the Morelos satellite system backbone. In all cases, the links have functioned adequately. However because the satellite sources are finite, Mexico's communications needs will soon exceed the satellites' capacity, the government must deploy alternative systems. One of the alternatives being considered is frame relay on the new fiber optic backbone, which has the ability to support transmission speeds up to 2 Mbps and can also reallocate bandwidth dynamically. The public Mexican network packet-switched (PSN) is known as TELEPAC, and is taking steps to migrate its X.25 network to a faster, more up-to-date frame relay and fast-packet network.

Unlike the US. and Canada, which have ubiquitous packet-switched networks (PSNs) across the country, Mexico has supplied its communications network interconnectivity needs have been supplied through the use of the Morelos Mexican satellite system. However, that will change since Mexico will need to evolve its telecommunication infrastructure to accommodate frame relay and fast-packet technologies.

Unlike the networks operating in the US. (TYMNET, SprintNet, and BITNET), Mexico's TELEPAC has rarely been used to support LANs. The reasons include the significant time delay associated with nodal processing and error detection / correction at each node in the TELEPAC network (symptomatic of X.25), its inability to support the bursty traffic typical of LANs, and its inability to sustain higher transmission speeds or dynamic bandwidth allocation. All of this creates bottlenecks on the network as the traffic load increases.

Once the TELEPAC network is able to support these technological advances, it can then be used as a high-speed backbone network. In addition, the proposal to improve TELEPAC has the strong backing of the Mexican federal government. The Mexican Institute of Communications, called the Instituto Mexicano de las Comunicaciones (IMC), and the technical office of Telecomunicaciones de Mexico, are both eager to modernize the network. Furthermore, customers in Mexico, the US., and Canada are also demanding that the government install a higher-capacity and faster backbone network. To achieve this goal, the IMC asked the Centro de Investigacion Cientifica y de Educacion Superior de Ensenada, BC (CICESE), a scientific and technological research center sponsored by the Mexican federal government, to study the feasibility of a project to modernize the TELEPAC PSN

The TELEPAC network to support the economic aggregation of Mexico in a North American Free Trade Agreement. TELEPAC will be able to meet these challenges in a timely manner if the following technologies are added: frame relay (as a switching framework), fast-packet switching, statistical multiplexing, and high-speed internetworking protocols.

Like X.25, frame relay uses packet-switching technology, but adds support for circuit-switched, time-division multiplexing (TDM). In essence, frame relay combines the best of both technologies, utilizing X.25's statistical multiplexing and the port-sharing capability with the high speed and low delay of TDM. Frame relay, fast-packet switching, and their attendant streamlined transport protocols together provide a high speed communications network to transport data.

When examining whether TELEPAC could be revamped to act as a high-speed network infrastructure, CICESE determined the three key minimum requirements necessary to apply frame relay technology: the use of terminal devices that are equipped with greater intelligence and with the capacity to manage higher-layer protocols, the use of noiseless transmission lines such as optical fiber, and the ability to manage applications that can tolerate variable delay.

One of the important characteristics of frame relay, which presents a favorable advantage for the TELEPAC network, is its ability to coexist in a hybrid environment. In other words, users can continue using the X.25 technology in those places of TELEPAC where its comparatively lower speed is sufficient, while at the same time applying the frame relay technology on those links where there exists a demand for frame relay's higher speed.

TELEPAC can migrate to frame relay either by adding frame relay technology to the X.25 network via software, thereby enabling the frame relay service to utilize the same procedures as the X.25 technology, or by modifying the hardware as well as the software in each of the nodes of the backbone. CICESE investigated converting TELEPAC to a frame relay network using the access equipment associated with the network—such as the customer premise equipment, the switching equipment in the backbone, and the physical lines used in the path, as well as the network's own topology (see **Figure 5-3**).

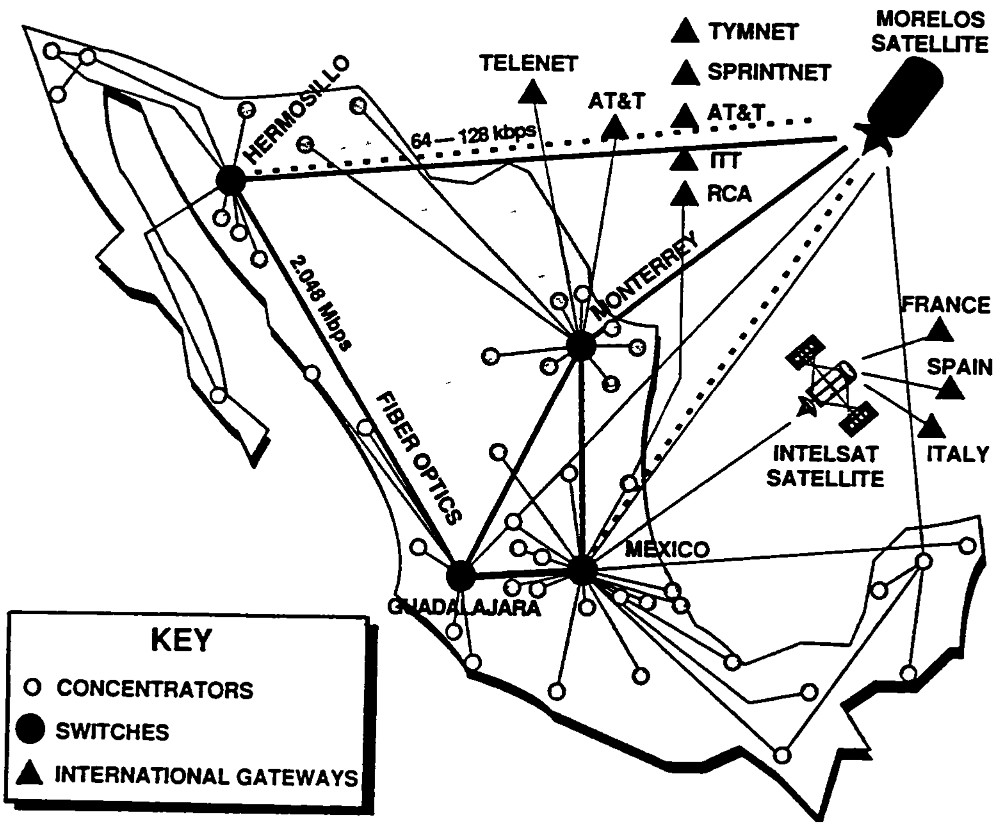

Figure 5-3. TELEPAC's Current Topology [3]

That study concluded that the fastest communications technology with the biggest payoff in Mexico this decade is the move toward higherspeed PSNs. CICESE determined that this development is feasible and will occur in three distinct stages.

1. gradual migration from X.25 to frame relay;

2. merging frame relay technology with fast-packet switching technology; and
3. fully implementing a switched multimegabit network.

The first stage will enable TELEPAC to support Mexico's national and international LAN needs while the second will add support for integrated voice, data, and image transmission. Finally, the third stage can provide complete high-speed and multiplexing services.

The modernization of the TELEPAC network is already being carried out. In addition, the U.S.'s economic integration with the other North American countries demands the use of a high-speed PSN, and it is forcing Mexico to provide similar services as its North American counterparts. For this reason, CICESE designates the Mexican TELEPAC PSN as the best for accommodating the country's growing communications requirements in the present decade

5.1.4 Advanced Services

The American Mobile Satellite Corporation, AMSC, is negotiating with companies and agencies in Central America about offering fixed and mobile telephone services from their M-Sat satellite, launched April 7, 1995. This service started several years ahead of competitors such as Globalstar and Iridium. MSS services will have drastically lower per minute charges than the current Inmarsat mobile telephone service. Technically, one could use a satellite phone anywhere within the coverage area. Also, fixed site satellite telephones could "leapfrog" the need for installing expensive wire-line or cellular towers systems in many regions and remote areas. The AMSC satellite, launch and network operations have cost $460 million. TMI Communications of Ottawa is launching an identical M-Sat satellite to serve users in Canada later this year. [4]

Telmex predicts new services in its 1993 annual report, such as video teleconferencing, Videotex, a service that can provide images as well as text for such things as home banking, telephone directories, consulting the library, and electronic periodicals.

5.1.5 Fiber-optic Network

Principle features of Mexico's long-distance infrastructure system are a microwave network and a fiber-optic network, which duplicates the major transmission routes of the microwave network. By the end of 1994, a 13,500-kilometer (about 8,400 miles) fiber-optic cable backbone linking 54 major cities throughout Mexico will be completed. This network will improve both the capacity and the quality of long-distance service.

5.1.6 Satellites

Demand for domestic satellite communications in Mexico over the last few years has been growing—in fact, the level of need has exceeded all expectation. In addition to being used for television and radio broadcasting, satellites are required for other telecommunication applications that cannot be serviced, due to the inadequate coverage and capability of terrestrial networks.

Like Brazil, Mexico first built up its domestic satellite earth station infrastructure through leasing Intelsat transponder capacity. With many remote communities throughout Mexico, satellite communications provided essential telephone and TV services. In 1985, Mexico launched its own Morelos 1 and MORELOS 2 satellites to meet the growing traffic demand. These satellites, supplied by Hughes Aircraft, are equipped with 18 C-band and 4 Ku-band transponders.

When the Solidaridad generation of satellites was launched, Mexico increased its C-band space segment by 50 percent, Ku-band by 150 percent and adding L-band.

In Mexico, Telecomunicaciones de Mexico (Telecomm), the sole authorized operator of satellites, provides communications satellite capacity and services for private and public networks, and operates several shared hubs.

The MORELOS domestic satellites, reached the end of their nine-year lives in early 1994, and in the summer of 1991, the Mexican government signed a $184 million contract with Hughes Aircraft Company to supply the country a second satellite system, Solidaridad. Two larger satellites, Solidaridad, have been launched (11/28/93) to replace the two original Morelos.

The Morelos System

In 1985, Mexico launched its first generation of satellites, comprising two spacecraft called Morelos l and Morelos 2. The first satellite began operations immediately. Because there was not enough demand initially, Morelos 2 was placed in a storage orbit until 1989, see **Table 5-1** for usage Morelos 2 transponders.

The Morelos satellites are versions of Hughes Space & Communications' HS 376 bus. Mexico was the first customer to use the HS 376 as a hybrid satellite operating in two frequency bands, C- and Ku- simultaneously. Morelos l and 2 are positioned at 113.5°W and l 16.7° W, respectively.

Table 5-1. Transponders Used for Radio/TV on Morelos F2 (116.7° West)

Transponder/Beam	Station	System
4N/spot	TV XHGC-TV (Channel 5)	NTSC
4N/spot	Radio XEWA-FM, Mexico City	
3W/L /spot	TV XHFM (Super Channel)	NTSC
3W/L /spot	TV CMC (Cine Mexicano for cable)	B-MAC
4W/U /spot	TV Canal 11 (XEIPN-TV)	NTSC
7N/spot	TV XEW-TV, Mexico City	NTSC / encryted
7N/spot	Radio XEX-FM 101.7, Mex. City	
8N/spot	TV Multivision	NTSC
9N/spot	TV Tele Hit	NTSC / encryted
12N/spot	TV Canal 13 (XHDF-TV)	NTSC

Currently, the two satellites are operating at full capacity in both C- and Ku-band, with more than 200 users. Non-preemptable 36 MHz transponders on Morelos cost approximately are $133,000 per month, 72 MHz transponders are $200,000 per month. [5]

The Solidaridad System:

To aid economic development and ensure that enough capacity will be available into the next century, the Mexican government plans to fill all three of its orbital positions with spacecraft that have the appropriate characteristics to meet a variety of needs.

The second generation of Mexican satellites, called Solidaridad, was built to cope with unmet demand and to guarantee service continuity when the Morelos 1 satellite's useful life ended at the beginning of 1994. The satellites will also be used to extend, diversify and improve the array of satellite telecommunications services presently available.

The Solidaridad system, **see Table 5-2**, which consists of two body-stabilized geosynchronous satellites based on Hughes's HS 601 bus, was placed in the 109.2°W and 113°W orbital positions. Solidaridad 1 was launched in November 20, 1993, and Solidaridad 2 on October 7, 1994.

Table 5-2. Solidaridad System

Satellite Type	Hughes HS 601
Position:	109.2° W and 113° W (see note below)
Mass at launch	2,740 kg
Primary power EOL	3,370 W
Stabilization	Body stabilized
Expected lifetime	14 years
Transponders	• 12 each 16-18 W SSPA 36 MHz at C-band, vert. polarized • 6 each 10 W TWTA 72 MHz at C-band, horiz polarized • 16 each 42.5 W TWTA 54 MHz at Ku-band • 1 ea. 4x21 W SSPA Rt. hand circular at L-band
Coverage areas	6, including parts of US.

Note: Morelos 2 occupies Mexico's third slot at 116.7°W.

The satellites are designed to provide 14 years of communications services, following their launch and in-orbit test period. The spacecraft are powered by a two-wing solar array that provides 3.4 kW (end of life). An integrated bi-propellant system supplies the necessary impulse for perigee augmentation, apogee injection, wheel momentum dumping and stationkeeping.

Telecomm will operate the system and offer communications services at C-, Ku- and L-band for Mexico. In addition, C-band services will extend to Central and South America and Ku-band services to major cities in the United States .

Table 5-3. Transponders Used for Radio/TV on Solidaridad F1 109.2° West

Transponder/Beam	Station	System
3 / spot	various radio	SCPC
5 / spot	TV SEP	NTSC
5 / spot	Mexican Radio	
5 / spot	Mexican Radio	
8 / spot	TV Telemax	NTSC
8 / spot	Radio Sonora	
21 / spot	TV XHTV, Mexico City	NTSC

The Solidaridad satellites will be used for voice and data networks, radio and TV distribution, **see Table 5-3**, public and private digital networks and mobile communications in Mexico (and on a regional basis). The cost of 36 MHz and 72 MHz C-band transponders will be slightly lower than that of the Morelos system .

C-band

The C-band payload on Solidaridad provides three coverage regions: Region I (RI) covers Mexico, the southern border of the United States and the northern part of Central America. This region receives and transmits in both polarizations. Region 2 (R2) covers R1 plus southern Florida, the Caribbean, Central America, Colombia and Venezuela. Region 3 (R3) covers most of the remaining parts of South America, with the exception of Brazil.

All transponders that cover more than one region can be reached from any of the related uplink or downlink service regions. Moreover, the uplink and downlink choices for each transponder can be made separately.

Another characteristic of the satellites' C-band uplink coverage is that R2 and R3 adjoin. To obtain transmit coverage between the regions, the R2 feeds use the west reflector and the R3 feeds use the east reflector on the spacecraft.

The uplink/downlink interconnectivity among R1, R2, and R3 provides the flexibility to easily switch the transponders between uplinks and downlinks.

Each satellite has six wideband 72 MHz channels and 12 narrowband 36 MHz channels. All wideband channels will serve only R1, and eight of the 12 narrow band channels may receive from region R1, R2 or R3. Four channels of this group may transmit to region R1 or R3, while the other four channels may transmit into region R1 or R2. Up to four transponders can be switched between regions R2 and R3.

The EIRPs for the R1, R2 and R3 regions are 37.5 dBW, 37 dBW and 37 dBW, respectively, for narrowband transponders, and 40.5 dBW for the wideband transponders.

Ku-band

The receive and transmit coverage regions of the Ku-band payload for both horizontal and vertical polarizations are footprint 4 (R4) and footprint 5 (R5). R4 covers Mexico, Los Angeles and San Antonio; R5 covers major United States cities and small parts of Canada and Cuba.

Each satellite has sixteen 54 MHz Ku-band channels, all of which provide uplink and downlink coverage for Mexico (R4). Two of the 16 channels can be individually and independently commanded from the ground to uplink from the United States (R5) . The downlink of one of these two channels can be switched, if needed, to cover the R5 region. The EIRPs for the R4 and R5 regions are 47 dBW and 46.4 dBW, respectively.

L-band

The L-band payload provides coverage of the Mexican territory and 200 nautical miles offshore. Since the entire nadir of the satellite bus is used for the L-band antenna, a large aperture is provided without the use of deployment, yielding high antenna gain and ample EIRP margin. The slow roll of the antenna gain outside the required coverage allows for usable extended coverage over North and Central America.

The L-band subsystem consists of two separate transponders—a Ku/L-band and an L/Ku-band—sharing a common L-band transmit/receive antenna. The mobile band of Solidaridad 1 and Solidaridad 2 is divided into four and three sub-bands respectively, with bandwidths ranging from 2.5 to 5.5 MHz. The usable bandwidth will be less than the total capability available in each satellite, as a result of the coordination process that is being carried out.

The L-band transponder requires a feeder link interconnection with the Ku-band. The EIRP of this band is 45.4 dBW.

National Priorities

Most of Solidaridad's C- and Ku-band capacity will be used to serve Mexico, and the planned capacity for regional communications can be switched, if necessary, to meet Mexico's needs.

Telecomm believes that the combined C- and Ku-band capacity of Morelos 2 and the Solidaridad system will satisfy all of the current and anticipated demand for domestic satellite services.

The C-band capacity on Solidaridad 1 will immediately be filled with the services that are carried on Morelos 1. Solidaridad 2's C-band space segment will satisfy additional demand for domestic services, as well as requirements for regional services.

Regional Options

If Mexican needs are met, other countries that fall inside Solidaridad's regional coverage areas can lease transponders. The Solidaridad satellite system can be used for radio and TV distribution and voice and data communications services on a domestic or regional basis through private and public networks.

For example, the economic interchange between Mexico and the United States is growing daily. As a consequence, Telecomm expects a high level of demand for transborder telecommunication services in the near future. The Ku-band transponders, in particular, will present a great opportunity for users to establish transborder links through teleports or private networks. In the field of broadcasting, Televisa, for instance, will use Solidaridad's R1 and R2 footprints, enabling it to reach a Spanish-speaking US. audience as well.

Types of Service

FSS	Intelsat, Solidaridad, PanAmSat
MSS	Inmarsat, AMSC, Solidaridad
BSS	PanAmSat (PAS 5), Inkari, DirecTV Latin America

5.1.7 VSATs

Mexico has been the focal point of a variety of VSAT applications.

Table 5-4. Total Earth Stations in Mexico in 1993

Type	Micro	Small	Medium	Large
International			4	4
Domestic		190	60	
Mobile	21			
VSATs	633	7		
Total	654	197	64	4

In early 1990, Spar Communications was awarded three separate contracts for satellite-based telecommunications networks from three major Mexican end-users worth some $15 million. The Secretariat of Communications and Transport placed a $4 million order for a backbone communications network linking earth stations in 12 Mexican cities. Servicios Industriales Penoles SA, the central mining organization, placed the next order with Spar for satellite communications business terminals for fully integrated voice, data and video services for 45 locations. The third order was placed by Petroles Mexico (PEMEX), to supply networks providing voice, data and image services using Spar business terminals in a digitally configured network.

Scientific-Atlanta also won three contacts in Mexico for three satellite-based networks. One project for Industries Resistrol calls for a VSAT network with nine 2.4 m and three 4.5 m earth stations throughout Mexico. The remote VSATs communicate via a 7 m hub station in Mexico City. The network allows both voice and data traffic to be carried at 64 kbps.

In another project, the Mexican Ministry of Natural Resource and Agriculture has established a point-to-point digital link between Mexico City and Merida. VSAT terminals (2.4 m) transmit technical, agricultural and weather information as well as hydraulic measurements of rivers, wells and dams in the south eastern Yucatan peninsula.

Another contract awarded to Scientific-Atlanta, due to be completed at the end of 1991, provides a VSAT network for Banca Serfin, one of Mexico's oldest banks. The VSAT network will link Banca Serfin s Mexico City headquarters and four regional offices with 172 of its branches throughout Mexico. The network will be used to manage all the two-way data communications now carried by dial-up lines. This includes communications required for automatic teller machine transactions, in-bank platform teller machine transactions and other centralized data management. The bank is converting to VSAT primarily because of the unreliability and inflexibility of existing terrestrial links.

Morelos II was filled in less than a year after its launch, particularly at Ku-band which filled with private VSAT Mexican networks. The Solidaridad Satellites were designed to double Morelos Ku-band capacity.

5.2 Trends in Telecommunications

In 1992 the terrestrial TELMEX network was in a poor state. Some 70% of small towns were reported to have no service at all, and where lines do exist, there is a high failure rate. Therefore, for organizations with branch offices scattered throughout the country, satellite communications will be an obvious choice for some time.

By the end of 1994, Telmex was to have provided automatic switched services to more than 18,000 towns with a population of 5,000 people or more. Telmex also must provide at least a public phone or a long-distance agency service to towns with

500 people or more. More than 20,000 of these towns already have telephone service, an increase of 50 percent since 1990.

TELMEX is upgrading 470,000 electromechanical and semi-electronic exchanges and installing state-of-the-art digital switching equipment and cable systems. The upgrades of the 1920s and '30s central office equipment occur at a rate of one office per week. This upgrade program is considered the most aggressive in the world. The network is now 70 percent digital, up from 29 percent in 1990. By the end of 1995, Mexico City will be digital, and the entire country is scheduled to be digital by the end of the decade.

5.2.1 Overall

With the privatization of TELMEX in 1990, Mexico's major carrier was reorganized into three discrete regional operating companies to provide long distance and special services. Fifty-one percent of the TELMEX voting stock was sold for $1.75 billion to a consortium comprising Southwest Bell, France Telecom and Grupo Carso, a Mexican group.

The other key telecommunications entity in Mexico is the government agency, Secretaria de Communicaciones y Transportes (SCT). With privatization, SCT s satellite operations were placed in a separate state-owned corporation, Telecommunicaciones de Mexico.

5.2.2 Satellite Demand Forecast

Solidaridad has recently been placed into operation, and will not need to be replaced for about 10 years. New services are emerging such as DTH-TV, that may justify another satellite; however, it is more likely that this service would be provided by an existing system such as PanAmSat. If a DTH-TV system could be sold to other smaller countries in South America, the increased revenues may justify Mexico's procurement of such a system. Other services like AMSC (for PCS) may also be utilized. It is unlikely that Mexico would want sole ownership of such a system. It is more likely that Mexico would want to participate by buying equity shares and gateways for terrestrial access to the PSTN.

5.2.3 Satellite Revenues

The 36 MHz transponders cost approximately $133,000 per month, and 72 MHz transponders are $200,000 per month. There are 12 C-band 36 MHz transponders, 6 C-band 72 MHz, and 16 Ku-band 54 MHz. Scaling gives a price of

$166,000 for a 54 MHz transponder. The total revenue generated from one satellite is shown in **Table 5-5**.

Table 5-5 Revenues Possible from a Solidaridad Satellite

Transponder Type	Quantity	Price/month	Total/Year
36 MHz C-band	12	$ 133 K	$ 19,152 K
54 MHz Ku-band	16	$ 166 K	$ 31,872 K
72 MHz C-band	6	$200 K	$14,400 K
Total for a fully leased satellite:		$5.45 M/Mo.	$65.4 M /yr.

The total revenues for Telmex in 1993 was 24,602 million new pesos, which would have been $7.936 billion US. Thus if two Solidaridads were 100% sold, they would represent only about 1.6% of the total revenues of Telmex. To augment the "system" with Solidaridad cost the Mexican government $184 million. The lease revenues alone could pay back the cost of this system in less than two years, and the expected life of the satellite is 14 years.

5.3 Country Overview - Mexico

Figure 4.4 lists Mexico's economic characteristics.

5.3.1 Mexico's Economic Importance

Mexico's economic growth is vital to its political prospects and has a substantial and direct impact on the U.S. economy. Mexico is the U.S.'s third-ranked trading partner, purchasing two-thirds of their imports from the United States and sending two-thirds of its exports here. Chief U.S. exports to Mexico include motor vehicle parts, office equipment, and agricultural products; top imports from Mexico include petroleum, cars, piston engines, and coffee.

Proven oil reserves total 45 billion barrels, about 7% of the world's proven reserves. The discovery of extensive oil fields in the coastal regions along the Gulf of Mexico in 1974 enabled Mexico to become self-sufficient in crude oil and to export significant amounts. With crude oil production averaging 3 million barrels per day during 1991, Mexico ranks as the world's fifth-largest oil producer. About half of the oil is refined and consumed domestically, leaving the remainder for export.

The U.S. is the source of two-thirds of direct foreign investment in Mexico. Both U.S. exports and investment have increased as Mexico has progressively opened its economy.

<u>Economy</u>
- GDP (1991): $282 billion.
- Annual real GDP growth: 3.6%
- Per capita GDP: $3,200.
- Inflation rate 19-50%. (interest rates as high as 80% in 1995)

<u>Defense. about 0.5% of GDP in 1991</u>
Mexico's armed forces in 1991 numbered about 170,000 The army makes up about three-fourths of the total. One year of limited training is required of all males reaching age 18. A paramilitary force of communal landholders is maintained in the countryside. Principal military roles include narcotics control, maintenance of public order, and civic action assignments such as road-building and disaster relief. Military expenditures constituted about 0 5% of GDP in 1991

<u>Natural resources:</u>
- Petroleum, silver, copper, gold, lead, zinc, natural gas, timber

<u>Agriculture</u>
- Products--corn, beans, oilseeds, feed grains, fruit, cotton, coffee, sugarcane, winter vegetables.

<u>Industry: Types</u>
- Manufacturing, services, commerce, transportation and communications, petroleum and mining.

<u>Trade (1991):</u>
- Exports--$27 billion: manufacturing 59%, petroleum and derivatives 30%, agriculture 9%, other 5%.
- Imports--$38 billion. intermediate goods 63%, capital goods 22%, consumer goods 15% Major trading partners--US, EC, Japan US imports--$30 billion.

<u>Official exchange rate:</u>
- (January 1993): 3.1 new pesos (introduced January 1993)=$1.
- (January 1995): 5.0 new pesos (introduced January 1993)=$1
- (March 1995). 7.0 new pesos (introduced January 1993)=$1.

<u>Total foreign investment at the end of March 1992 was $33.2 billion.</u>
The government announced sweeping revisions of Mexico's foreign investment regulations in 1989. The most important of these is the explicit permission for foreigners to have majority ownership in companies. This is, in effect, a reversal of laws which, in most cases, limited foreign ownership to 49%. The government has also announced that special trust funds will be set up to liberalize foreign access to the Mexican stock market.

Figure 5-4. Mexico's Economic Characteristics

5.3.2 General Background

Area: about three times the size of Texas.

- 2 million sq. km. (764,000 sq. mi.);

People:

Mexico is the most populous Spanish-speaking country in the world; it is the second most populous country in Latin America , after Portuguese-speaking Brazil. About 70% of the people live in urban areas. Many Mexicans emigrate from rural areas that lack job opportunities--such as the underdeveloped southern states and the crowded central plateau--to the industrialized urban centers and the developing areas along the US-Mexico border. According to 1991 census estimates, the population of greater Mexico City is roughly 20 million, which would make it the largest urban concentration in the world. The border region and Guadalajara, Monterey, and other cities have undergone a sharp rise in population. **Figure 5-5** shows Mexico's overall population characteristics.

Terrain:

Coastal lowlands, central high plateaus, and mountains up to 5,400 m. (18,000 ft.)

Agriculture

Mexico's agrarian reform program began more than 50 years ago, when land was distributed to landless farmers. By now, almost all available land has been distributed. Raising productivity and living standards of subsistence farmers has been slow, however, due to poor soils and rural population growth. The government stresses increased production of basic crops, such as corn and beans. Emphasis also is given to export crops such as coffee, tomatoes, and winter vegetables. The government hopes to revitalize food production by extending its economic reform program to the agricultural sector.

After years of stagnant agricultural production, improved weather conditions in 1990 helped boost Mexico's production of corn, sorghum, and beans. On the other hand, rice and soybean production fell, as farmers shifted toward more profitable crops.

In 1992, President Salinas introduced major reforms to Article 27 of the Mexican Constitution, which regulate rural land tenure. As a consequence, Mexican farmers have more autonomy. They may own their land outright, mortgage it, or associate themselves with outside investment. The reforms are aimed at increasing rural productivity and living standards.

Total Population (1992).
• 89 million. Annual growth rate: 2%
Density:
• 44.5 per sq. km. (116.5 per sq. mi.)
Ethnic groups:
Indian-Spanish (mestizo) 60%, American Indian 30%, Caucasian 9%, other 1%
Religion:
• Roman Catholic 90%, Protestant 5%, other 5%
Education: Literacy--90% of adult population.
Education in Mexico is being decentralized and enhanced in rural areas. The increase in school enrollments during the past 2 decades has been dramatic Education is mandatory from ages 6 through 14 or until primary education is completed Primary enrollment from 1970 through 1989 increased from less than 10 million to nearly 15 million. In 1990, 80% of the population between the ages of 6 and 14 were in school. (Latin America as a whole averages 85% enrollment.) Enrollments at the secondary school level have also shot up from 1.4 million in 1972 to as many as 5 million in 1990. Between 1959 and 1990, enrollments in institutions of higher learning skyrocketed from 62,000 to 1.5 million
Health:
• Infant mortality rate--30/1,000.
• Life expectancy-- male 68 yrs, female 76 yrs.
Work force (1992, 30 million).
• Services--30%.
• Agriculture, forestry, hunting, fishing--24%
• Manufacturing--19%.
• Commerce--13%
• Construction--7%.
• Transportation and communication--4%.
• Mining and quarrying--0.4%.
Cities (1994):
• Capital--Mexico City (est. 25 million)
• 56 Other main cities including --
• Guadalajara, Monterey, Puebla de Zaragoza, Leon

Figure 5-5. Mexico's Population Characteristics

Transportation

Mexico's land transportation network is one of the most extensive in Latin America. The 36,000 kilometers of railroads are government owned. Tampico and Veracruz on the Gulf of Mexico are Mexico's two major ports, although the government is developing additional ports on the Gulf of Mexico and on the Pacific as well. A number of international airlines serve Mexico, with direct or connecting flights from most major cities in the United States, Canada, Europe, and Japan. Most Mexican regional capitals and resorts have direct air lines with Mexico or the United States.

The Salinas Administration attempted to modernize infrastructure and services, deregulate and develop more efficient transport systems, and privatize all sectors except those constitutionally restricted.

5.3.3 History

For over 60 years, Mexico's Government has been controlled by the Institutional Revolutionary Party, PRI, which has won every presidential race and most gubernatorial races. To secure its continuance in power, the PRI has, over the years, relied on extensive patronage and massive government and party organizational resources.

Following federal elections in 1988, a total of six parties gained representation in the Chamber of Deputies and two in the Senate--the latter a first in Mexican history. The combined opposition won an unprecedented 237 seats out of a total of 500 in the lower house and 4 of 64 in the upper. In municipal elections held through December 1989, the government recognized several opposition victories by both left-of-center and right-of-center parties. In the state of Michoacan, for example, the center-left Party of the Democratic Revolution won almost half of the state's municipalities, including the state's capital and most populous city, Morelia.

In mid-term elections held in August 1991, the PRI bounced back with a major victory. It increased its representation to 320 in the Chamber of Deputies and 61 in the Senate, won numerous local and municipal offices, and based on official figures released, won several gubernatorial contests. However, opposition claims of electoral fraud in Guanajuato and San Luis Potosi states resulted in one governor-elect declining to take office and another resigning less than 2 weeks after his inauguration. In Guanajuato, an opposition leader was appointed interim governor.

5.3.4 Government Privatization

The government has taken steps to put public finance on a sound footing through privatization and deregulation of state-owned companies, elimination of subsidies to inefficient industries, dramatic reduction of tariff rates, and shrinking the overall financial deficit from nearly 17% of GDP in 1987 to a projected surplus equal to 0.8% of GDP in 1992. In 1982, the Mexican Government owned 1,155 parastatal enterprises; by mid-1992, the number had dropped to 230. Eighty-seven of these were in the process of being privatized. Such measures, along with increased confidence in the economy, have brought down real short-term interest rates to about 4% in mid-1992, from 30% in 1990.

Telmex has a monopoly on local service until 2026, but loses its long distance conecession in 1996.

5.3.5 Global trade

Total foreign investment in Mexico at the end of March 1992 was $33.2 billion following sweeping revisions of Mexico's foreign investment regulations in 1989. The most important regulation gave permission for foreigners to have majority ownership in companies. This is, in effect, a reversal of laws which, in most cases, limited foreign ownership to 49%. The government has also announced that special trust funds will be set up to liberalize foreign access to the Mexican stock market.

Mexico's cooperation in world affairs has extended outside the hemisphere. In August 1990, immediately after the Iraqi invasion of Kuwait, the Mexican Government announced that it would increase oil production capacity by 100,000 barrels a day to demonstrate its solidarity.

North American Free Trade Agreement (NAFTA)

In separate ceremonies in the three capitals on December 17, 1992, President Bush, Mexican President Salinas, and Canadian Prime Minister Mulroney signed the historic North American Free Trade Agreement. NAFTA went into force on January 1, 1994. The agreement eliminates restrictions on the flow of goods, services, and investment in North America. This includes phasing out tariffs over a period of up to 15 years, elimination (as far as possible) of non-tariff barriers, and full protection of intellectual property rights (patents, copyrights, and trademarks). The agreement also includes provisions covering trade rules and dispute settlement. NAFTA marks the first time in the history of US trade policy that environmental concerns have been directly addressed in a comprehensive trade agreement. In addition, parallel labor agreements with Mexico reflect concerns raised in connection with NAFTA.

Before the NAFTA most Mexican tariffs ranged from 10 to 20 percent, and the trade-weighted average tariff was about 10 percent. Today, approximately one-half of all U.S. exports enter Mexico duty-free. Under the terms of the NAFTA, Mexico will eliminate tariffs on all industrial and most agricultural products imported from the United States within 10 years. Remaining tariffs and non-tariff trade measures on certain agricultural items are phased out over 15 years.

Mexico has eliminated import duites on on-line equipment, PBXs, cellular phones and modems. These account for 80% of U.S. telcomm imports into Mexiico Tariffs on central office switching apparatus and telephone sets will be phased out by 1999, and tariffs on paging devices, certain coaxial cables and antennas will be gone by 2004.

General Agreement on Tariffs and Trade (GATT)

As another indication of its commitment to economic reform and trade liberalization, Mexico acceded to the General Agreement on Tariffs and Trade (GATT) in 1986.

Reference Import Prices

The Mexican Government introduced a "reference price" system aimed at reducing fraud in customs valuation; however, the effect has been to restrict trade. In August 1993, Mexico published "reference prices" for imports of various products, including liquor, textiles, apples and apparel, and some electronic products. Mexican authorities subjected imports invoiced below the "reference price" to additional restrictions, including documentation requirements and bonding. The sudden imposition of the system and its arbitrary nature, resulted in considerable confusion and problems at the border, particularly for textiles and apparel exporters, who considered the reference prices unreasonably high.

As a result of U.S. complaints, the Mexican government modified the provisions in November 1993 to exempt the largest importers from bonding requirements. Further modifications were made in March 1994 to provide for automatic cancellation of bonds. However, Mexico is still using its reference price system for customs valuation purposes. In addition to normal payment of import duties, if the declared price of a good is less than the reference price, importers must post a bond for the difference in duties between the transaction value and the higher reference price. As currently implemented, the system may not be consistent with Mexico's GATT and NAFTA obligations. The U.S. and Mexico continue to consult on this issue.

5.3.6 Trends in Industrial Development

Manufacturing

During 1991, Mexico's manufacturing sector accounted for about one-fourth of the GDP and nearly 60% of exports. It grew by 3.7% during that year. Important gains have been made in the production of cement, aluminum, synthetic fibers, chemicals, fertilizers, petrochemicals, and paper. A growing automobile industry has become one of Mexico's most important industrial and export sectors.

Investment Climate in Mexico

Thanks in part to the North American Free Trade Agreement, which binds Canada, the United States and Mexico into one massive, $6 trillion trading bloc, U.S. corporations are noticing Mexico like never before.

During the first seven months of 1994 alone, more than $8 billion worth of foreign investment poured into Mexico - a 31.6 percent jump over the same period last year. Nearly two-thirds of direct foreign investment came from American firms. According to Kal Wagenheim, publisher of the newsletter, Mexico Business Monthly, foreign investment during President Salinas' administration will total $49.7 billion - more than twice his stated objective of $24 billion.

In 1994 General Motors planed to invest $316 million in a new auto factory, while Chrysler is building a $677 million plant and Ford is spending $55 million to upgrade its own facility. On the retail side, Dillard's, Office Depot and JCPenney all plan to open Mexican outlets.

Cultural Considerations

Central to cultural expression are Mexico's history and quest for national identity. Contemporary artists, architects, writers, musicians, and dancers continue to draw inspirations from a rich history of Indian civilization, colonial influence, revolution, and the development of the modern Mexican state. Artists and intellectuals alike emphasize the problems of social relations in a context of national and revolutionary traditions.

FINANCE - Credit

In 1989 Mexico was the first country to participate in the U.S.-sponsored "Brady Plan" to help developing countries reduce foreign commercial bank debt. This helped reduce Mexico's foreign debt from its high of $107 billion in 1987, and has further restored business confidence and sparked a return of expatriated capital

To meet and exceed all of the mandated requirements, Telmex is investing more than $2 billion a year in capital expenditures. When the six-year monopoly period expires for Telmex in 1996, more than $13 billion will have been spent on capital upgrades.

5.3.7 Currency Crisis, in 1994-95

Since it was first devalued in December 1994, the peso lost half its value. The volatility has wreaked havoc on Mexican trade and investment. Exporters don't know whether they'll receive 5, 10, or 15 pesos per dollar six months from now. That makes planning, production, and costing very difficult. Mexican interest rates currently at staggering 90% levels include a 40% spread to compensate for political and exchange risk.

Delivery of $5.2 billion in US. loans and $7.73 billion in aid from the International Monetary Fund helped calm the markets. As a result, the peso, which had reached 7.2 to the dollar at the height of speculation, has stabilized at around 6.5. The peso was 3.5 to the dollar in December 1994.

On Apr. 25, 1995 the Chicago Mercantile Exchange began trading Mexican pesos again. Reviving a peso futures market is just one of many measures being taken to stabilize the currency. Futures will let equity investors with big positions in Mexican hedge their peso holdings. "The Mexican economy is likely to begin to recover from its financial crisis by the end of 1995" [6] [1]

Impacts for satellite industry

This currency crisis is not uncommon in emerging nations. Many nations such as Brazil have experienced hyper-inflations. An exporter of satellites should set the price in his own currency, and perhaps a mix of other stable currencies for protection. International lenders rarely assume the risk of local currency devaluation. They instead denominate their repayments in foreign currency terms.

In the past, public enterprises or governments have borne the currency risk. In private finance, the risk of currency depreciation falls on the project sponsor, and ultimately on the consumers of the service. In many recent private projects, service rates have been linked to international currency. [7]

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[1]Michel Camdessus, chief of the International Monetary Fund from kick off of the IMF-World Bank spring 1995 meeting

5.4 Summary and Conclusions

Satellites have been, and will continue to be, a major part of the modernization of the telecommunications infrastructure of Mexico. Like most of the emerging nations of the world, Mexico is rapidly acquiring telecommunications equipment to satisfy the pent up demand for services. It has been estimated that the 1995 market for telecomm equipment, local, long distance, and cellular is $12 billion. These equipment are new and cost competitive, but not necessarily new technologies. In the near future, Mexico will introduce satellite cellular phone service, and direct to the home TV distribution. These services are new to the consumer, yet use bigger and better "conventional" satellite technologies like higher power transmitters and bigger reflectors, rather than breakthrough technologies like on-board switching or scanning spot beams.

Although Mexico maybe following the developed nations, it is leading the emerging nations in terms of developing its telecommunications infrastructure. Mexico is fortunate to be a neighbor of the U.S. in this regard. Mexico is the third-ranked trading partner with the U.S., purchasing two-thirds of its imports from the United States and sending two-thirds of its exports here. With this partnership, a growing Mexican economy can support the growth of the telecommunications infrastructure.

The development plan of Mexico covers adding new phone lines at 12% per year [8] (above the world average) doubling its public phones, and adding basic phone services to rural villages. Like many other nations they are using a mix of equipment to accomplish this goal. Mexico is now into their second generation of satellites, exploiting Ku-band and even selling excess capacity to the U.S. Mexico will continue to emulate the developed nations in its acquisitions.

The implications for future technologies is that Mexico will acquire new technologies as they are proven. This means new technologies will probably have to be developed, tried and tested first, before acquired by Mexico. In this way Mexico has become a model for other developing nations.

Section 6

Market Analysis for Developing Countries

This section is organized as follows:

6.1 Introduction

This section examines the potential market for satellite technology among developing nations The cost effectiveness of satellites within a general telecommunications infrastructure will be addressed in Section 8, the Financial Analysis.

Telecommunications technology has gone through many rapid changes in the past decade. These changes, such as fiber optics and digital processing, have greatly reduced costs and resulted in wider communications bandwidths In order to define the role of satellites in developing countries, unique technological, lifestyle, regulatory, demographic, and geopolitical factors must be considered for each country. This was done for the three case studies presented in Sections 3, 4, and 5. In this section, we focus on generalizing these results to developing nations as a whole.

This section begins with a definition of developing countries and then focuses on the demand for telecommunication services. This section addresses SOW Task 1a, 1d, and 1e.

6.2 Definition of Developing Countries

The World Bank classifies economies according to income where income is the country's per capita Gross National Product or GNP According to the World Development Report [1] the following categorizations apply (all amounts in 1992 $US):

- Low-income GNP per capita of less than $675
- Middle-income: GNP per capita between $675 and $8,356
- High-income: GNP per capita higher than $8,356

Typically, Low and middle income economies are referred to as *developing countries*. The World Development Report goes on to say that while this distinction is convenient, it does not necessarily reflect the development status of a country. In fact, the United Nations classifies some high-income countries as developing (e.g., Singapore, Israel, and Hong Kong) Furthermore, countries within a given region often do not operate independently, but more as a regional economic unit. Obvious examples of this are the Asia-Pacific region and the European Community. **Table 6-1** shows the World Bank's classification of countries according to region and income.

6.3 Forecast of Demand in Developing Countries

SOW Task 1a. Forecast the demand (need) for conventional (telephony, data ,and video) and new (multi-media, movies on demand, interactive TV, direct broadcast, etc) communications services by advanced satellites in the developing nations

This section forecasts the demand for services within the developing countries and relates that demand to the demand for advanced satellites

6.3.1 Telecommunications in Developing Countries

Figure 6-1 shows the availability of major infrastructural items per capita The first panel relates the number of main telephone lines per 1000 inhabitants to Gross Domestic Product in purchasing power parity (PPP)[1] dollars [1] **Table 6-2** [1]shows the data used for this plot

The graphing of GDP to the number of telephones lines does not imply any cause-effect relationship. The graph is merely intended to show the high degree of correlation between the development of a country's telecommunications infrastructure and a country's income level

[1] purchasing power parity (PPP) currencies are currency units used by the U N International Comparison Program to compare GNPs between countries PPP currencies are used instead of exchange rates and conversion factors This provides a more realistic comparisons of GNP

Table 6-1. Classification of Economies by Region and Income

		Sub-Saharan Africa		*Asia*		*Europe and Central Asia*		*Middle East and North Africa*		
Income group	*Subgroup*	*East and Southern Africa*	*West Africa*	*East Asia and Pacific*	*South Asia*	*Eastern Europe and Central Asia*	*Rest of Europe*	*Middle East*	*North Africa*	*Americas*
Low-income		Burundi Comoros Eritrea Ethiopia Kenya Lesotho Madagascar Malawi Mozambique Rwanda Somalia Sudan Tanzania Uganda Zaire Zambia Zimbabwe	Benin Burkina Faso Central African Republic Chad Equatorial Guinea Gambia, The Ghana Guinea Guinea-Bissau Liberia Mali Mauritania Niger Nigeria São Tome and Principe Sierra Leone Togo	Cambodia China Indonesia Lao PDR Myanmar Viet Nam	Afghanistan Bangladesh Bhutan India Maldives Nepal Pakistan Sri Lanka	Tajikistan		Yemen, Rep	Egypt, Arab Rep	Guyana Haiti Honduras Nicaragua
Middle-income	*Lower*	Angola Djibouti Namibia Swaziland	Cameroon Cape Verde Congo Côte d'Ivoire Senegal	Fiji Kiribati Korea, Dem. Rep Marshall Islands Micronesia, Fed Sts Mongolia N Mariana Is Papua New Guinea Philippines Solomon Islands Thailand Tonga Vanuatu Western Samoa		Albania Armenia Azerbaijan Bosnia and Herzegovina Bulgaria Croatia Czech Republic Georgia Kazakhstan Kyrgyz Republic Latvia Lithuania Macedonia FYR[a] Moldova Poland Romania Russian Federation Slovak Republic Turkmenistan Ukraine Uzbekistan Yugoslavia, Fed Rep	Turkey	Iran, Islamic Rep Iraq Jordan Lebanon Syrian Arab Rep	Algeria Morocco Tunisia	Belize Bolivia Chile Colombia Costa Rica Cuba[*] Dominica Dominican Republic Ecuador El Salvador Grenada Guatemala Jamaica Panama Paraguay Peru St Vincent and the Grenadines
	Upper	Botswana Mauritius Mayotte Reunion Seychelles South Africa	Gabon	American Samoa Guam Korea, Rep Macao Malaysia New Caledonia		Belarus Estonia Hungary Slovenia	Gibraltar Greece Isle of Man Malta Portugal	Bahrain Oman Saudi Arabia	Libya	Antigua and Barbuda Argentina Aruba Barbados Brazil French Guiana Guadeloupe Martinique Mexico Netherlands Antilles Puerto Rico St Kitts and Nevis St Lucia Suriname Trinidad and Tobago Uruguay Venezuela
Subtotal	169	27	23	26	8	27	6	9	5	38

(Table continues on the following page)

Table 6-1 (cont.). Classification of Economies by Region and Income

		Sub-Saharan Africa		*Asia*		*Europe and Central Asia*		*Middle East and North Africa*		
Income group	*Subgroup*	*East and Southern Africa*	*West Africa*	*East Asia and Pacific*	*South Asia*	*Eastern Europe and Central Asia*	*Rest of Europe*	*Middle East*	*North Africa*	*Americas*
High-income	*OECD countries*			Australia Japan New Zealand			Austria Belgium Denmark Finland France Germany Iceland Ireland Italy Luxembourg Netherlands Norway Spain Sweden Switzerland United Kingdom			Canada United States
	Non OECD countries			Brunei French Polynesia Hong Kong Singapore OAE[b]			Andorra Channel Islands Cyprus Faeroe Islands Greenland San Marino	Israel Kuwait Qatar United Arab Emirates		Bahamas, The Bermuda Virgin Islands (US)
Total	208	27	23	34	8	27	28	13	5	43

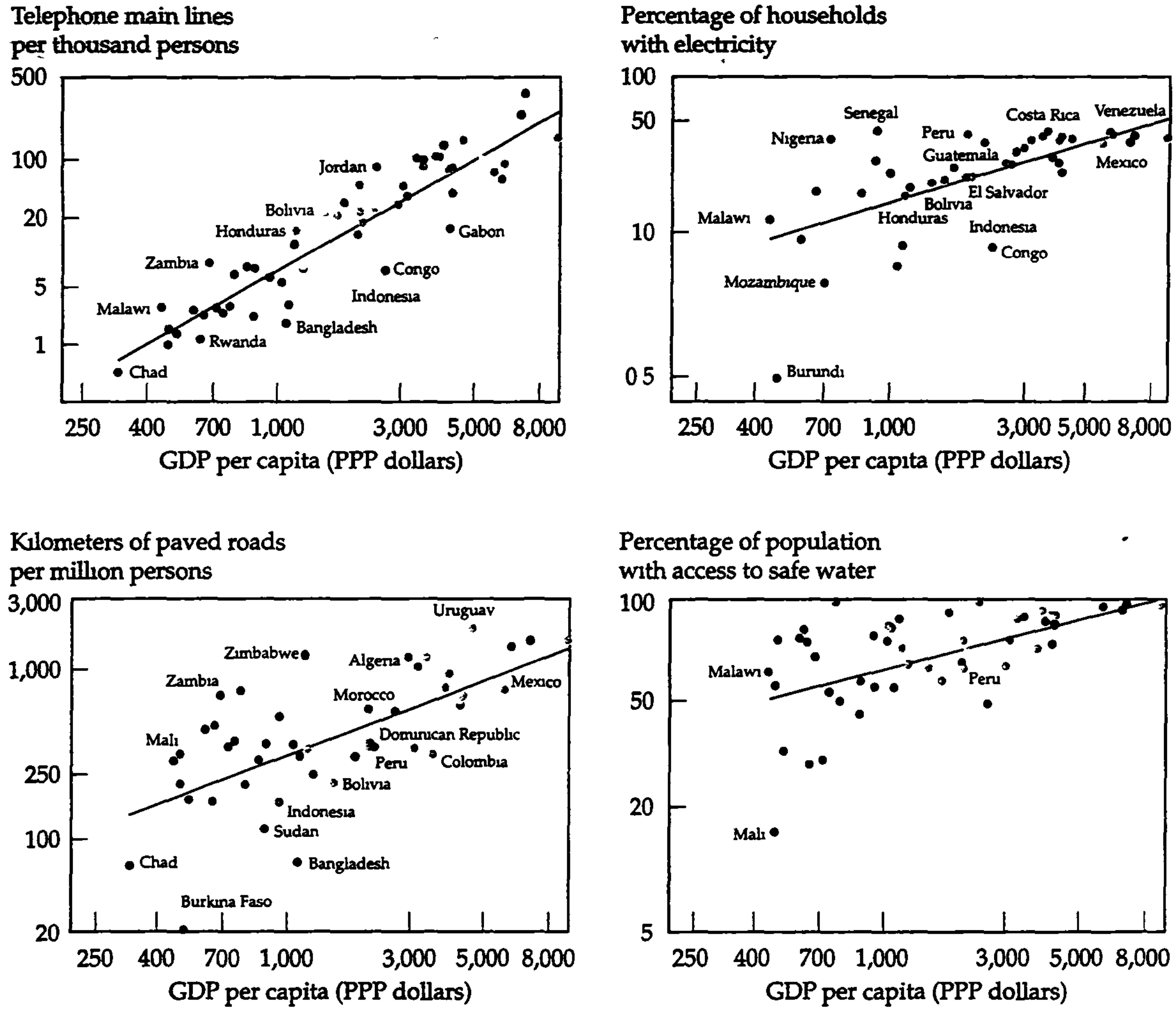
a Former Yugoslav Republic of Macedonia
b Other Asian economies—Taiwan, China

Definitions of groups

These tables classify all World Bank member economies, and all other economies with populations of more than 30,000

Income group Economies are divided according to 1992 GNP per capita, calculated using the *World Bank Atlas* method The groups are low-income, $675 or less, lower-middle-income, $676–2,695, upper-middle-income, $2,696–$8,355, and high-income, $8,356 or more

The estimates for the republics of the former Soviet Union are preliminary and their classification will be kept under review



- Middle East and North Africa
- Latin America and the Caribbean
- East Asia and Pacific
- Sub-Saharan Africa
- South Asia
- Europe and Central Asia

Note Axes are logarithmic; infrastructure quantities and GDP are for 1990, purchasing power parity (PPP) dollars are valued in Summers and Heston 1985 international prices
Source WDI table 32; Summers and Heston 1991

Figure 6-1. Per capita availability of major infrastructural components

6.3.2 Telecommunications Demand in Developing Countries

Figure 6-2 shows the waiting time distribution for telephone connections in a sample of 95 developing countries as compiled by the ITU in 1992 [1]. Eighty-four countries have a waiting time longer than one year, and thirteen countries have waiting times longer than twelve years! Clearly there is a huge unmet demand within the developing world. These countries are trying to meet the demand, but the demand clearly outstrips there ability to provide service. **Figure 6-3** [1] shows the average growth of infrastructure, including telecommunications, among the low and middle income nations. Middle income countries have seen an increase of 55% in their telecommunications infrastructure (mainlines installed) over the last 10 years, whereas in lower-income nations the growth has been less than half the middle-income rate (approximately 25%). These correspond to average annual rates of growth of 3.2% and 5.6%, respectively.

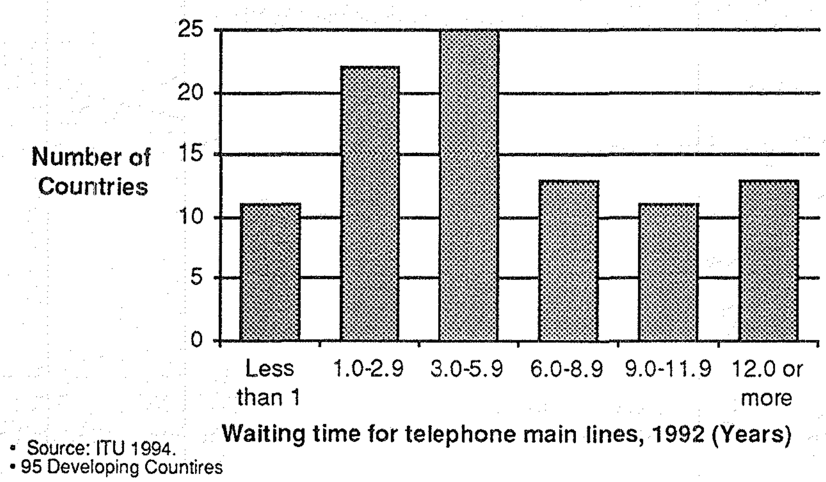


Figure 6-2. Main telephone line waiting time distribution.

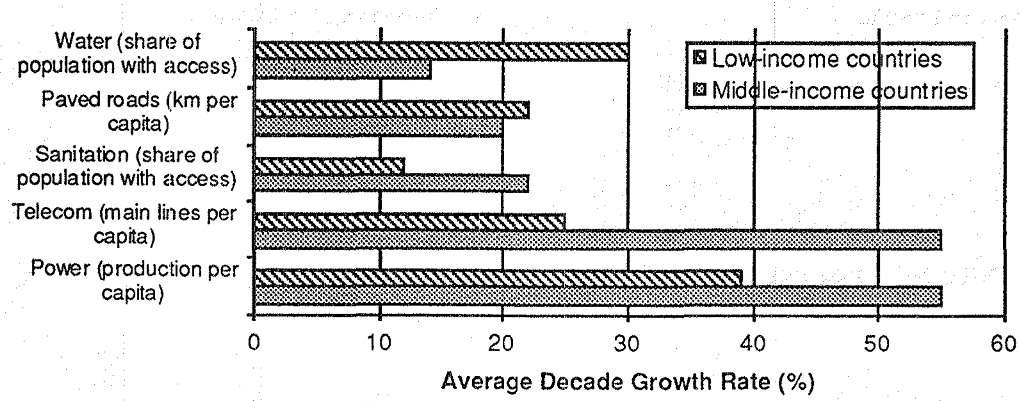


Figure 6-3. Infrastructure growth rates.

6.3.3 Demand for Services and Required Quality

SOW Task 1e. Develop estimates of quality of service (QOS) (required BERs, availability, etc.) for different communication services.

As our case studies revealed, the primary demand within developing nations is for conventional services. That is basic telephone, broadcast television, and narrowband data services. This does not mean to imply that these services will be delivered by conventional or out-of-date technology, just that the immediate demand is for conventional services. Furthermore, the demand is for these services to meet the quality of service objectives set forth in the CCITT standards **Figure 6-4** shows the number of faults per 100 main lines as a function of telephone line density. As the figure shows, many developing countries fall far short of the QOS objectives, and just having the telecommunications infrastructure does not mean high QOS.

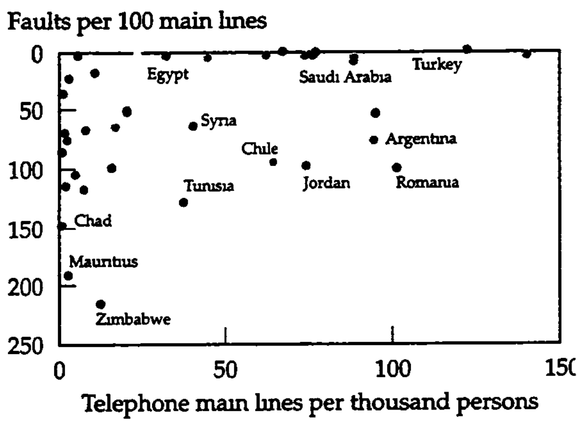


Figure 6-4. Telephone Faults within Developing Countires

6.3.4 Demand for Satellites

The translation of the need for telecommunications services into a demand for satellites, in general, and advanced satellites, in particular, is a difficult task. This is because of the number of ways in which satellite service can be provided and the wide variety of regulatory environments Below we list some of the satellite customers that may purchase satellites.

6.3.4.1 Satellite Customers

1. Intelsat

Intelsat is the current international monopoly for satellite services This service is transparent to the international carriers Most countries in the world have at least one INTELSAT terminal to provide for international telephone access

2. National or Domestic Satellites

Domsats, such as the Mexican Morelos, are used for services sold within the borders of an individual nation. The coverage pattern focuses on that country, and in many countries, the satellite is administered by the government Other countries such as Thailand, have given license or franchise to private companies to provide telecommunications services to that country. Services, such as TV distribution, would be an augmentation to that already available terrestrially

3. Regional satellites

These systems can cover several countries The ITU will license the service provided it does no economic damage to INTELSAT

4. Transponder (and other services) leases

These independent brokers, such as Tongasat, sell partial satellite capability to whoever can afford it.

In addition to the question of, "who buys satellites", there is the question of, "who buys advanced satellites (i e , advanced technology)?" The buyers of high technology are really the satellite manufacturers supposedly responding to the needs of their customers. This means that any demand for high technology insertion into communications satellites passes through several parties before being translated into specific satellite designs and features

6.3.4.2 Demand Forecast for Satellites

The 1994 World Space Market Survey [2] estimates the satellite market between 1992 and 2004 at 178 satellites (excluding Russian-made satellites) with a total value of $16B (1992 $US) Half of this market is ordered by existing satellite operators to replace existing satellites, and approximately 27 to 37 of these satellite are destined for developing nations (excluding international systems)

Only 11 commercial geostationary satellites that are under contract or construction are intended for operation in L-, S-, or Ka-bands for commercial mobile services, audio or video broadcasting or high-data rate business services The report estimates that 195 to 232 S-band or Ka-band transponders will be over Europe, Asia and North America by 1998 (approximately twice that of 1994) This must be balanced against the 4,489 to 5,448 estimated number of equivalent 36 MHz C/Ku-band transponders across over the same area (4 9% growth per year) [2]

The World Space Markets Survey [2] points out that growth in the satellite market depends on the demand for new services In particular, Direct Broadcast Services (audio and TV) and Mobile Satellite Services Mexico and Indonesia are contemplating the acquisition of DBS satellites, and APStar is currently seeking proposals for a satellite that contains a DBS capability

The mobile services market is becoming a significant market with six geostationary satellites under firm order and six more in planning Furthermore, proposals for some 268 non-geostationary satellites have been filed with the US FCC for launch between 1995 and 2000 Both India and China are the only two developing countries we know of that are considering a geostationary satellites for L-band mobile services No developing country is currently considering developing their own LEO/MEO-based mobile satellite system, but many are considering purchasing services on them. Exactly how this market develops is highly uncertain, and will depend heavily on how the developed nations embrace this new service and its comitant cost.

6.3.4.3 Relationship between Market Needs and Climate

SOW Task 1f. Determine if there is any relationship between market needs and regional climates (i.e., wet, dry)

Currently, no evidence in any marketing data indicates a direct relationship between climate and satellite markets A coincidental correlation exists between latitude and GNP simply because a majority of poor nations lie close to the equator. This correlation is due to primarily economic and climatic (agricultural) reasons

Table 6-2. Infrastructure Indicators Data

Country	*Telephone main lines (number of connections)* 1975	1980	1990	*Railroad tracks (kilometers)* 1960	1970	1980	1990	*Irrigated land area (thousands of hectares)* 1970	1980	1990
Low-income economies										
1 Mozambique	29,700	35,400	47,439	3,218	3,703	3,845	3,150	26	65	115
2 Ethiopia	52,100	64,080	125,398	1,090	1,090	987	781	155	160	162
3 Tanzania	28,500	39,770	73,011	3,545	5,895	2,600	2,600	38	120	150
4 Sierra Leone		11,450	26,550	500	449	84	84	6	20	34
5 Nepal	7,700		57,320			101	52	117	520	1,000
6 Uganda	20,000	19,600	27,886	1,300	5,895	1,145	1,241	4	6	9
7 Bhutan										
8 Burundi		2,000	10,263	0	0	0	612	27	56	72
9 Malawi	9,300	14,374	26,170	509	566	782	782	4	18	20
10 Bangladesh		89,000	241,824				2,892	1,058	1,569	2,936
11 Chad	2,400		4,015	0	0	0	0	5	6	10
12 Guinea-Bissau										
13 Madagascar	15,100	19,100	30,000	864	864	883	1,030	330	645	920
14 Lao PDR										
15 Rwanda	2,300	3,300	10,381	0	0	0	0	4	4	4
16 Niger	3,800	5,870	9,272	0	0	0	0	18	23	40
17 Burkina Faso	2,600	4,000		517	517	517	504	4	10	20
18 India	1,465,000	2,295,530	5,074,734	56,962	59,997	61,240	75,333	30,440	38,478	45,500
19 Kenya	57,000	80,200	183,240	6,558	6,933	4,531	2,652	29	40	54
20 Mali		5,380	11,169	645	646	641	642	80	152	205
21 Nigeria		163,360	260,000	2,864	3,504	3,523	3,557	802	825	870
22 Nicaragua	25,300	30,900	47,000	403	403	345	331	40	80	85
23 Togo	4,800	5,800	10,516	445	491	442	514	4	6	7
24 Benin	6,900	11,410	14,778	579	579	579	579	2	5	6
25 Central African Rep		2,617	5,000	0	0	0	0			
26 Pakistan	227,000	303,000	843,346	8,574	8,564	8,815	12,624	12,950	14,680	16,960
27 Ghana	33,900	37,000	44,243	951	952	925	950	7	7	8
28 China	3,262,000	4,186,000[a]	6,850,300					37,630	44,888	47,403
29 Tajikistan		140,000[a]	240,000						617	690
30 Guinea	6,600	10,380	12,100	805	819	662	940	5	8	25
31 Mauritania		2,500	6,248	675	675	650	650	8	11	12
32 Sri Lanka		54,200	121,388	1 445	1,535	1 453	1,555	465	525	520
33 Zimbabwe	84 600	95,600	123,665	3,100	3,239	3,415	2,745	46	157	220
34 Honduras		31,726	88,038	1,230	1,028	205	955	70	82	90
35 Lesotho		4,470	13,000	0	0	0	0			
36 Egypt, Arab Rep	353,000	430,000	1,717,498	4,419	4,234	4,667	5,110	2,843	2,445	2,648
37 Indonesia	219,400	375,800	1,069,015	6,640	6,640	6,637	6,964	4,370	5,418	8,177
38 Myanmar	25,900	28,200		2,991	3,098	4,345	4,664	839	999	1,005
39 Somalia		8,000	15,000	0	0	0	0	95	105	118
40 Sudan	43,200	45,355	62,000	4,232	4,756	4,787	4,784	1,625	1,770	1,900
41 Yemen Rep		24,171	124,516	0	0	0	0			
42 Zambia	28,400	30,400	65,057	1,158	1,044	1,609	1,894	9	19	32
Middle-income economies										
Lower-middle-income										
43 Côte d'Ivoire	24,600	32,180	64,177	624	656	680	650	20	44	64
44 Bolivia		142,000	183,880	3,470	3,524	3,328	3,462	80	140	165
45 Azerbaijan		390,000[a]	620,000						1,195	1,401
46 Philippines	304,000	420,000	610,032	1,020	1,052	1,059	478	826	1,219	1,560
47 Armenia		340,000[a]	560,000						274	305
48 Senegal		18,900	44,326	977	1,186	1,034	1,180	110	170	180
49 Cameroon		18,300	37,414	517	925	1,168	1,104	7	14	30
50 Kyrgyz Republic									955	1,030
51 Georgia									409	466
52 Uzbekistan		660,000[a]	1,402,844						3,476	4,159
53 Papua New Guinea	17,800	25,400	30,187	0	0	0	0			
54 Peru	254,000	321,651	564,504	2,559	2,235	2,099	2,505	1,106	1,160	1,260

(Table continues on the following page.)

Table 6-2 (cont.). Infrastructure Indicators Data

Country	*Telephone main lines (number of connections)* 1975	1980	1990	*Railroad tracks (kilometers)* 1960	1970	1980	1990	*Irrigated land area (thousands of hectares)* 1970	1980	1990
55 Guatemala		97,670	191,938	1,159	819	927	1,139	56	68	78
56 Congo	6,300	8,500	15,852	515	802	795	510	1	3	4
57 Morocco	123,000	167,000	402,410	1,785	1,796	1,756	1,901	920	1,217	1,270
58 Dominican Republic		113,900	341,201	270	270	590	1,655	125	165	225
59 Ecuador	176,000	227,000	490,508	1,152	990	965	965	470	520	552
60 Jordan		71,641	245,500	371	371	618	618	34	37	63
61 Romania		1,700,000[a]	2,365,830					731	2,301	3,216
62 El Salvador	55,000	75,500	124,969	618	618	602	674	20	110	120
63 Turkmenistan		120,000[a]	220,000						927	1,240
64 Moldova		240,000[a]	462,082						217	290
65 Lithuania		420,316[a]	780,965							
66 Bulgaria		1,144,300[a]	2,175,423					1,001	1,197	1,263
67 Colombia	861,200	1,075,700	2,414,726	3,161	3,436	3,403	3,239	250	400	520
68 Jamaica	49,700	56,204	106,152	330	330	293	339	24	33	35
69 Paraguay	32,000	49,500	112,452	441	441	441	441	40	60	67
70 Namibia										
71 Kazakhstan		900,000[a]	1,740,000						1,961	2,300
72 Tunisia	71,300	112,000	303,318	2,014	1,523	2,013	2,270	90	156	232
73 Ukraine		3,400,000[a]	7,028,300						2,013	2,600
74 Algeria	172,400	311,400	794,311	4,075	3,933	3,907	4,653	238	253	384
75 Thailand	237,000	366,000	1,324,522	2,100	2,160	3,735	3,940	1,960	3,015	4,300
76 Poland								213	100	100
77 Latvia		470,000[a]	620,000							
78 Slovak Republic										
79 Costa Rica	90,800	157,400	281,433	665	622	865	696	26	61	118
80 Turkey	770,000	1,301,558	6,893,267	7,895	7,985	8,193	8,695	1,800	2,090	2,370
81 Iran, Islamic Rep	814,000	1,025,403	2,254,944	3,577	4,412	4,567	4,996	5,200	4,948	5,750
82 Panama		126,700	216,026	158	158	118	238	20	28	32
83 Czech Republic										
84 Russian Federation										
85 Chile	308,000	363,000	860,075	8,415	8,281	6,302	7,998	1,180	1,255	1,265
86 Albania								284	371	423
87 Mongolia			66,357					10	35	77
88 Syrian Arab Rep	137,000	239,000	496,360	844	1,040	2,017	2,398	451	539	693
Upper-middle-income										
89 South Africa	1,229,000	1,632,000	3,315,022	20,553	21,391	20,499	23,507	1,000	1,128	1,128
90 Mauritius	16,300	23,600	59,927	0	0	0	0	15	16	17
91 Estonia										
92 Brazil	2,457,000	4,677,000	9,409,230	38,287	31,847	28,671	22,123	796	1,600	2,700
93 Botswana	5,000	7,817	26,367	634	634	714	714	1	2	2
94 Malaysia	194,000	396,000	1,585,744	2,100	2,160	2,082	2,222	262	320	342
95 Venezuela	578,000	859,739	1,494,776	474	295	280	445	70	137	180
96 Belarus									163	149
97 Hungary								109	134	204
98 Uruguay	193,000	220,000	415,403	3,004	2,975	3,005	3,002	52	79	120
99 Mexico	1,853,000	2,576,000	5,354,500	23,369	24,468	20,058	26,334	3,583	4,980	5,180
100 Trinidad and Tobago	42,200	44,000	173,965	175	0	0	0	15	21	22
101 Gabon		10,440	20,754	0	0	224	683			
102 Argentina	1,678,000	1,879,000	3,086,964	43,905	39,905	34,077	35,754	1,280	1,580	1,680
103 Oman	6,800	13,200	104,324	0	0	0	0	29	38	58
104 Slovenia										
105 Puerto Rico										
106 Korea, Rep		3,325,000	13,276,449	2,976	3,193	3,135	3,091	1,184	1,307	1,345
107 Greece	1,806,000	2,270,000	3,948,654	2,583	2,571	2,461	2,784	730	961	1,195
108 Portugal	820,602	989,470	2,379,265	3,597	3,563	3,588	3,598	622	630	631
109 Saudi Arabia	141,000	407,000	1,234,000	402	577	747	1,380	365	555	900

Table 6-2 (cont.). Infrastructure Indicators Data

Country	*Telephone main lines (number of connections)*			*Railroad tracks (kilometers)*				*Irrigated land area (thousands of hectares)*		
	1975	*1980*	*1990*	*1960*	*1970*	*1980*	*1990*	*1970*	*1980*	*1990*
High-income economies										
110 Ireland	357,000	483,000	983,000	2,911	2,190	1,987	2,464			
111 New Zealand	1,054,996	1,102,740	1,469,000	5,364	4,847	4,449		111	183	280
112 †Israel	642,000	860,000	1,626,449	420	470	827	1,148	172	203	200
113 Spain	5,118,000	7,229,000	12,602,600	18,033	16,592	15,728	19,089	2,379	3,029	3,402
114 †Hong Kong	910,000	1,279,000	2,474,998	56	61	92		8	3	2
115 †Singapore	249,600	523,400	1,040,187			38	38			
116 Australia	3,700,000	4,743,000	7,786,889	42,376	43,380	39,463	40,478	1,476	1,500	1,832
117 United Kingdom	14,059,000	17,696,000	25,368,000	29,562	18,969	18,028	16,629	88	140	164
118 Italy	10,166,000	13,017,000	22,350,000	21,277	20,212	16,133	25,858	2,561	2,870	3,120
119 Netherlands	3,612,100	4,892,000	6,940,000	3,253	3,148	2,880	3,138	380	480	555
120 Canada	8,614,000	9,979,000	15,295,819	70,858	70,784	67,066	93,544	421	596	860
121 Belgium	1,941,000	2,463,000	3,912,600	4,632	4,263	3,978	3,568			
122 Finland	1,430,000	1,740,000	2,670,000	5,323	5,841	6,096	5,054	16	60	64
123 †United Arab Emirates										
124 France	8,444,000	15,898,000	28,084,922	39,000	36,532	34,382	34,593	539	870	1,170
125 Austria	1,623,000	2,191,000	3,223,161	6,596	6,506	6,482	6,875	4	4	4
126 Germany	14,212,000	20,535,000	29,981,000	36,019	33,010	28,517	41,828	284	315	332
127 United States	82,802,000	94,282,000	136,336,992	350,116	331,174	288,073	205,000	16,000	20,582	18,771
128 Norway	939,000	1,171,000	2,132,290	4,493	4,292	4,242	4,168	30	74	97
129 Denmark	1,835,000	2,226,000	2,911,198	4,301	2,890	2,461	3,272	90	391	430
130 Sweden	4,356,000	4,820,000	5,848,700	15,399	12,203	12,010	12,000	33	70	114
131 Japan	34,444,000	39,934,000	54,523,952	27,902	27,104	22,235	23,962	3,415	3,055	2,846
132 Switzerland	2,523,000	2,839,000	3,942,701	5,117	5,010	5,041	5,020	25	25	25
Selected economies not included in main WDI tables										
Angola		36,700	70,000	3,110	3,043	2,952	2,523			
Barbados	29,200	49,600	83,366	0	0	0	0			
Cyprus	51,500	86,140	254,510	0	0	0	0	30	30	36
Fiji	17,400	23,900	42,425	644	644	650	644	1	1	1
Gambia, The		1,980	10,700	0	0	0	0	8	10	12
Guyana	15,300	16,243	16,003	127	127	188	187	115	125	130
Haiti		20,000	47,470	254	121	250		60	70	75
Iceland	73,900	84,800	130,500	0	0	0	0			
Iraq		275,000	675,000	2,019	2,528	1,589	2,372	1,480	1,750	2,550
Kuwait	103,000	157,000	331,406	0	0	0	0	1	1	2
Liberia		7,000		493	450	493	493	2	2	2
Luxembourg	111,000	132,000	183,700	393	271	270	270			
Malta	28,500	51,100	128,249	0	0	0	0	1	1	1
Suriname		16,174	36,812	136	86	167	166	28	42	59
Swaziland	3,550	5,210	13,524	225	220	295	316	47	58	62
Zaire	26,900	26,600	34,000	5,074	5,024	4,508	5,088		7	10

†Economies classified by the United Nations or otherwise regarded by their authorities as developing
a Data refer to 1981

6.4 Summary

What this says to the satellite manufactures is that over the next ten years, the geostationary market will still be dominated by conventional C-band and Ku-band transponder satellites (irrespecitive of climate) Emerging markets that justify the expenditure of internal R&D monies are in technologies that compete in the DBS and MSS markets.

From the standpoint of the overall satellite market, developing nations represent less than one-quarter of the total market, and while significant, it is questionable whether any manufacture would be willing to invest large sums of R&D to develop unique satellite hardware for that market However, the satellite market in the Asian-Pacific region is growing, and companies may want to approach this region as a niche market and develop technologies for this specific region.

It is unlikely that developing countries have the foreign capital necessary to develop unique satellite technology themselves It would seem more prudent for them to use existing technology, perhaps extended a bit, and maintain overall compatibility with satellite developed in the West Furthermore, they can leverage off the West's development of new technology.

This compatibility with the West extends to the QOS developing countries will establish within their networks. As developing countries interconnect into the world's telecommunications infrastructure they will be under pressure to have compatible service quality in order to conduct business Therefore, the developing countries will likely impose CCITT standards on their telecommunications systems.

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Section 7

Technical Feasibility of NII Augmentation via Satellites

This section addresses the general issue of technical feasibility for use of satellites by developing countries to augment their National Information Infrastructure (NII). Sections 2 through 6 of this report have addressed the potential demand for satellite-delivered communications services in the developing nations This section begins the process of definition of a space based communications infrastructure for developing countries. The first step (Section 7) is to assess technical feasibility, and the second step (Sections 8) is to perform a financial analysis and comparison. This section is organized as follows:

7.1 Augmentation for Large Geographic Areas
7.2 Potential Applicability of VSAT Technology
7.3 Universal Applicability of Solidaridad Concept
7.4 Summary of Results

7.1 Augmentation for Large Geographic Areas

SOW Task 2a *Determine if a national infrastructure augmentation (such as the Mexican Morelos or Solidaridad) is technically feasible for large geographic areas such as Brazil, China, or the Philippines (Assess in terms of sufficient capacity, quality of service, etc)*

In short, conventional satellite technology provides sufficient capacity and quality of service to augment the NII of geographically large nations

China, Brazil and Mexico all are using satellites to augment their respective NIIs However, they are not relying solely upon satellites to meet their needs Each of these countries is pursuing a both wireless and wired telecommunications technologies in parallel. China, for example, is installing terrestrial fiber networks in urban areas along with wireless cellular systems In parallel, they are pursuing both a VSAT-based backbone data network and a nation-wide fiber network interconnection.

In a similar manner, Mexico supports Ku-band VSAT networks via their national satellites while they aggressively pursue modernization of their terrestrial systems. Brazil has just recently deregulated their cable TV industry to allow entry of the DTH-TV market. This has brought a flurry of recent activity as foreign investors seek to capture one of the largest South American markets.

The augmentation is not just for telecommunications, but for television and other services as well A large demand for capacity in Asia is driven by TV broadcasters trying to penetrate the Asian market

Some of the services driving the satellite markets include

a. Broadcast TV distribution
b. Rural Telephone Exchange (RTX) Interconnection
c. Private VSAT Networks
d. Mobile telephony
e. DTH-TV

The current limiting factor for satellite markets in developing countries is the basic cost of user equipment. Neither India nor China, for example, can neither afford to provide everyone with a telephone nor provide everyone with universal access similar to the West. This means that the demand for service in developing nations will be different from that in the U.S. or western developed world

Business will lead the demand for services in developing nations, primarily because they can afford the service and equipment. Providing local village telephones is as far as developing nations can go to providing universal access to telecommunications to their respective general population—and that alone is an immense task.

Because the cost of ground terminal equipment limits demand, current satellites have sufficient capacity to meet the demand for telephony and VSAT services (at the typical QOS specifications) In fact, regions like Asia may experience a capacity "glut" at the current rate capacity increase[1]. However, the demand for television services is exploding and television broadcasters, such as CNN, BBC, DeutscheWella, etc., hope to expand their markets through satellites. China has over 120 million televisions house-holds. The choice for alternative programming has brought the desire for even more choices, and the lure of such a market has brought a large increase demand for TV transponder capacity. Currently, this demand for capacity is being met with conventional technology satellites.

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[1] Note that the communications satellite industry experiences capacity cycles where a shortage is followed by a glut followed by another shortage and so on

7.2 Potential Applicability of VSAT Technology

SOW Task 2b Determine the potential for (1) conventional VSAT technology, (2) voice and interactive VSAT technology; (3) hybrid technology when applied to large geographic areas

Satellite users in the past used large, expensive fixed earth terminals that connected into the national terrestrial infrastructure, and therefore, incurred a large fixed cost to enter the satellite communications market. Others could access satellites, but through these satellite transponder brokers The users preferred this arrangement because the they did not have to commit to large up-front capital expenditures. Satellite operators benefited as well because they had a limited number of users and they limit the different methods for using the satellites (i.e., the type of waveform, power levels, data rates, etc). Intelsat is a typical model for this method of satellite operation

VSATs have allowed users with less demanding data rate requirements to access the satellites directly using smaller terminals and less expensive equipment. However, the sophistication of VSAT networks generally demanded that specialists be called in to install the network. Therefore, there was still a fairly substantial investment required to use satellites for communications. There are many examples of VSAT networks that have been established for businesses around the world that fit this model.

However, in the case of both large terminals and VSATs, a limiting factor to the direct demand for satellites is the cost and complexity of the ground terminal equipment. How many small business are willing to spend thousands or millions of dollars to establish a VSAT network?

If a country were to rely heavily on satellites to augment its telecommunications infrastructure then, the use of VSATs would be almost imperative. The obvious reason for this is the cost of user equipment Small villages and businesses simply cannot afford expensive satellite ground terminal equipment. Therefore, the potential market for VSATs in developing countries is large, but the VSATs they need must be much simpler than the VSATs of today.

As Sections 3 through 6 show, the primary demand in developing nations is for POTS and TV. Furthermore, this demand must be met without the use of an up-to-date terrestrial infrastructure. This means that the terminal equipment must be widely available, inexpensive, and easy to use Furthermore, the overall satellite network must incorporate many of the functions of the terrestrial telephone system, namely switching, routing, and access control This places a much greater burden on both the satellite and network operators than previous systems that combine terrestrial systems and satellites.

There are two primary applications for VSATs (excluding non-TVRO and mobile telephony) in developing nations

a. Rural Telephone Exchange (RTX) Interconnection

b. Private VSAT Networks

The potential for VSATs in both of these areas is high The applicability of private VSAT networks is obvious, whereas the applicability of VSATs to RTXs needs examination.

The applicability of VSATs to RTXs basically comes down to a decision on the overall network designer as to where to place the VSATs in the switching hierarchy. The higher up the VSAT is placed, the higher the data rate, and the larger the terminal equipment. Thus, for financial reasons it is most likely that VSATs would be used as regional switching nodes that are then interconnected via larger fiber optic trunks as shown in **Figure 7-1**. For example, a regional VSAT network may interconnect four for five telecommunications islands. The VSAT hub (functionally, the hub functions could be on-board) would provide inter-island switching within the region and act as a switching gateway to the other regions via a fiber optic backbone.

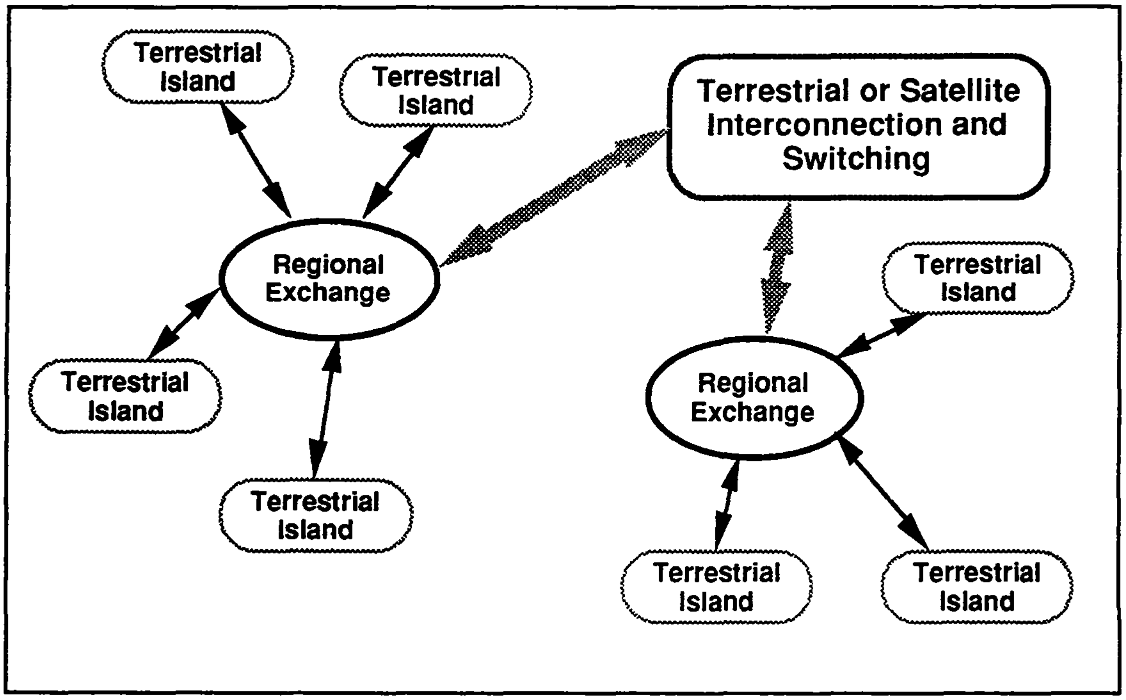


Figure 7-1. Rural Telephone Exchange Interconnection

These islands would each contain wired/wireless switching centers of 100 to 1,000 access lines each, and the trunking lines between each island would be carried by the VSAT network. The obvious detriment to this arrangement is the long transit delay to a geostationary satellite Whether or not a satellite-based cellular system could accommodate the traffic is a topic for further study

As to the question of interactive and hybrid technologies, Section 6 tells us that this is not a high priority with developing nations The idea is to provide basic services first, and we take that to mean basic telephony perhaps using the ISDN interface. It is very doubtful that rural areas will be connected for broadband services. Wideband services will exist, but they will be based on private VSAT networks, not on the overall national infrastructure.

7.3 Applicability of Solidaridad Concept

SOW Task 2c. Determine if the Solidaridad concept is universally applicable (for Brazil, China, or Philippines for example)? Determine whether a large geographic area raises technical and economic issues Compare Solidaridad with Morelos and Brazilsat for capacity and economics

7.3.1 Description of Solidaridad

With imminent privatization of TELMEX in 1990, Mexico's major carrier was reorganized into three discrete regional operating companies to provide long distance and special services. Fifty-one percent of the TELMEX voting stock was sold for $1.75 billion ($US) to a consortium Southwest Bell, France Telecom, and Grupo Carso, a Mexican group [2].

The other key telecommunications entity in Mexico is the government agency, Secretaria de Communicaciones y Transportes (SCT) With privatization, SCT's satellite operations were placed in a separate state-owned corporation, Telecommunicaciones de Mexico The present domestic satellites, MORELOS, reached the end of their nine-year lives in early 1994, and in the summer of 1991, the Mexican government signed a $184 million contract with Hughes Aircraft Company to supply the country's second satellite system, Solidaridad. Solidaridad I and II are were both launched on an ARIANE 4 in November 1993 and October 1994, respectively. See **Table 7-3** for more details on Soldaridad or the case study in Section 5 [1].

7.3.2 Universal Applicability of Solidaridad Concept

Solidaridad is a conventional bent-pipe satellite that uses multiple frequency bands. As such, it is very flexible and could support the augmentation of NIIs. Its primary use for POTS would be in conventional telephone trunking between switching nodes in NII network. In this sense, Solidaridad has wide applicability. However, if the developing country wanted to mitigate some of the satellite transit delay by moving some of the switching functions up to the satellite, then Solidaridad could not support those functions since it has no on-board processing.

In terms of television services, Solidaridad supports such services today, and demand is increasing. It cannot support DTH-TV market Therefore, if a developing country wanted to avoid the installation of terrestrial broadcast stations or expensive cable TV networks, a different satellite than Solidaridad would be needed.

In short, Solidaridad has universal applicability as a conventional bent-pipe satellite, but if a developing country desires more sophisticated satellite, a Solidaridad type satellite would not apply.

7.3.3 Issues Raised by Large Geographic Area Coverage

Often rural areas of developing nations are very poor and have a low population density. The key issue for geographically large areas is the priority of bringing service to these areas. Rural areas often do not account for a large proportion of the country's GNP, and as such, do not justify large expenditures of capital to connect them In addition, Governments do not view telephones as a necessity, and therefore, the issue of telephone access is not viewed in the same social light as in the west. Thus, the primary issue in dealing with geographically large countries is to provide economic justification for extending the telecommunications infrastructure to rural areas. Solidaridad has apparently addressed this as the director general of Telecomm in Mexico, Carlos Mier y Teran, states that, "[Telecomm] has a plan to extend basic communications services via satellite to 20,000 villages and towns throughout Mexico by the year 2000 at one tenth the cost of terrestrial systems." [1]

7.3.4 Comparison of Solidaridad with Morelos and Brazilsat

Tables 7-1 through **7-3** summarize the capabilities of Brazilsat, Morelos, and Solidaridad. Brazilsat A has 24 transponders of 36 MHz each for a total capacity of 864 MHz. The Brazilsat B satellites will upgrade this to 28 C-band transponders plus one X-band transponder for military use for a total commercial capacity of 1,008 MHz [3]. Morelos, on the other hand, has 12 C-band narrow and 8 C-band wide transponders [3]. In addition, it has 4 Ku-band transponders each with a capacity of 108 MHz [3]. These combine to give Morelos a total capacity of 1,296 MHz Solidaridad is similar to Morelos except that it has 11 more Ku-band transponders for 1,188 MHz more capacity, and an L-band transponder this brings Sodidaridad's total capacity to 2,500 MHz.

Comparing these three satellites shows that Solidaridad has almost three times the capacity of Brazilsat A, and two and one-half times the capacity of Brazilsat B This means that Solidaridad has a much greater potential to generate revenues than Brazilsat A or B

Table 7-1. Brazilsat A Characteristics [3]

Satellite Name	Brazilsat A-1, Brazilsat A-2
Longitude	65° W (Brazilsat A-1) 70° W (Brazilsat A-2)
Launch Vehicle	Ariane
Manufacturer and Model	Spar Aerospace (Brazilsat A-1) Hughes HS-376 (Brazilsat A-2)
Data of Launch	February 1985 (Brazilsat A-1) March 1986 (Brazilsat A-2)
Frequency Band(s) Transmit Receive	C-band 5 925-6 425 GHz 3.700-4 200 GHz
Transponders Number Bandwidth Polarization	 24 36 MHz Linear (12 vertical, 12 horizontal)
Antenna Coverage (EIRP) National Beam	 34-36 dBW
Primary Power W EOL	 799 W
Stabilization Type	Spin
Mass (kg BOL)	1,200 kg
Design Life (yr)	8 yr

Table 7-2. Morelos Characteristics [3]

Satellite Name	Morelos F1, Morelos F2
Longitude	113 5° W (Morelos F1) 116 8° W (Morelos F2)
Launch Vehicle	NASA
Manufacturer and Model	Hughes HS-376
Data of Launch	June 1985 (Morelos F1) November 1985 (Morelos F2)
Frequency Band(s) C-band, Narrowband Transmit Receive C-band, Wideband Transmit Receive Ku-band, Wideband Transmit Receive	C-band 3 700-4 200 GHz 5 925-6.425 GHz 3 700-4 200 GHz 5 925-6 425 GHz 14 000-14 500 GHz 11 700-12 200 GHz
Transponders Number Bandwidth Polarization	 18 (12 C-band narrow, 6 C-band wide, 4 Ku wide) 36 MHz (C-band narrow) 72 MHz (C-band wide) 108 MHz (Ku-band wide) Orthogonal
Power Output TWTA	 7.0 W (C-band narrow) 10 5 W (C-band wide) 20 0 W (Ku-band wide)
Antenna Coverage (EIRP) Central America	 36 dBW (C-band narrow) 36 dBW (C-band wide) 44 dBW (Ku-band wide)
Primary Power W EOL	 760 W
Stabilization Type	Spin
Mass (kg BOL)	666 kg
Design Life (yr)	10 yr

Table 7-3. Solidaridad Characteristics [3]

Satellite Name	Solidaridad I, Solidaridad II
Longitude	109.2° W (Solidaridad I) 113 0° W (Solidaridad II)
Launch Vehicle	Ariane
Manufacturer and Model	Hughes HS-601
Data of Launch	November 1993 (Solidaridad I) October 1994 (Solidaridad II)
Frequency Band(s) Transmit Receive	C-band 5 925-6 425 GHz 3 700-4 200 GHz
Transponders Number Bandwidth Polarization	 18 C-band (12 narrow, 6 wide) 15 Ku-band, 1 L-band 36 MHz narrow, 72 MHz wide Orthogonal
Antenna Coverage (EIRP) National Beam	 34.5-46 5 dBW
Primary Power W EOL	3,156 W (Summer Solstice) 3,370 W (Autumn Equinox)
Stabilization Type	3-axis
Mass (kg BOL)	1,672 kg
Design Life (yr)	14 yr

7.4 Summary of Results

Developing countries each want to improve their individual nation's basic telecommunication services (telephone, television, and narrowband data). We call these conventional services. To completely wire large countries such as China and Brazil would require large investments in both time and money that many developing countries lack. Therefore, developing countries will use wireless systems to supply basic telephone service and narrowband data, broadcast and cable systems for television services, and VSAT networks for large private data networks For interconnecting telephone exchanges or where widespread distribution of TV is desired, developing countries will use satellites to augment their telecommunications infrastructure.

Today, China, India, Brazil, Mexico, and the Philippines each augment their telecommunications infrastructure with satellites China currently uses satellites of similar design as Solidaridad, but with less power, to augment their terrestrial telecommunications infrastructure These satellite primarily carry Public Switched Telephone Services (PSTN), broadcast television and radio signals, and private

VSAT data networks. In this way, satellites such as Solidaridad can augment large countries telecommunications infrastructure

For developing countries, conventional VSAT networks are best suited to meeting the needs of private business customers and rural telephone exchange interconnectivity. Conventional satellites provide the best near-term cost-benefit for these applications, but as the capacity demands of the rural areas rise, the incorporation of technologies that increase the capacity of PSTN services could improve the cost-effectiveness of satellites. At the point where the demand for PSTN capacity exceeds the capability of conventional satellites transition to hubless or hybrid VSAT system may become necessary It is certainly feasible to incorporate switching on board a satellite and employ hubless VSAT system However, the transistion to these systems is the primary issue that developing countries would have to face. Not all exchanges could be transistioned at once, therefore, older hubbed VSAT systems would have to coexist with newer hubless VSAT networks. This could become very difficult Furthermore, the terrestrial system may have had the time to install fiber optic systems that could compete with advanced satellites. In summary, hubless and hybrid VSAT networks could be used, but developing countries demand conventional VSAT systems and the lower associated costs will dominate their decisions.

Section 8

Financial Analysis for Developing Countries

This section examines the financial aspect of using satellites to augment the telecommunications infrastructure in developing nations The section is organized as follows:

8.1 Estimate of Potential Revenues
8.2 Need for Subsidies
8.3 Economic Base Required
8.4 Initial Cost for NII Augmentation
8.5 Financing Advanced Technology Satellites
8.6 Impact of Large Inflation Rates
8.7 Comparison Between Brazilsat and Solidaridad
8.8 Summary of Results

8.1 Estimate of Potential Revenues

SOW Task 1b From this forecast, estimate potential revenues and determine if a potential return on investment can be positive

Table 8-1 and **Figure 8-1** show the maximum possible return-on-investment (ROI) for a satellite. This analysis estimates the ROI based on the average price of transponder capacity (in terms of annual revenues per MHz of capacity) times the maximum capacity of the satellite times the number of years of operation (in this case twelve years is assumed). These revenues offset the cost of the satellite and result in a profit for the satellite operator. This analysis does not include any costs incurred by the satellite operator. It is difficult to estimate these costs as they vary from operator to operator, and if included, would substantially reduce the ROI shown. Nevertheless, the analysis indicates the maximum upside potential of a satellite investment, and can be used as limiting case to investigate the effects of satellite cost upon ROI.

Table 8-1. Estimated Maximum Satellite ROI for Conventional Services

Average Lifetime	12	years
Revenues	32	$K per MHz
Conventiona	90	$US Million
State-of-Art	$130	$US Million
Advanced	$350	$US Million

Capacity		Annual Revenues	Low-cost Satellite-$90M	Moderate-cost Satellite-$130M	High-cost Satellite-$350M
Xpndrs	MHz	thousands	ROI-%	ROI-%	ROI-%
4	144	4,608	-7%	-11%	-21%
8	288	9,216	3%	-2%	-14%
12	432	13,824	11%	4%	-10%
18	648	20,736	21%	12%	-5%
24	864	27,648	29%	18%	-1%
48	1,728	55,296	61%	42%	12%
64	2,304	73,728	82%	56%	18%
100	3,600	115,200	–	89%	32%

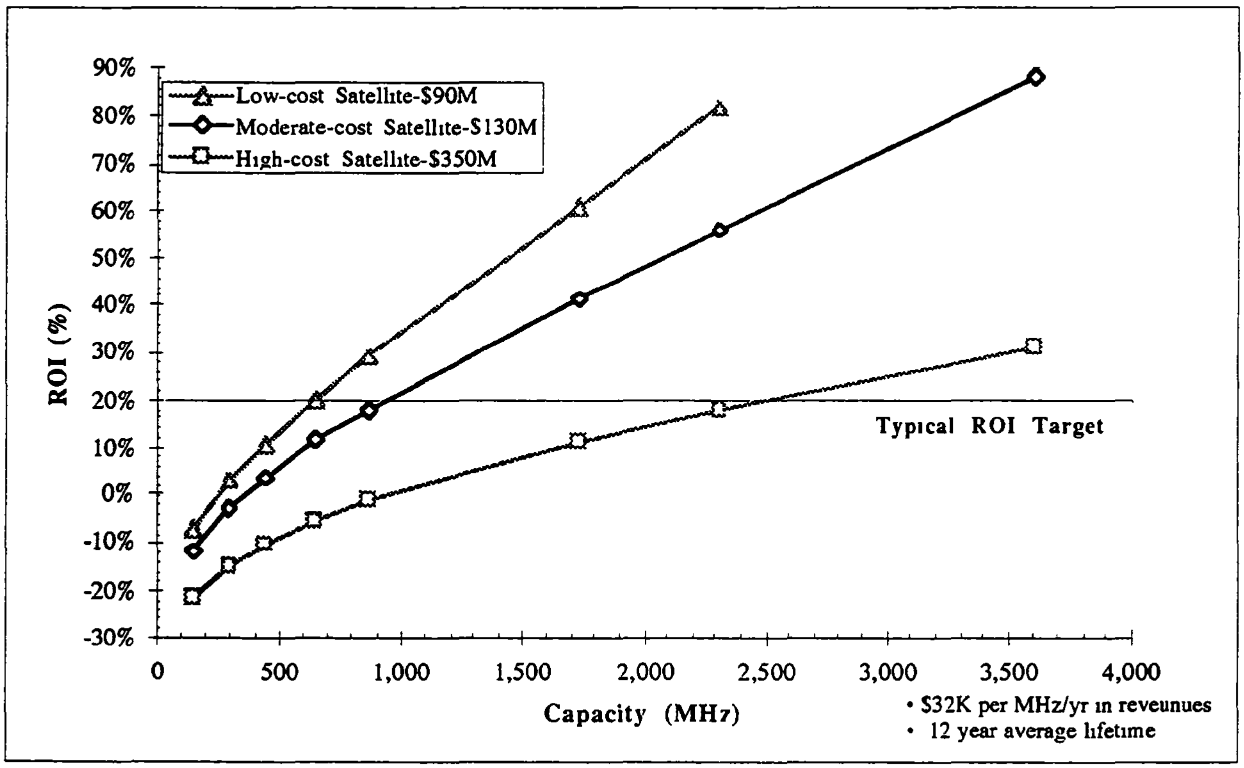


Figure 8-1. Estimated Maximum Satellite ROI for Conventional Services

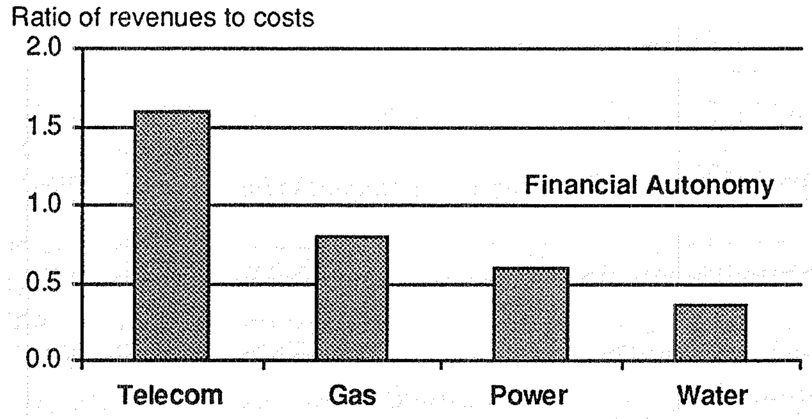
Figure 8-1 shows that for a given ROI, satellite cost has a dramatic impact upon the financial viability of a satellite. For example, at a 20% ROI, a $90M satellite needs approximately 600 MHz of capacity whereas a $350M satellite requires almost

2,500 MHz of capacity. Alternately, a satellite with 2,304 MHz of capacity that costs $90M would have an 82% ROI, whereas if a satellite with the same capacity costs $130 M, the ROI would be reduced to 56%. In other words, a 44% increase in costs reduces the ROI 26%.

8.2 Need for Subsidies

SOW Task 1c. *If the return on investment isn't positive, determine what kind and size of government subsidy would make it positive. This subsidy could bootstrap the startup problem which would stimulate the economy and eventually pay for the subsidy in increased tax revenues.*

The World Bank reports that between four basic infrastructure services (gas, power, water, and telecommunications), telecommunications is the only one that can achieve financial autonomy (see **Figure 8-2**). That is the revenues from the infrastructure can recover the costs of its installation and continued maintenance and operation. Furthermore, the World Bank has historically (1974-1992) had a 20% return-on-investment[1] for telecommunications projects. Because of the prospect for a positive return of investment, the World Bank may be hesitant to subsidize projects that show a negative return, believing that the overall project may be flawed in some way. Therefore, we believe that subsidies will likely take place in the privatization process rather than in the initial development of a telecommunications infrastructure.



Source: Telecom, ITU 1994, World Bank Data; power, Besant-Jones 1993, water, Bhatia and Falkenmark 1993.

Figure 8-2. Potential Cost Recovery of Infrastructures [1]

Historically telecommunications services have been run as a monopoly—usually by the Ministry of Telecommunications. Early on these services were

[1] Return is in financial terms not economic terms.

necessary just to maintain the most basic economic functions. As a country's economy expands, or desires to expand, the telecommunications infrastructure must expand with it. Such an expansion is particularly necessary for a country to expand its export markets Today, many developing countries do not have the foreign capital to fund large telecommunications projects and look to private institutions and investment. This is often part of their larger effort to develop market economies. To seek private investment, developing countries must promise a return to these private investors, but they must also balance the "shock" of large rate increases to customers. Often this is done by imposing tariffs on profitable segments of the telecommunications traffic to subsidize the non-profitable ones. Furthermore, these tariffs often have a timeline for when they are phased out, and the private organizations begin to operate in a free market A similar situation occurred in the US where long distance revenues were used to subsidize local phone service keeping local phone rates down

Therefore, our belief is that future subsidies of telecommunications projects will likely be in the form of tariffs that minimize the effects of large investments in telecommunications infrastructure on customers used to heavily government subsidized rates. Because of the potential for positive ROIs, developing nations should have little trouble attracting investment provided the country is willing to privatize its telecommunications system. Where poor countries have problems is when they desire to upgrade the telecommunications infrastructure without privatization. In this case, they must have sufficient foreign funds to purchase the technology and know how from the developed nations

8.3 Economic Base Required

SOW Task 1d. Are the developing countries in a "catch 22" situation (need satellites for economic growth but have insufficient economic base for the first satellite?

The World Development report issued by the World Bank [1] states that adequate infrastructure is a necessary but not sufficient condition for economic growth. Many developing countries are coming to the realization that in order to improve their economies, they must improve their infrastructure including their telecommunications infrastructure. Limited funds will force most developing countries to improve their telecommunications systems incrementally.

For terrestrial systems, that generally means concentrating the improvements on populated areas of commerce (i.e., cities and ports). Prior to regional satellite operators, developing countries had two choices to meet their satellite service needs–Intelsat or construction of a national satellite system Today, however, many regional satellite operators exist that can lease transponders to developing countries as they need it. This means that developing countries are not in a "catch 22" situation where they must make large up-front investments in satellites prior to sufficient demand generated revenues to offset this cost.

8.4 Initial Cost for NII Augmentation

SOW Task 7a. *Determine the initial cost of a national infrastructure augmentation for large geographic areas (such as Brazil, China, or others) versus system capacity*

Reports from China indicate that by the year 2000 they will add 48 million main lines at a cost of $48.6 B—approximately $1,000 per main line [3]. This would require some 768 Gb/s of satellite capacity, or approximately 307 conventional satellites. Even if sufficient spectrum were available for such a constellation of satellites, the system would cost some $78.7 B. Forty-eight million lines loaded at 80% at busy-hour means that 38.4 million lines would be simultaneously active. If each line uses 20 kb/s through satellites that has a bandwidth efficiency of 2 bits per Hertz, then 10 kHz per simplex line is needed Since two channels per line are required, 768 GHz of satellite capacity are required A conventional satellite can provide roughly 2.5 GHz of capacity. Therefore, 307 satellites are required, and at $100M per satellite, the total cost of the system would be $30 7B This is less than the terrestrial cost, but the solution is infeasible due to the extensive bandwidth requirements and user terminal costs Users would need satellite terminals capable of communication through conventional satellites These terminals could easily cost $1K per user for another $48B, so that total system cost would run $78.7B.

This demonstrates the primary cost issue for satellites in direct competition with terrestrial systems, namely that satellites must provide service to users at less than $1,000 per user for up-front costs, and recurring costs less than the equivalent terrestrial system. A key financial issue for satellites is low-cost user equipment. Terrestrial systems usually have low user up-front costs, and recover their costs incrementally through monthly recurring revenues from their customers. Satellites also recover their costs incrementally, but have higher user up-front costs. To directly compete with terrestrial system, satellites must offer lower recurring customer prices at the up-front cost of an expensive terminal.

The key here is "direct competition." Satellites seldom directly compete with terrestrial systems. Satellites are generally used where terrestrial systems cannot be installed, the capacity of terrestrial systems is insufficient for the desired service, the reliability of the terrestrial system is inadequate or where the need for service does not allow sufficient time to install a terrestrial system In these instances, satellites can charge more for service since no other competing service is available. Futhermore, this is where satellites are essentially competing amongst themselves.

8.5 Financing Advanced Technology Satellites

SOW Task 7b Determine how a cash rich (e g Singapore) and cash poor (e g Philippines) nation might approach financing an advanced technology satellite system

The are many methods of financing large infrastructure projects The subtle complications of such financing are beyond the scope of this report. However, from a macro standpoint, there are four financing options for developing countries,

1. Foreign Aid from Developing Countries
2. Loans from the World Bank
3. Public investment with funds raised through taxation
4. Private investment
5. Combined public, private or foreign investment

Today developing countries spend approximately $200B per year on infrastructure investment, some 90 percent derived from taxation [1] This typically represents between 30 and 70 percent of government expenditures[ref. 1, pg 90]. With regard to telecommunications infrastructure, developing countries are privatizing their telecommunications systems This means that the developing country has in place, or is putting in place, some form of a private investment mechanism (i.e., a stock and bond market) These domestic stock and bond markets within developing countries combined with stable monetary policy and with adequate regulatory conditions, can attract sufficient capital to fund large telecommunications projects

Today, few developing countries have all of the necessary components to attract enough private investment to accomplish all of the desired projects, but the trend is toward privatization and all it requires Therefore, we expect that the future financing of advanced satellites for developing countries will largely be through private financing.

8.6 Impact of Large Inflation Rates

SOW Task 7c Evaluate the impact of large annual inflation rates (such as 1,000% in Brazil)

International lenders rarely assume the risk of local currency values, preferring to receive payments in foreign currency terms This means that the country assumes the risk, and the result impacts primarily the local economy, namely decreased foreign reserves and rising prices

The primary impact on a developing country depends on the source of financing used for the satellite project If an international loan was used where repayment is in foreign currency terms, they country must raise prices and supply any shortfall from the countries public funds. With a falling currency, this can bring additional pressure to raise taxes further worsening the economic conditions. For this reason, many developing countries seriously attempting to improve their economies are also taking steps to stabilize their currency

8.7 Comparison between Brazilsat and Solidaridad

SOW Task 7d Compare the Mexican systems with Brazilsat, PhillipineSat, and/or Solidaridad for cost and revenues versus system capacity

Hughes reported [4] that the cost of both Brazilsat B satellites[2] at $175.2 M ($US), or $87.6 M each. Each Solidaridad is reported to have cost approximately $138M each[3]. Thus, Brazilsat B has a capacity cost of $7,200 per MHz per year, whereas Solidaridad has a capacity cost of $3,900 Thus, 57% more invested in the satellite like Solidaridad results in two and one-half times the capacity

Table 8-2 shows the potential ROI when the satellite transponders are leased at the average price of $32K per MHz per year for the operational life of each satellite. Brazilsat-B has a maximum potential ROI of 36%, whereas Solidaridad has return of 58%. We repeat the caution that these returns do not include the costs incurred by the satellite operators Actual returns would be less

The difference in ROI simply reflects the fact that a 57% increase in satellite cost resulted in a 248% increase in capacity If a 57% increase in satellite cost brought about less than a 57% increase in capacity, then the ROI would reduce

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2 Includes launch on an Ariane 4

3 Hughes reports a contract amount of $184 M for two satellites including ground equipment Solidaridad II was launched on an Ariane with Thaicom Assuming $4 M for ground equipment, discounting the $88.5 M for an Ariane 44L launch by 10% since Huhges contracted for two lauunches, and further assuming a 60-40 split between Solidaridad and Thaicom on launch costs results in an estimated cost of $138 M (($184-$4)/2 + $88.5*0 9*0 6) for a single Solidaridad

Table 8-2. Financial Comparison between Brazilsat and Solidaridad

Satellite System	Brazilsat-B	Solidaridad	
Satellite Cost	87 600	138 000	$M, U S
Capacity	1,008	2,500	MHz
Transponder Price	32 000	32 000	$K/yr, U S

ROI	36%	58%

Cash Flow	Brazilsat-B	Solidaridad
Year	$K	$K
0	($87,600)	($138 000)
1	$32,256	$80,000
2	$32,256	$80,000
3	$32,256	$80,000
4	$32,256	$80,000
5	$32,256	$80,000
6	$32,256	$80,000
7	$32,256	$80,000
8	$32,256	$80,000
9	$32,256	$80,000
10	$32,256	$80,000
11	$32,256	$80,000
12	$32,256	$80,000
13		$80,000
14		$80,000

8.8 Summary of Results

The marketing analysis given in Section 6 shows that the developing countries primarily need conventional satellite services. Competition within the conventional satellite service market limits profit margins and forces satellite manufacturers to supply the highest capacity satellites at the low-cost. This means that manufacturers, to minimize cost, will evolve existing hardware designs rather than adopt a revolutionary hardware technology. Advanced technology satellites with their associated higher costs can compete within the conventional satellite market place provided that the capacity improvement exceeds the increased cost to obtain that increased capacity This assumes, of course, that the market does not become saturated with satellite capacity. A saturated market would further drive transponder lease prices down, possibly causing the return on a high-cost satellite to become negative.

In the area of newer or advanced services where the market place is not so competitive, advanced satellites have more financial leeway Newer more advanced services have less competition and operators can charge more for these services. As such, the profit margins are higher and satellite manufactures can assume more financial risk to adopt newer hardware technology with the promise of more payoff (i.e., selling more satellites). Eventually, this service market will also become mature forcing service prices down and squeezing profits. However, for both conventional and advanced services, subsidies should not be required to achieve profitable operations

A typical $130 M satellite has an opportunity cost of 130,000 main terrestrial lines. A conventional satellite with 2,500 MHz of capacity could carry a maximum of 125,000 simplex voice grade channels. Thus, not considering ground equipment, satellites are almost equivalent to terrestrial systems However, if the cost of ground equipment is included, the cost-effectiveness of conventional satellites drops dramatically. Ground equipment for conventional satellites costs a minimum of $1,000 each. Terminals for 130,000 users would add an additional $130 M to the satellite bringing the total equivalent satellite cost to $260 M Thus, the equivalent satellite cost per main line is $2,000 per line. It currently costs developing countries approximately $1,000 per main line for terrestrial installations This means that countries that want to supply both terrestrial services and terrestrial services via satellite must somehow provide a $1,000 subsidy per line or somehow provide for the sharing of terminals.

Developing countries could incrementally buy the satellite capacity they need from Intelsat or regional satellite operators. When their needs exceed the available capacity of regional satellites, they can consider the purchase of a national satellite. In this way, developing countries can supply the capacity a country needs while avoiding large up costs. In some instances, however, nations will purchase satellites as a source of revenues by leasing transponders to other countries in the region.

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Section 9

Conclusions

This section summarizes the primary conclusions of this study. This section is organized as follows:

9.1 Market Definition

The largest demand expressed from developing countries is for conventional telecommunications services. These services include telephony (trunking and thin-route), broadcast television distribution, and narrowband data networks. The demand for new services in the DTH-TV market is second, followed by newer broadband services that support value-added networks (VANs). Value added networks include e-mail, LANs, and new broadband services.

Developing countries have too many people to provide universal telecommunication service to everyone. Therefore, the telecommunications infrastructure in the developing world will center around supplying businesses with the services they need This will be particularly true for countries like China and Mexico that want to expand their export markets Businesses in developing countries will initially require conventional services with some specific sectors, such as banking, requiring the newer VAN services In addition to the expansion to meet business needs, public telephone access and DTH-TV markets are expected to grow to meet demand within general population Public telephones are expected to be introduced to provide village and rural inter-connectivity. This will require satellites to be able to interconnect thin-route telephone exchanges (wired or wireless) over broad areas.

Most developing countries are expected to follow western technology rather than spearhead new technology. They want to minimize both the cost and risk of their satellite procurements. Recent launch mishaps and satellite failures have stiffened their resistance to purchase new technologies.

The U.S. will continue to feel international competitive pressure Both China and India want to develop their own spacecraft industry and begin exporting conventional satellites. China even wants to become a regional satellite operator and lease transponders to other users and broadcasters. The likely scenario is to begin with the sales of western satellites to China is followed by joint ventures with China that involve significant technology transfer This would then be followed by direct competition with China for satellite sales. Such competition may put further pressure on satellite operators to reduce transponder costs that lead to demands for still lower cost satellites. Such price pressures may reduce profit margins making significant R&D efforts more difficult for satellite manufactures

Overall, the satellite market is expected to grow at 4%-5% per year for the next five years. Half of the market will be satellite operators purchasing replacement satellites and the other half from new satellite operators or existing satellite operators expanding their operations

9.2 Financial Implications

The World Bank conducted a study that showed of all of the infrastructural services (gas, power, water, and telecommunications), telecommunications is the only one that can achieve financial autonomy This is the revenues generated from the sale of telecommunications services can recover the costs of installation, maintenance, and operations. Therefore, government subsidies are only required if the country does not want to privatize the telecommunications systems Private investment can be obtained provided the country is willing to protect the investment and support the return on that investment.

Competition for conventional satellite services has made the market price competitive. Therefore, low-cost per unit capacity is required. Conventional services have an annual capacity price of approximately $32,000 per MHz. Newer services run approximately $111,000 per MHz of capacity, see **Figure 9-1** The risk averse nature of satellite customers along with price competition limits the ability of satellite manufacturers to invest R&D into new technologies that support conventional satellite services. This is an area where some subsidized support could aid US satellite competitiveness. On the other hand, newer services are not so price competitive and their revenues provide profit margins compatible with larger R&D investments by satellite manufacturers Therefore, government support for development of technologies that support new services will likely not have dramatic impact on US satellite industry competitiveness around the world

Figure 9-1 shows the capacity versus cost comparison for conventional and DTH-TV services based on open market competition for transponder leasing (i.e , constant lease cost per capacity). The lines on the plot show the break-even point for satellite costs (i e., zero percent ROI).

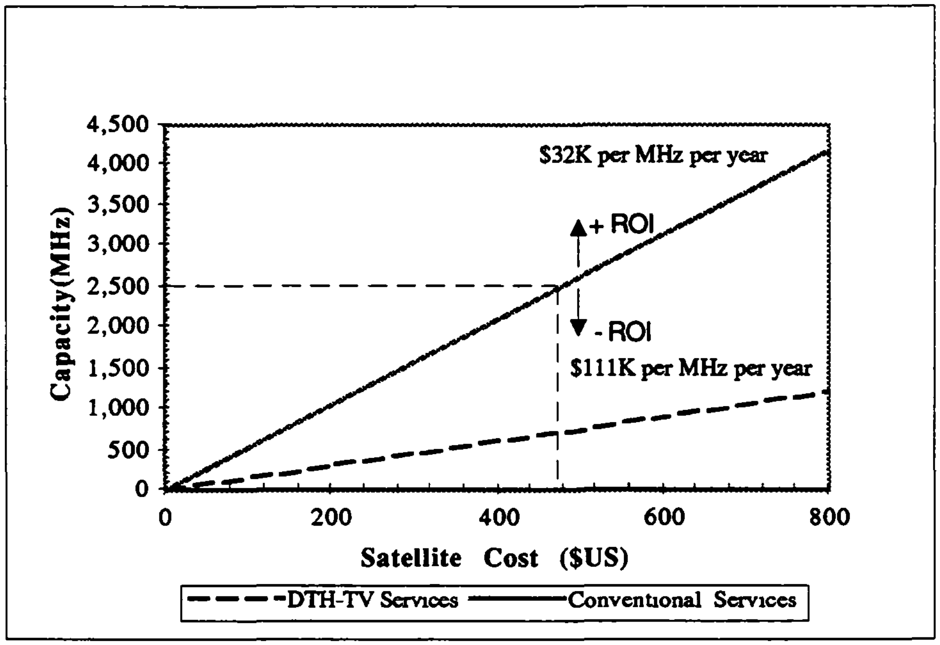

Figure 9-1. Capacity-Cost Comparison[1].

For conventional services, we see that to provide 2.5 GHz of capacity, the satellite(s) must cost less than $500 M. If the satellites cost more than that, the costs cannot be recovered by the revenues generated by leasing the transponders. If 2.5 GHz of satellite capacity costs more than $500 M, then some form of subsidy is required to encourage investment in the project.

Figure 9-1 has several implications for the satellite market place in developing countries. First, the slopes are different for DTH-TV services from conventional services. There are many more satellites supplying conventional services than there are satellites providing DTH-TV. As competition comes to the DTH-TV satellite market, we expect a reduction in price. This price reduction will narrow profit margins, but it will also reflect the lower risk of these satellites since the hardware and designs will be flight proven. This is primarily due to competition. There is competition between satellite operators for conventional services whereas the newer services lack competition and can support higher prices. The implication is that newer services have higher prices and potentially higher profit margins to satellite operators. This is typical of new markets. As the figure

[1] This figure was based upon the fact that the developing countries operated 600 equivalent 36 MHz transponders in 1994 that generated $700 million in revenues. That equates to approximately $1.17 M dollars per transponder or $32K per MHz of capacity. As we stated above, 178 satellites are planned over the next 10 years at a value of $16 B or about $90 M per satellite. An example of newer services is the DTH-TV market. The current cost for a 27 MHz transponder is approximately $3M. This corresponds to $111K per MHz per year of annual revenues. Any satellite above its respective service line will have a positive ROI for a 12 year satellite, and any satellite below the respective line will have a negative ROI. The different slopes for each line reflect differences in competition between the two services.

shows, for a given capacity, newer services can support much more expensive satellites. That means satellite manufacturers can afford more R&D to develop satellites that deliver newer services. On the other hand, conventional services cannot support large satellite costs because the profit margins of satellite operators are kept low by price competition. Therefore, satellite manufactures must spend most of their time keeping costs low to maintain their profitability, and therefore, they can ill afford to invest large amounts of R&D funds into radical new technologies for these types of satellites

9.3 Technology Recommendations

Research and development efforts should be concentrated in two primary areas: (1) the development of satellite production methods, techniques, tools, and technologies that reduce cost (time, labor, and materials) of satellites for any given capacity; (2) the development of technologies that increase the capacity for a given satellite cost. For developing country applications, these R&D efforts should be focused on reducing the cost per unit capacity for conventional satellite telecommunication services

Technologies that reduce the productions costs of satellites

a. CAD/CAM systems specific to satellites
b. Streamlined production techniques
c. Automated testing systems and procedures
d. Advanced satellite design simulation techniques, tools and systems
e. Automated assembly techniques

For developing country applications, in particular, R&D efforts need to be encourage in developing thin-route rural telephone exchange interconnections and increasing the capacity for satellites in the $90M to $130M range. Technologies that lower the cost per unit capacity:

a. On-board satellite switching
b. Light weight bus materials
c. Ion/electric thrusters
d. Multibeam satellites
f. High capacity payloads
g. High power satellites

Technology to meet emerging demand from developing for newer Services:

a. Low cost return orderwires for DTH-TV
b. Controlled access methods for DTH-TV
c. Lower spillover techniques
d. Lower cost user terminal equipment
e. High power payloads and components
f. Increased capacity of CDMA systems
f. High data rate links

9.4 Recommendations for R&D

The West will lead the world in developing advanced technology and it will likely be its own customer for this advanced technology. Where U.S. satellite competitiveness becomes and issue is in the area of conventional bent-pipe satellites. Here competition from Europe, Japan and China will become apparent. To compete, the U.S. must quickly produce low-cost satellites with higher capacities than other satellite manufacturering countries Price competition has lowered profit margins in the satellite industry forcing it to become more cost conscious and to extract economies from specialization The recent series of mergers and acquisitions support this trend

Just as the automotive industry had to reduce the cost of car production through the application of new production techniques (and technology), so must the satellite industry. However, unlike the car industry the satellite industry is a low volume industry. In fact, the sale of a single satellite is comparable to the sale of 5000 cars. Annual sales for a satellite manufacture equal the sale of 15,000 to 20,000 cars. Furthermore, the transportation costs for satellites (i.e., launch and orbit raising) account for almost half of the total satellite costs. Thus, satellites have a very high fixed non-recurring cost to deliver their services. Below, we offer specific recommendations to address U S. satellite manufacturing competitiveness.

9.4.1 Recommendations for Industry

In the end, lower user costs will make U.S. satellites more competitive on the world market. Lower user costs means lowering the cost per unit capacity. There are three ways to lower the cost per unit capacity; (1) increase the capacity of for a fixed satellite cost, (2) lower the satellite cost, and (3) lower the non-recurring user equipment costs. Since satellites are low volume production item development costs are spread over only a few units One way to lower the costs for satellites it is to invest in technologies and techniques that lower the development costs of satellites. This could include computer-aided design software and techniques specific to the satellite industry, development simulation techniques that permit the testing of satellites designs prior to hardware development, and supporting industrial techniques that minimize the time and labor required to develop and produce new satellite designs.

9.4.2 Recommendations for Industry and NASA

The second way to lower the cost per unit capacity is to increase the capacity of satellites where the cost of these satellites remains relatively fixed This means that any new technologies that increase the capacity must be able to be produced with same cost of materials and labor as previous satellite designs. Alternately, if the new higher capacity payload costs more to produce, it must save costs somewhere else in the satellite. There are many possible technologies that can increase the capacity of satellites and Appendix E lists many of them, but for developing countries the technologies that increase capacity must increase the capacity of satellite to carry conventional services (i.e., voice, TV and narrowband data) In addition, any payload that incorporates these new technologies to increase capacity must maintain reasonable compatibility with the country's terrestrial systems High power, satellites, on-board thin route switching payloads, multiple beam satellites are some of the technologies that may accomplish this goal

A third way to reduce user costs is to lower the user equipment costs. Lower user costs generally means smaller, simpler terminals. Higher satellite RF power satellites and satellites with larger satellite G/Ts will directly result in smaller terminals. High effieciency solar cells, high voltage buses, high power oyput multiplexers, high power RF amplifiers, low noise receivers, and high gain antennas can all improve user link margins and reduce terminal size. Both large scale integration of satellite modems and high efficiency RF amplifiers would simplify user terminals and improve their reliability.

9.4.3 Recommendations for NASA

NASA faces the challenge of supporting the U.S satellite industry and while protecting the proprietary rights of individual U S companies We recommend that NASA support both the development of advanced satellite production tools and techniques and the development of low-cost high capacity satellite designs, but at the precompetitive stage. For example, in the area of satellite production processes, we recommend NASA :

- Develop general simulation software libraries that are available to U.S. satellite manufacturers
- Develop a CAD/CAM workstation skeleton that U.S manufactures could build upon using their own proprietary software and processes
- Collect a single satellite market data repository that supplies information of the activities and technologies of international satellite manufacturers
- Investigate high risk precompetitive technologies for improving satellite capacity. High risk technologies are technologies that industry cannot afford to fund with their own R&D funds.

In taking these steps, NASA can continue to preserve US competitiveness in the international satellite market place and directly support the growth of the U.S satellite industry well into the next century

Section 10

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Section 9

None

Appendix A

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Appendix D

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Appendix E

None

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Appendix A

Use of On Board Processing

This Appendix compares a bent pipe transponder versus an on board processing (OBP) transponder. An OBP transponder is a communication payload that demodulates and (optionally) error corrects the uplinks. The resultant baseband signals are (optionally) switched, error encoded, and remodulated onto the downlinks.

This appendix is organized as follows:

Section A.1 shows the comparison between a bent pipe transponder and an OBP with respect to a number of system parameters. Section A.2 extends the link efficiency of a single link to a broader concern of system downlink EIRP required. Section A.3 provides several system examples. Section A.4 presents the technology assessment. Section A.5 discusses the issues related to size, weight, power and cost. Section A.6 gives conclusions.

A.1 Tradeoff Summary

The relative advantages between a bent pipe and an OBP transponder are shown in **Table A-1**.

Table A-1. On-Board Processing Trade-off Summary

Areas of Evaluation	Bent Pipe: Fixed Connections	Bent Pipe: Flexible Connections (IF switch)	OBP: Fixed Connections	OBP: Flexible Connections (digital switch)
General				
Connectivity		More flexible		Most flexibility
Comm services		Efficient		Most efficient
Survivability	Best	Small probability of switch failure		OBP susceptible to radiation degradation.
Flexibility	Service mix of terminals and modems	Service mix of terminals and modems	On-board processor allows mixed modulations	Allows on board routing independent of uplink frequency
Terminals	No difference	No difference	Lower power transmitters	Lower power transmitters
Control	Insignificant	Insignificant	Insignificant	Insignificant
Spacecraft				
Mass	Heavier transmitter	Heavier transmitter	Adds weight	Adds weight
Power	No power required for on-board processing	No power required for on-board processing.	Lower power satellite transmitter	Lower power satellite transmitter Higher power for digital switch
Other				
Waveform	N/A	N/A		TDM downlink, FDA uplink
Critical technologies	N/A	N/A	Baseband processor or switch	Baseband processor or switch
Cost				
Non-recurring	N/A	Insignificant	High	Higher
Recurring	Lowest cost			Highest cost

A.2 System Downlink EIRP

It has been shown [1] that approximately 3 dB savings in the required E_b/N_o can be achieved by an OBP transponder. The idea of savings in EIRP is a simple one. For a bent pipe transponder, the end-to-end bit error rate (BER) under an additive white Gaussian noise (AWGN) is determined by the end-to-end E_b/N_o which, under some judicious condition, is given by Equation (1):

$$\frac{E_b}{N_o} = \frac{1}{\left(\frac{E_b}{N_o + I_o + J_o}\right)_u^{-1} + \left(\frac{E_b}{N_o}\right)_d^{-1}} \quad (1)$$

An OBP transponder, by separating the uplink from the downlink, exploits the non-linear relation between BER and E_b/N_o. Since the end-to-end BER of two separate links is the sum of the two separate BERs and the resultant E_b/N_o for uplink and downlink in that case is lower than that required by the above equation. This is shown in **Figure A-1.**

The savings in E_b/N_o however is not the only contributing factor to the savings in downlink EIRP. A power amplifier typically has to be backed off by 3 to 6 dB to operate in the FDM mode to avoid intermodulation interference. With a TDMA structure, on the other hand, the power amplifier could be operated in a saturated mode thus gaining an advantage of 3 to 6 dB.

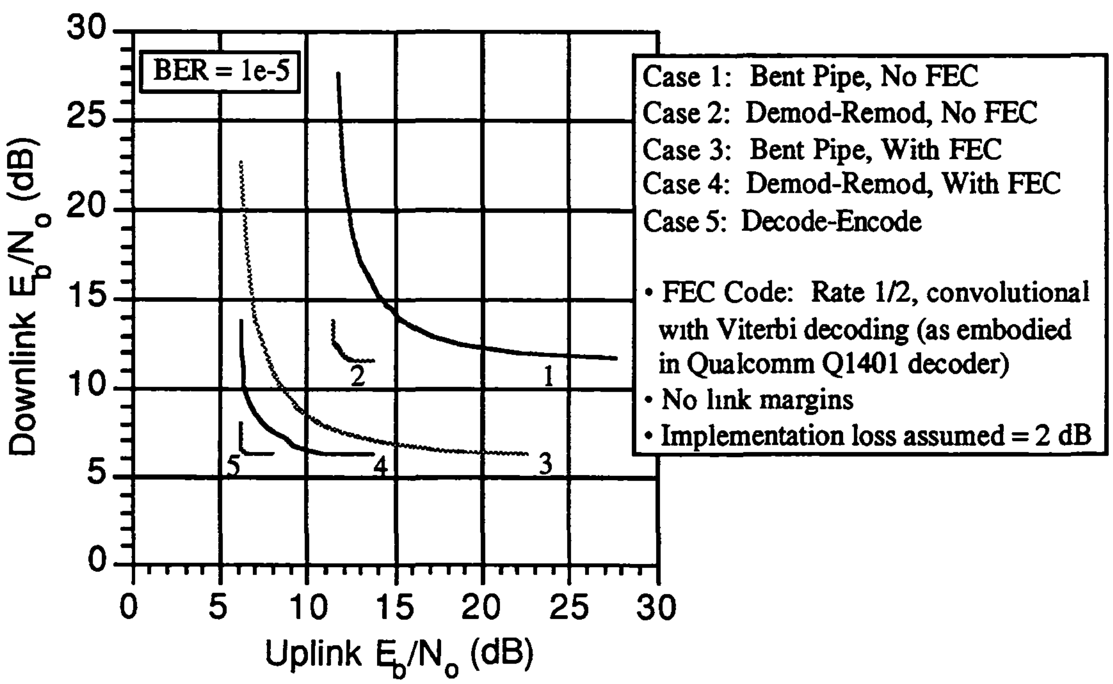


Figure A-1. Downlink E_b/N_o vs. Uplink E_b/N_o for Five Cases

It should be noted that Equation (1) addresses only one link at a time. To estimate the degree to which the savings in link E_b/N_o translates into savings in downlink E_b/N_o, it is necessary to examine the aggregate of the links. As it turns out, assuming identical noise temperature for the receiving terminals, the difference between the EIRP required for a TDMA, P_T, the EIRP required for FDMA, and P_F, is given by Equation (2):

$$P_T - P_F = \frac{1}{\alpha}\left[\operatorname*{Max}_{i}\left(\frac{E_{bi}r_i^2}{G_i}\right)\sum_{i=1}^{N}\frac{1}{T_i} - \sum_{i=1}^{N}\frac{E_{bi}r_i^2}{G_i T_i}\right] \tag{2}$$

where:

E_{bi} = the energy per bit requried of the i - th downlink

G_i = the antenna gain of the i - th terminal receiving the i - th downlink

r_i = the range from the satellite to the i - th terminal

T_i = bit duration of the i - th link

N = total number of downlinks.

Equation (2) shows that $\hat{E}_i = \frac{E_{bi}r_i^2}{G_i}$ is a critical parameter in evaluating whether or not a TDMA structure may require more transmit EIRP. When this parameter is the same among the receiving terminals, the required EIRP is indeed the same in both cases. When the $\hat{E}_i$s are different, a savings in EIRP is not guaranteed. The worst case happens when $\hat{E}_i$ is constant for all i except, say i = N:

$$\frac{E_{bN}r_N^2}{G_N} = M\frac{E_{bi}r_i^2}{G_i} \text{ and } T_N = \frac{T_i}{K} \text{ for all } i \neq N \tag{3}$$

and 0 < K < 1 < M. In this case,

$$P_T - P_F = \frac{(N-1)(M-1)}{\alpha M}\left(\frac{E_{bN}r_N^2}{KG_N T_N}\right) \tag{4}$$

which may become negative, i.e., changing the FDMA structure to a TDMA structure may in fact require higher transmit EIRP. For the system as a whole, any possible savings in downlink EIRP from reduced link E_b/N_o and increase efficiency in the power amplifier must be weighed against any possible increase in downlink EIRP from the use of a TDMA structure.

The following examples will illustrate some of the points in the consideration of a full processing satellite.

A.3 System Examples

The analysis in Section A.2 suggests that no general statements can be made regarding the relative advantages or disadvantages of an OBP versus a bent pipe transponder insofar as downlink EIRP is concerned. In order to make specific recommendations, it is necessary to define the boundary conditions of the system under consideration.

Of the performance parameters listed in **Table A-1**, we shall separate the consideration on spacecraft mass, power, weight, and cost from the rest since they tend to be more a function of time in terms of technology maturity than anything else, and will be discussed separately in Section A.4. Within this context, several examples are given in this section.

A.3.1 Example 1: Small Nation, One Beam Coverage

In **Table A-1** the "connectivity" parameter is relevant only under the assumption that the connectivity between a transmit terminal and a receiving terminal may vary with time and may also be from one region (or beam) to another. When the communication system serves a small nation that could be covered by one beam, flexibility in connectivity is no longer an issue.

In this case, system evaluation is reduced to a matter of terminal and satellite EIRP. From the terminal's point of view, the savings in E_b/N_o from an OBP could indeed translate to a savings in EIRP and hence cost by the reduction of either the antenna size or transmit power. From the satellite point of view, however, system level consideration must now be taken into account. Here we divide the system into two categories: GEO satellite with similar terminals, and GEO satellite with dissimilar terminals.

Example 1A: GEO orbit satellite with all terminal the same size

As stated in Section A.2, the required EIRP remains invariant between a TDMA and an FDMA structure as long as the critical parameter $\hat{E}_1 = \frac{E_{b1}r_1^2}{G_1}$ is the same for all terminals - assuming same system noise temperature. Since one of the factors in this parameter is the range between the receive terminal and the satellite, a geostationary satellite will have less impact on this critical parameter as the shown in **Table A-2**.

Table A-2. Range Ratio of GEO and LEO

Altitude of Orbit	0° Elev	90° Elev	Ratio of $\hat{E}_1$
Geostationary	42,062 km	36,164 km	1.35
900 km	3,506 km	900 km	15.17

In this case, an OBP transponder will indeed result in a savings of nearly 6 dB for the payload EIRP. Whereas a LEO has a ratio of 15.17 and thus the advantages of TDMA may be lost. The LEO MSS systems currently under construction (Iridium, a TDMA system; Globalstar, a CDMA system) use shaped antenna patterns that have higher gain on the horizon to compensate for the increased range.

This example would be pertinent to developing a communication satellite intended to support, for example, only voice communications from public pay phones for which all of the data rates are equal and all of the terminals could be made the same.

Example 1B: GEO orbit satellite with terminals of different sizes

If terminals of dissimilar G/T need to be connected occasionally, one now runs into the situation described in Section A-2. There is no guaranteed in savings in EIRP from the processing transponder.

On the other hand, there may be savings if there are only two groups of terminals each of which has substantially the same G/T, and that one group of terminals is not required to be connected to the next group.

A possible scenario is when the satellite supports a voice net and a data net (having much higher data rate) and that a data terminal will never have to be connected to a voice terminal. In this case, the processing transponder will still achieve the full savings in EIRP as long as there are two separate amplifiers each of which is dedicated to only one net. In other words, the two nets are separated by two downlink frequencies but access within a net is via TDMA.

A.3.2 Example 2: Large Nation with Multiple Beam Coverage

This example differs from Example 1 only in that flexibility in connectivity is now an added relevant consideration. Consideration in total downlink or satellite EIRP is substantially the same as that shown in Example 1. The selection criterion must now be weighted between connectivity and EIRP. For example, when the total EIRP required of the satellite for a given traffic loading is well below the capability that can be supplied by existing technology, connectivity requirement may be more heavily weighted when system selection is made.

Alternately, an OBP may have several power amplifiers and employs a combination of FDMA and TDMA in a manner similar to Example 1B.

A.4 Technology Assessment

An OBP requires the use of large scale digital integrated circuits (ICs) having high component density per chip, low power consumption, and high speed operation while maintaining reasonable tolerance for radiation hits. **Figure A-2** shows the density and speed performance trends in digital semiconductor chips [2]. **Figure A-3** shows the propagation delay and power dissipation performance of various digital technologies [3]. **Tables A-3** gives the performance of promising technologies. Mass and power estimates for a 2 Gb/s OBP payload using these technologies is shown in **Table A-4** [4].

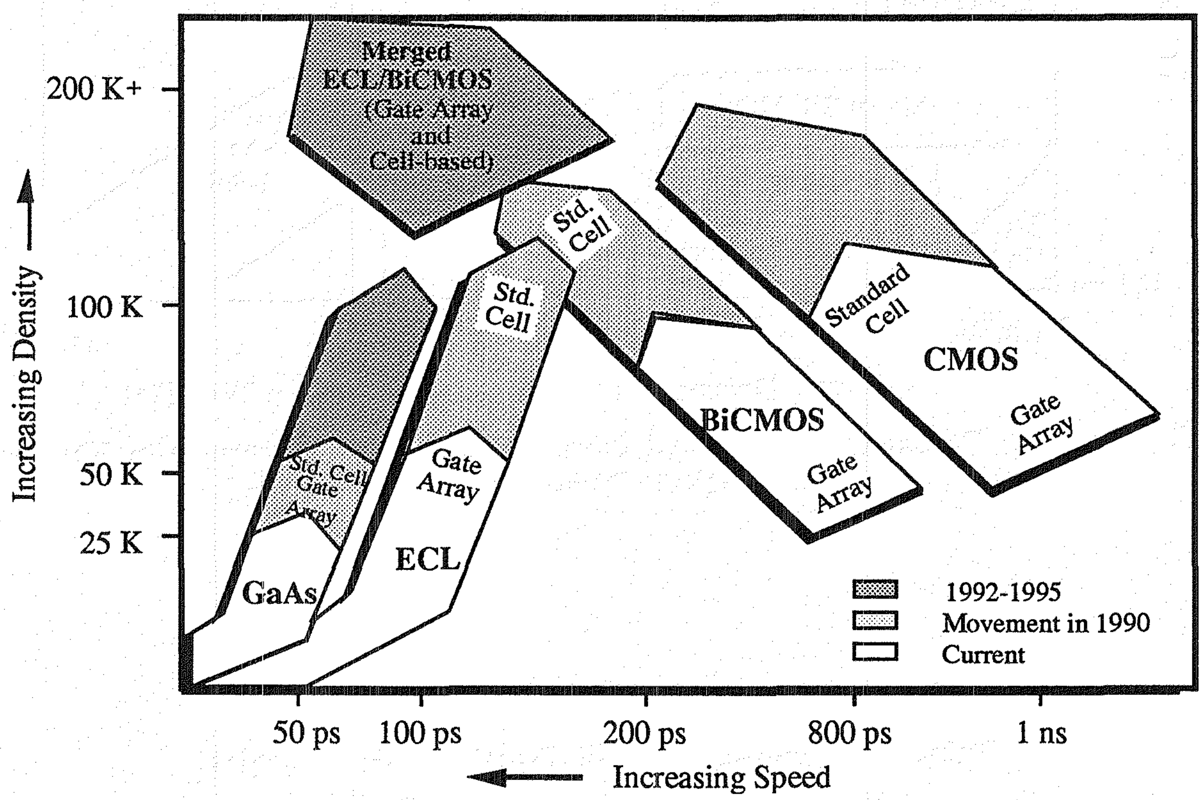


Figure A-2. Density and Speed Performance Trends in Digital Semiconductor Chips

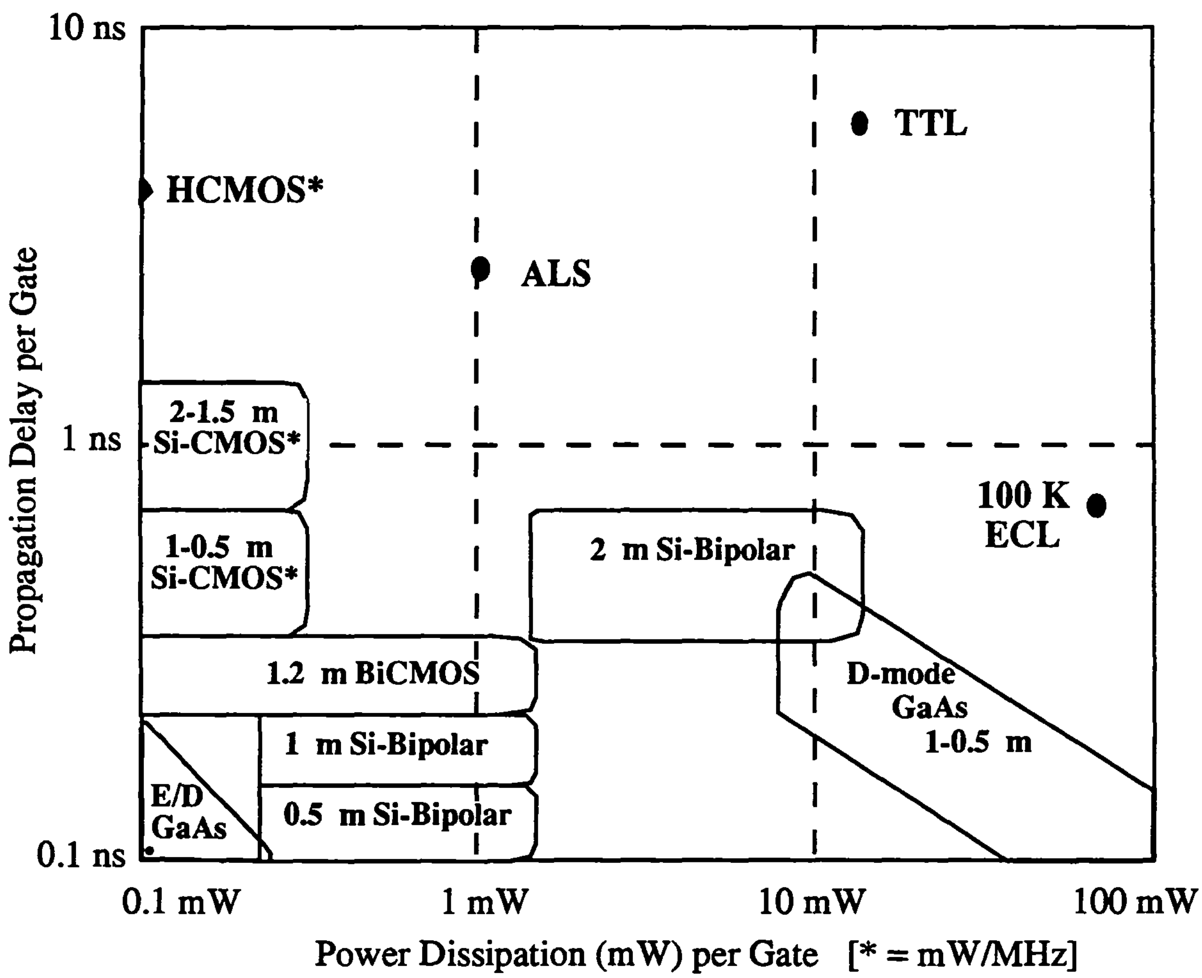


Figure A-3. Propagation Delay and Power Dissipation Performance of Various Digital Technologies

Table A-3. Performance of Promising Technologies

Technology	Power per Gate	Density (usable Gates)	Speed
GaAs	0.1 mW	50,000	1 to 5 Gb/s
HCMOS (rad hard)	12 µW/MHz	50,000	400 Mb/s
ECL/TTL mix	0.5 to 1 mW	10,000	650 Mb/s

Table A-4. Mass and Power Estimates (Year 1996-2000)

Component	No. of Active Units	No. of Redundant Units	Parts Count	Power (W)	Mass (kg)
Multi-carrier demodulator	16	4	400	320.0	6.7
Input Processor	16	4	480	50.4	8.0
Output Processor	24	4	616	66.2	10.3
Modulator	24	4	28	3.6	4.2
Autonomous Network Controller	1	1	66	12.2	1.1
Timing Source	1	2	3	3.0	3.0
Power Supply (90% eff.)				50.6	12.0
Structure					13.0
Totals				506.0	58.3

Consideration of a sample processor leads to the identification of the following critical technologies for an OBP:

1. Multicarrier Demodulator
2. Bit Synchronous System
3. Multicarrier FEC decoder
4. High Speed Optical Bus Interface
5 Autonomous Network Controller

A major need is for construction of proof-of-concept hardware and flight demonstration of OBP hardware for satellite switching applications.

A.5 Size, Weight, Power, and Cost Considerations

In terms of size, weight, and power, an OBP transponder requires added weight and power and that it may also be also the most costly (see **Table A-1**). But it offers the potential of a lower power satellite transmitter; however, it is seen in Section A.2, the potential for lower satellite transmitter power is scenario dependent. Nonetheless, size, weight, and power tend to decrease as the technology matures.

Conservative estimates are for 70% size, 50% weight, and 15% power reductions per decade. These trends, derived from the early military applications of on-board processing, i.e. the MILSTAR low data rate (LDR) channel, are shown in **Figures A-4, A-5,** and **A-6**. Note that the term "LL" refers to Lincoln Labs where these early on-board processing prototypes were developed. The military application exploits on-board processing for anti-jam protection.

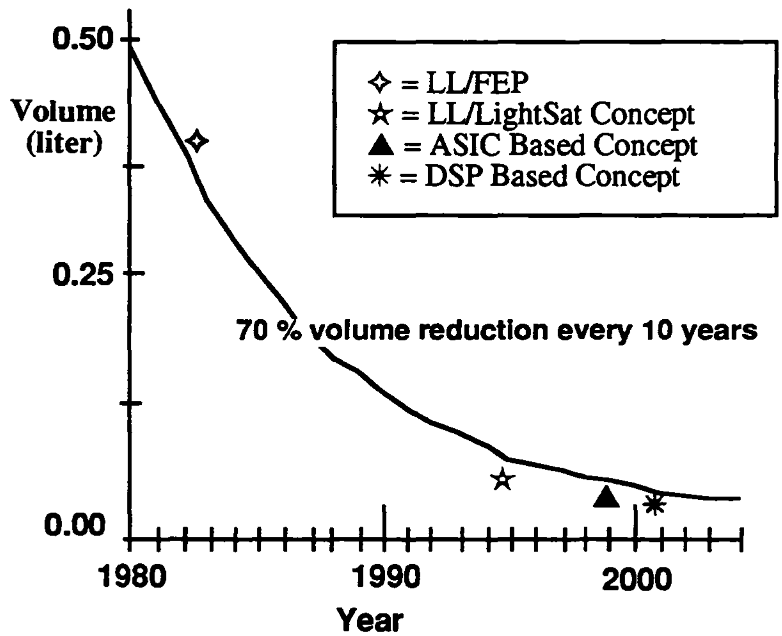


Figure A-4. Volume Trends

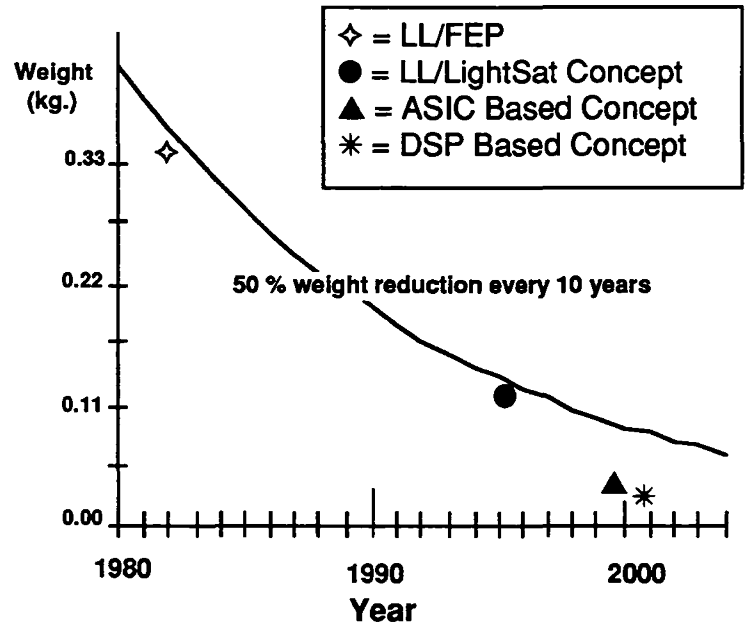


Figure A-5. Weight Trends

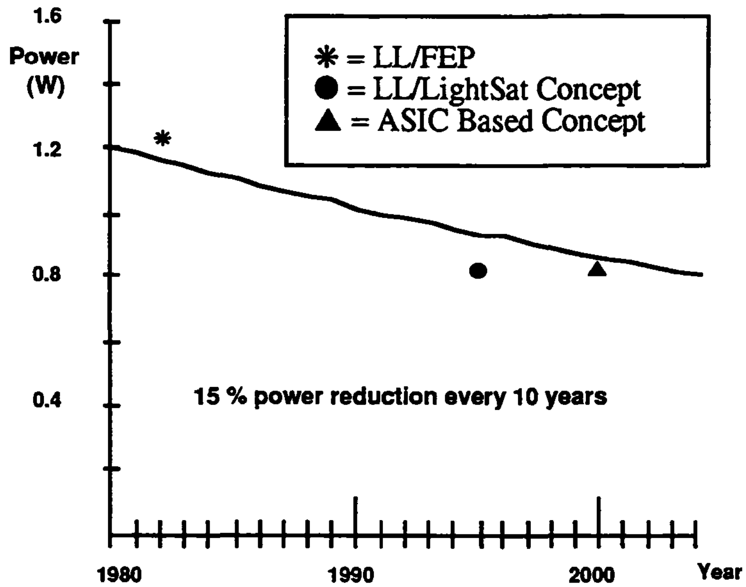


Figure A-6. Power Trends

Due to the relatively high power requirements shown in **Figure A-4**, prime power is the key issue for comparing the full processing and the bent pipe transponders. The Lincoln Laboratory "Lightsat" projection for an MDR demodulator is approximately 6-W per channel. Assuming this model, the power required for the DSP based demodulator is estimated in **Table A-5**. Hence, the estimate for an MDR demodulating receiver is about 2.5 W per MDR channel for a year 2000 satellite. (MDR channel size is 1.5 Mb/s.)

These estimates for near and mid term MDR processor power per channel are shown in **Figure A-7** with the excess transmitter-related power of the bent pipe transponder. It is evident that the power per channel for OBP will be greater than the excess transmitter-related power per channel of the bent pipe transponder at least until the far term.

Table A-5. MDR DC Power Estimate

Function	Power (W)
Downconvert	0.3
A to D	0.5
DSP	1.5
Total (minimum)	2.3

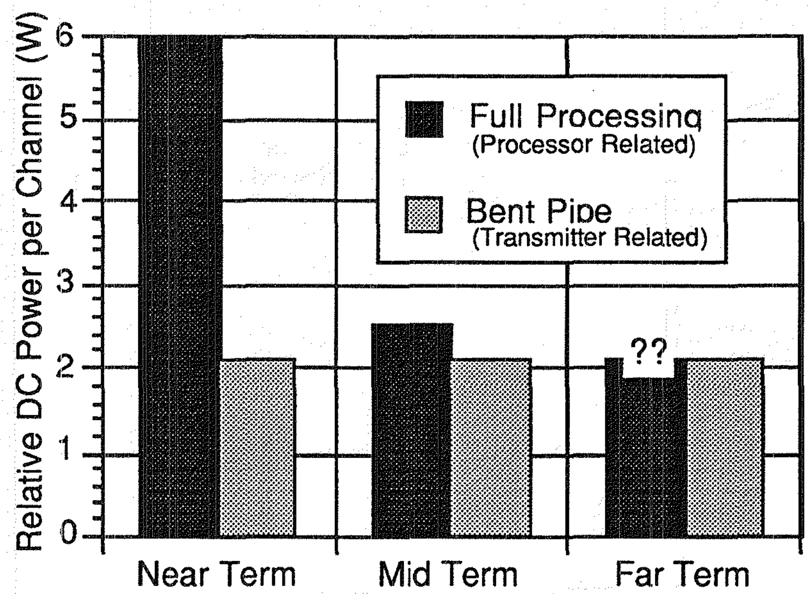


Figure A-7. Processor DC Power (per Channel)

Finally, satellite cost projection based on the U. S. Air Force Unmanned Satellite Cost Model (version 6) **(USCM-6)** is shown in **Table A-6** [5]. It is clear that, based on available cost data, the cost of an OBP is estimated to be about 23% higher. It is therefore recommended that the cost data be tracked if an OBP is to eventually offer cost advantage.

Table A-6. Selected Inputs to and Results from the USCM-6 Cost Model

Parameter	OBP	Bent Pipe
Model Inputs (8)		
Payload Weight	720 lb	460 lb
Payload Weight Overhead	215 lb	210 lb
Payload Power	810 W	580 W
Payload Power Overhead	75 W	75 W
Dry Bus Weight (5% margin)	1,005 lb	970 lb
Bus Power (5% margin)	355 W	325 W
Model Outputs (^)		
Payload Non-Rec. Cost	$44 M	$45 M
Payload Rec. Cost	$27 M	$10 M
Bus Non-Rec. Cost	$49 M	$40 M
Bus Rec. Cost	$37 M	$38 M
Recurring Satellite Cost	$65 M	$48 M

A.6 Conclusions

SOW Task 3. *Determine if on board processing is a net benefit or handicap. For example, on-board processing would enable service cross-strapping on demand and beam interconnectivity on demand. In addition regeneration improves links and save power. However, a mass and power penalty comes with the required equipment. The alternative hub service may be less expensive, but remote-to-remote communications is not possible without a double hop.*

A.6.1 Is On-Board Processing a Net Benefit or Handicap

On board processing (OBP) imposes a burden in terms of mass, power, volume, and thermal impact on the satellite, compared with a bent pipe transponder satellite. This impact is directly related to the data throughput. Thus the impact is considerably more for a multi-gigabit DBS satellite compared to an MSS satellite with several Mb/s throughput.

OBP technology is immature and not generally being used on current satellites, with the exception of experimental satellites such as the NASA ACTS. However, a number of satellite concepts have been proposed (Spaceway, Teledesic, Inmarsat-P), and some are even under construction (Iridium, Odyssey), that need on-board switching and thus incorporate OBP technology. Thus for the proper application, OBP is judged to be a net benefit by the commercial market place. OBP with digital switching and intersatellite links make a good combination for those system architectures that require routing of traffic between satellites (e. g., Iridium, Odyssey, Inmarsat P, and Spaceway).

For developing country applications that require switching, OBP and switching on the satellite may be desirable. However, the increased cost of OBP satellite services may preclude their usefulness for developing countries Thus OBP can be used for MSS applications (4.8 kb/s voice to 64 kb/s data services). A developmental challenge is to reduce the cost of OBP for high data rate FSS services (switched fractional T-1 supplied from satellites of several Gb/s capacity).

Appendix B

Frequency Band of Operation

This appendix summarizes the considerations involved in selecting a frequency band of operation. The discussion is organized as follows:

B.1 Introduction and Summary

B.2 Link Impairments

B.3 Technology Assessment

B.4 Conclusions

Subsection B.1 gives a summary table of frequency band advantages and disadvantages. Subsection B-2 discusses link impairments, and Subsection B-3 gives a technology assessment. Section B.4 contains the conclusions.

B.1 Introduction and Summary

Table B-1 gives the relative advantages and disadvantages of the frequency bands that could be considered for use by developing countries. The choices for FSS satellite service are C-band, Ku-band, and Ka-band (this is the primary trade in this appendix). The BSS band is fixed at 17 GHz uplink and 12 GHz downlinks (no choice, except whether to use FSS (100-W) or BSS (200-W) for high power DBS service. The table includes the L/S MSS band and "little LEO" UHF message forwarding service band for completeness. Also included are the military bands at UHF, X-band, and EHF since they are often included (quietly) on non-U.S. National satellites for foreign government use.

The choices between MSS, FSS, and BSS bands are generally made based on type of service, and is not a subject of this appendix Occasionally, the system designer must decide whether to operate at high power DBS (200 W transponders in the BSS Ku-band), or else high power FSS (100 W transponders in the FSS band).

For the FSS band, the choice is between C, Ku, and Ka-bands. As seen from the **Table B-1**, the higher frequency bands tend to have more spectrum and orbital slots available, but more expensive technology and higher rain margin. The conclusion is to use the lowest frequency that can supply the service, possibly using both C and Ku-band transponders on the same satellite if more capacity is required.

Use of Ka-band would require special circumstances such as need for narrow spot beams and/or large bandwidths for high data rates.

Table B-1: Advantages and Disadvantages of Different Frequency Bands

Freq. Band	Freq. Range (GHz)	Advantages	Disadvantages
UHF	0.3 – 0.8	Military use. Also "little LEO" message forwarding use.	Narrow bandwidth. Requires large antennas.
L	1.6	MSS service band (uplinks)	Narrow bandwidth, large antennas.
S	2 – 2.5	MSS service band (downlinks)	Narrow bandwidth, large antennas.
C	4 – 6	FSS band. Mature, low cost technology	Spectrum is crowded. Interference from terrestrial microwave links.
X	7.25 – 8.5	Worldwide military band.	Gov't or military use only.
Ku	12 – 14	FSS band. Smaller antennas feasible, or more gain from same size antenna.	Spectrum/orbit is becoming crowded. Limited DBS power allowed. More rain margin needed.
Ku	12 – 17	BSS band. High power DBS service allowed.	Wide orbital slot spacing. More rain margin required.
Ka	20 – 30	Wide bandwidth available (1 GHz to 3 GHz)	Immature, expensive technology. Rain attenuation outages.
Ka	20 – 44	Military EHF band. Wide bandwidth available.	Immature, expensive technology (especially at 44 GHz). Rain attenuation outages. Gov't or military use only.

B.2 Link Impairments

This subsection presents data on natural and man-made environments that impair the use radio frequencies. Data showing degradation of the RF signal, particularly due to rain attenuation and sky noise, is provided for specific frequency ranges. The natural phenomena that affect the propagation of RF energy through the ionosphere generally cause varying degree of attenuation as a function of frequency. The principal causes for degradation of the frequency bands due to natural propagation effects that are discussed here are: (1) atmospheric noise; (2) rain attenuation; (3) atmospheric attenuation, and (4) atmospheric scintillation. (5) Interference from man-made signals is also discussed. There are also man-made impairments that are not discussed, including nuclear effects and jamming.

B.2.1 Atmospheric Noise

Sources of atmospheric noise, generally referred to as sky noise, include: cosmic noise, atmospheric thermal noise, and noise resulting from certain gases. Cosmic noise typically decreases as a function of frequency and is small above 1 GHz, Above 1 GHz, atmospheric thermal noise becomes predominant (see **Figure B-1**). This is true as long as the antenna is not pointing toward the sun or other discrete noise sources.

Noise temperature also varies with antenna elevation angle due to the different radio path lengths through the atmosphere. The combined effect of the noise sources and elevation is shown in **Figure B-2**. The hump at 22 GHz due to water vapor absorption in the atmosphere.

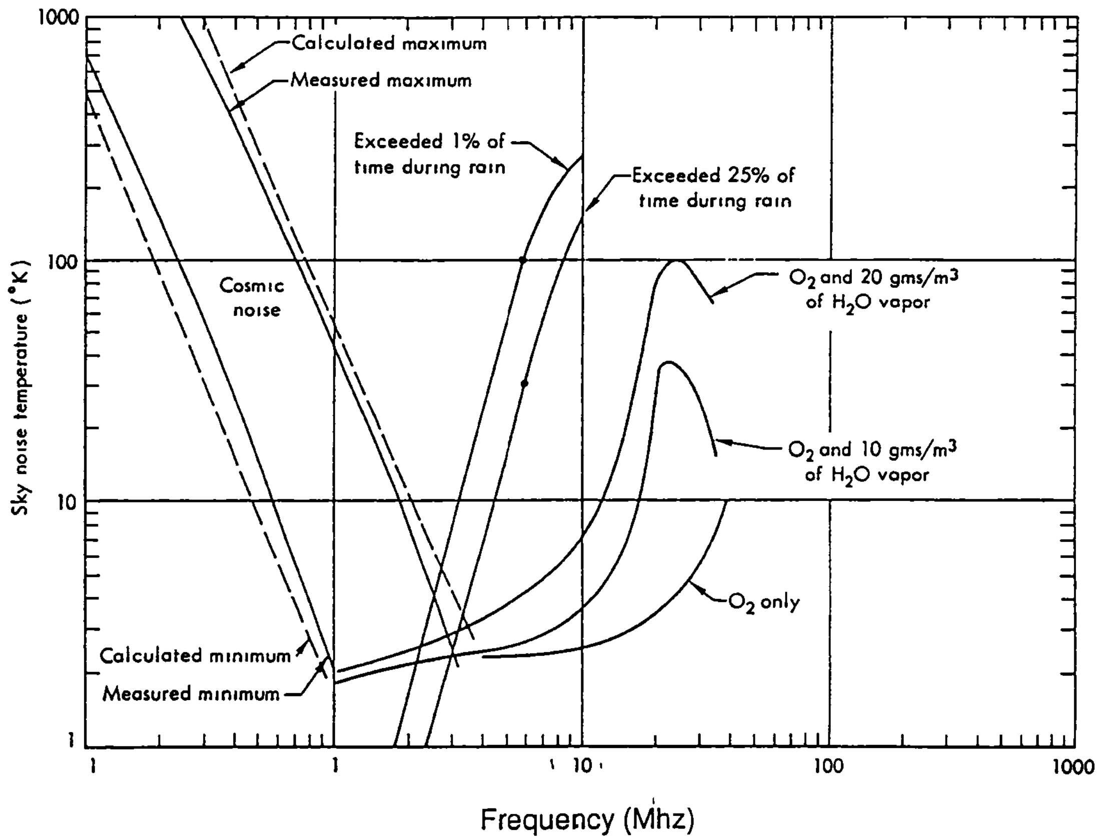


Figure B-1: Contributions of Natural Phenomena to Sky Noise

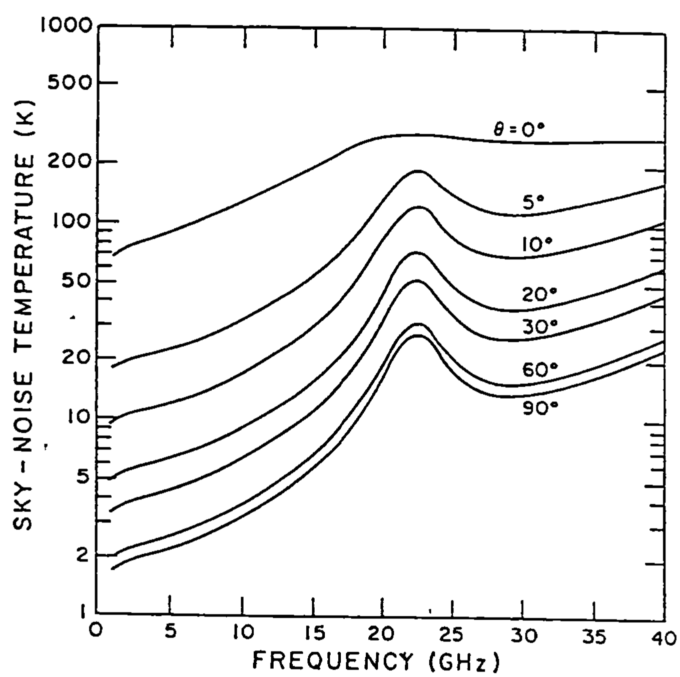


Figure B-2: Sky Noise Temperature vs. Frequency and Elevation Angle

B.2.2 Rain Attenuation

Attenuation of the RF energy due to rain has the most severe impact in terms of frequency selection. Physically, as the wavelength of the signal and the size of the rain drops are about the same, the rain particles both absorb and scatter the transmission. Large rain drops become oblate spheres as their downward speed increases. The increased motion increases the effective surface area presented to the RF energy and increases the resultant attenuation in the signal path. Thus, the effect of rain attenuation is a function of the rain rate, for example, in terms of mm of rain per hour as well as the path of the propagation. The rain rate is plotted as function of frequency at a constant attenuation rate (dB/km). **Figure B-3** shows the rain attenuation computed from empirical formulas vs. rain rates at a number of frequencies, for 99.5% availability, for several geographic locations (HI = Hawaii; NH = New Hampshire; DG = Diega Garcia).

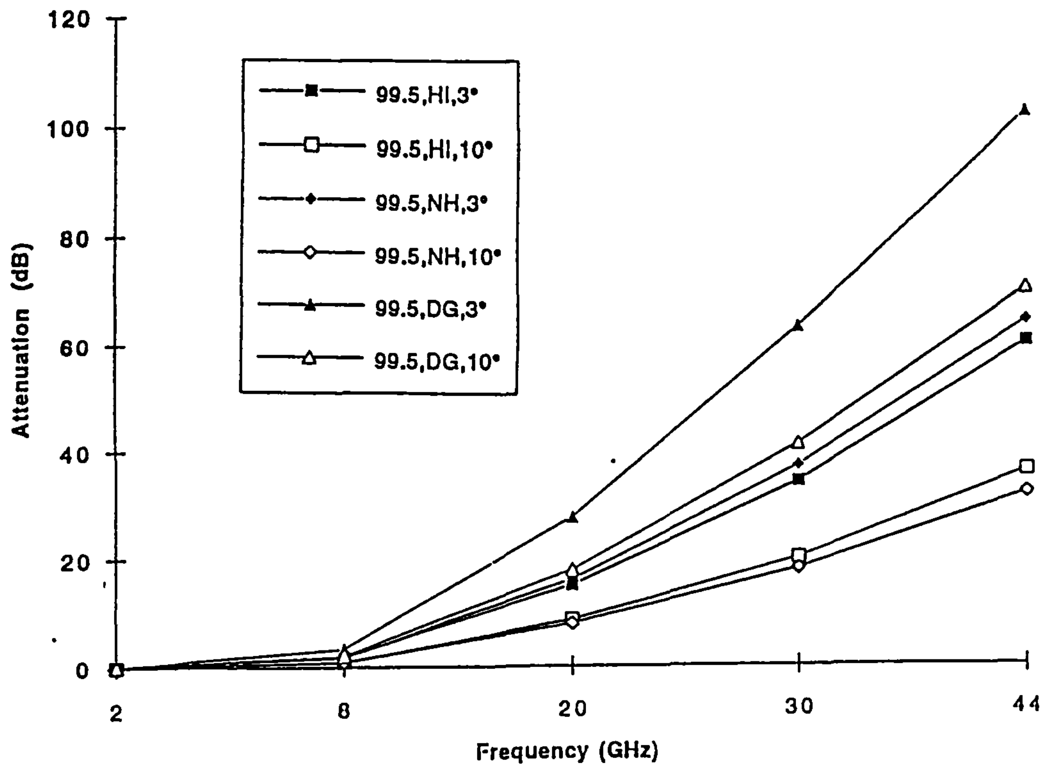


Figure B-3: Rain Attenuation versus Frequency

To improve system performance, the effect of rain attenuation is measured in terms of availability. For a given link, there is a minimum EIRP that is required of the transmitter. Any extra EIRP capability is the link margin. Depending link specifics, the probability that the rate of rainfall will result in the need for an amount of additional EIRP which surpasses the capabilities of the transmit terminal defines the "availability" of that link. A simple statistical interpretation of the availability is the average outage time of the link, which is shown in **Table B-2.**

Table B-2. Mean Outage Time as a Function of Availability

Availability (%)	Outage Probability (%)	Mean Outage Time per Year	Month	Day
99.9999	0.0001	31.5 s	2.6 s	0.1 s
99.999	0.001	5.3 min	25.9 s	0.9 s
99.99	0.01	52.6 min	4.3 min	8.6 s
99.9	0.1	8.8 hr	43.2 min	86.4 min
99.0	1.0	87.6 hr	7.2 hr	864.0 min

Since the weather pattern is not homogenous over the entire surface of the earth, it is important that the location of the terminal be part of the consideration for rain attenuation effects. **Figure B-4** shows the worldwide rainfall chart based on the generally acceptable Crane Model and rain climate region designations.

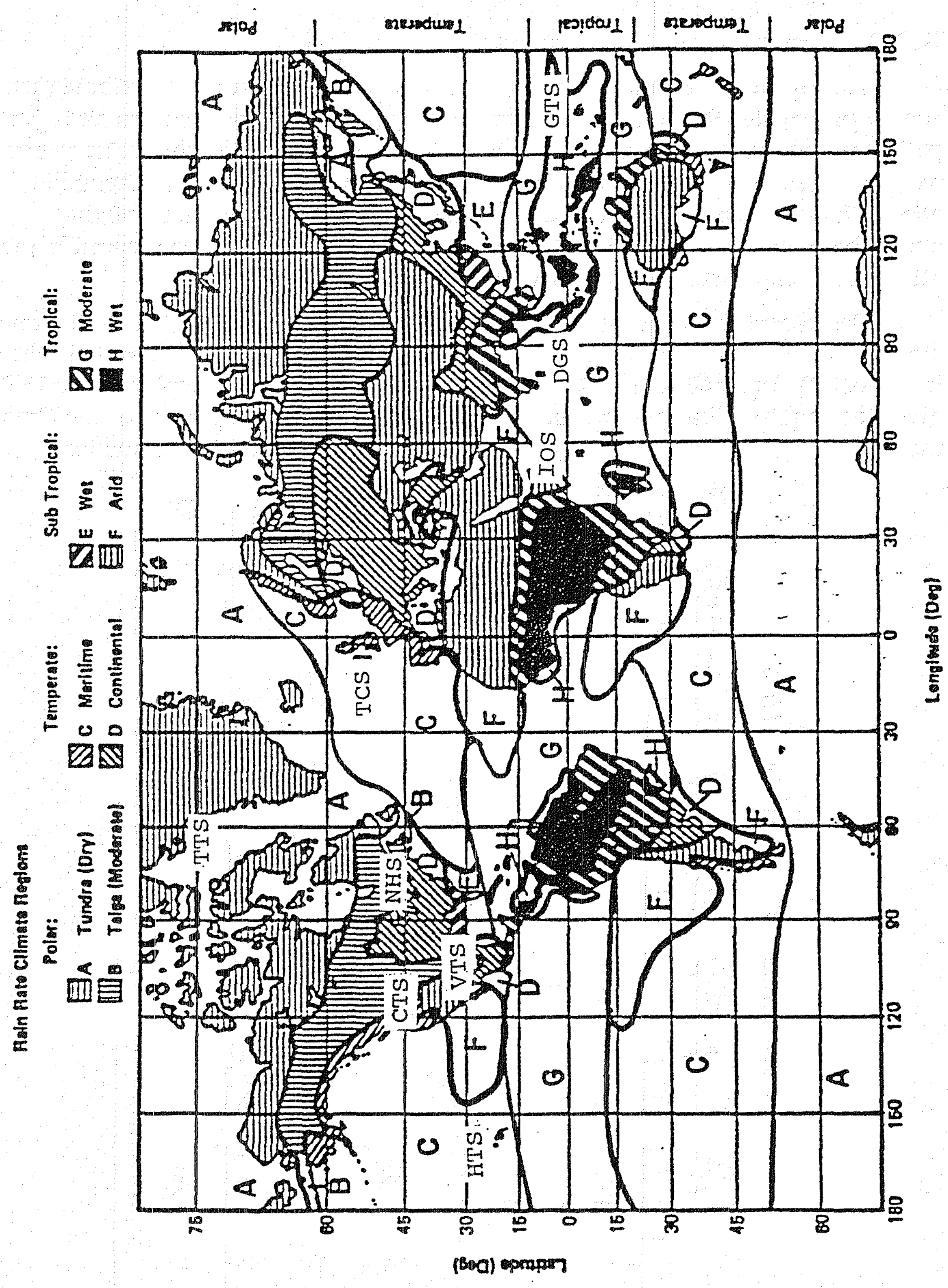


Figure B-4: World Rainfall Chart

B.2.3 Atmospheric Attenuation

Atmospheric attenuation is the loss that results when the electromagnetic energy propagates through a gaseous medium. It occurs in addition to free space path loss and rain attenuation. **Figure B-5** shows the absorption by water vapor and oxygen across the frequency spectrum (1 GHz to 300 GHz). There is negligible attenuation at C-band (4/6 GHz) and Ku-band (12/14 GHz), and only slight atmosphere attenuation at Ka-band (20/30 GHz). (The figures are for zenith angle attenuation, and increase as the secant of the zenith angle.)

Based on these absorption characteristics, it is possible to calculate the total attenuation as a function of frequency and elevation angle. An example is shown in **Table B-3** for 20 GHz and 44 GHz over a hot and humid atmosphere. **Table B-4** gives the required link margin for the tropical wet region (Region H of the Crane model, see **Figure B-4**) to compensate for rain and atmospheric attenuation.

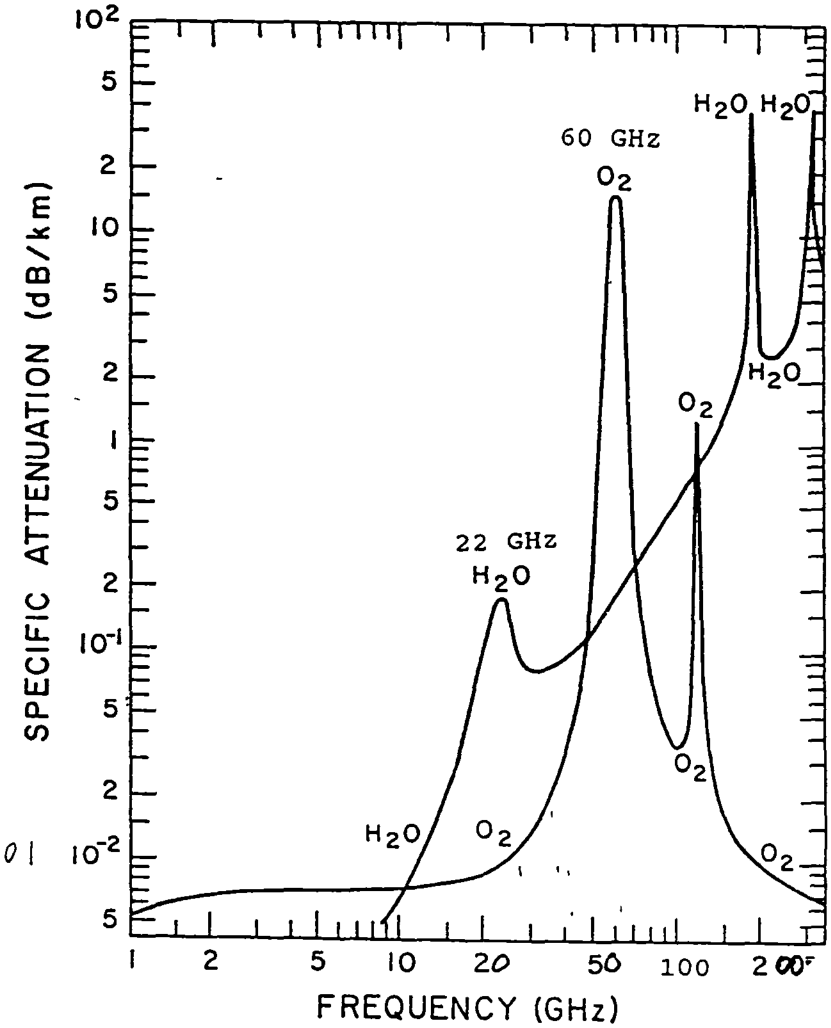


Figure B-5: Atmospheric Attenuation of Oxygen and Water Vapor vs. Frequency

Table B-3. Calculated Losses (dB) for Hot, Humid Atmosphere

Elevation Angle	Loss 20 GHz	Loss 44 GHz
20°	2.7 dB	3.0 dB
15°	3.0 dB	3.9 dB
10°	4.4 dB	5.8 dB
5°	8.7 dB	11.3 dB
0°	60.1 dB	77.6 dB

Table B-4. Required Link Margin (dB) for Tropical Wet Region (Crane H) (Rain plus Atmospheric Attenuation)

Freq. GHz	90° elevation angle			20° elevation angle		
	99.0%	99.5%	99.9%	99.0%	99.5%	99.9%
2	0	0	0	1	1	1
7	0	0	1	1	1	2
20	3	5	24	10	16	45
30	6	13	53	23	37	100
40	10	20	82	28	60	152
45	12	24	95	46	73	177

Figure B-6 shows an example of measured atmospheric losses versus elevation angles at 20 GHz for far north and equatorial locations. There is a rapid rise in the loss for elevations below 5°. Loss is considerably higher at high humidity and high temperature.

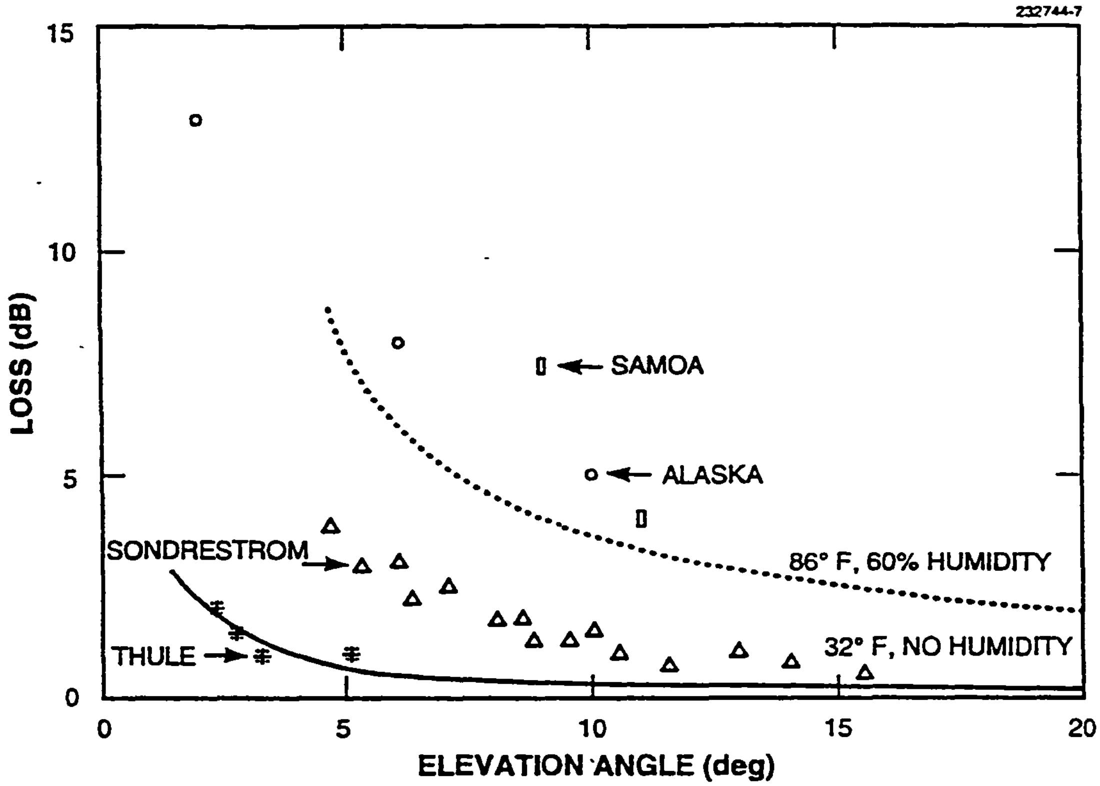


Figure B-6: Measured Atmospheric Losses (20 GHz) at Low Elevations

B.2.4 Atmospheric Scintillation

Atmospheric scintillation causes rapid fluctuations in the RF signal amplitude and phase due to variations in the troposphere. Scintillation is significant at low elevation angles at frequencies above 20 GHz. **Figure B-7** shows the predicted scintillation at 20 GHz and 30 GHz. **Figure B-8** shows measured scintillation at 20 GHz (top) and 30 GHz (bottom).

B.2.5 Man Made Interference

The developed countries have many more sources of man-made electromagnetic interference (e. g., microwave heaters and ovens at L and S-band) and terrestrial communication services sharing the same band (e. g., microwave relay links at C and Ku-bands) than those in developing countries. Thus the use of C-band and Ku-band in developing countries should be more widely available (i. e., ease in finding locations for ground terminals that do not interfere with existing applications). However, there is potential for the local government to license interfering systems, such as LMDS for distribution of TV at Ka-band.

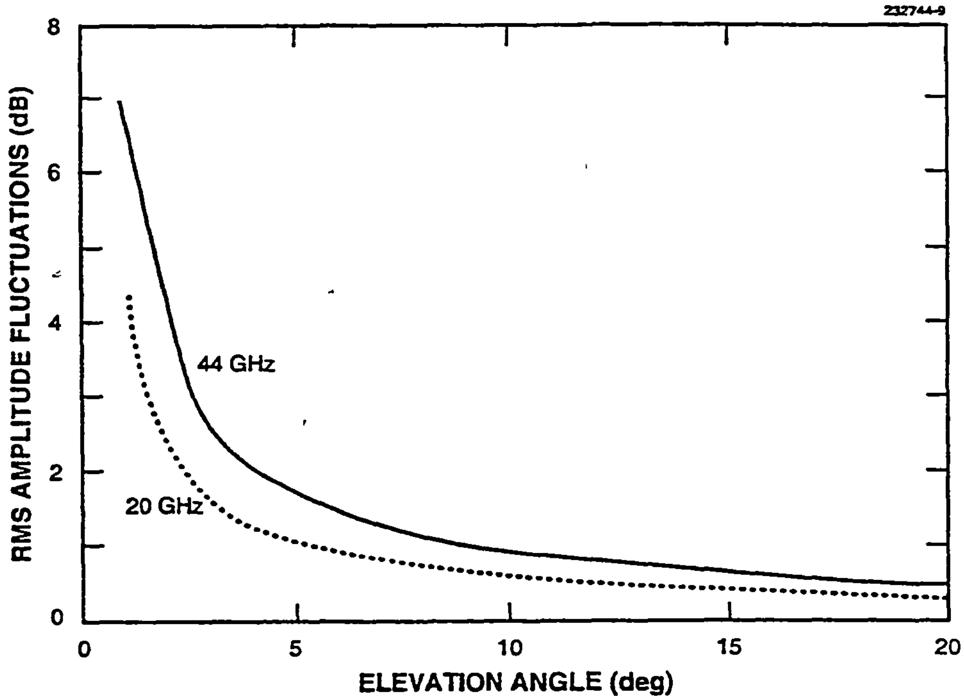
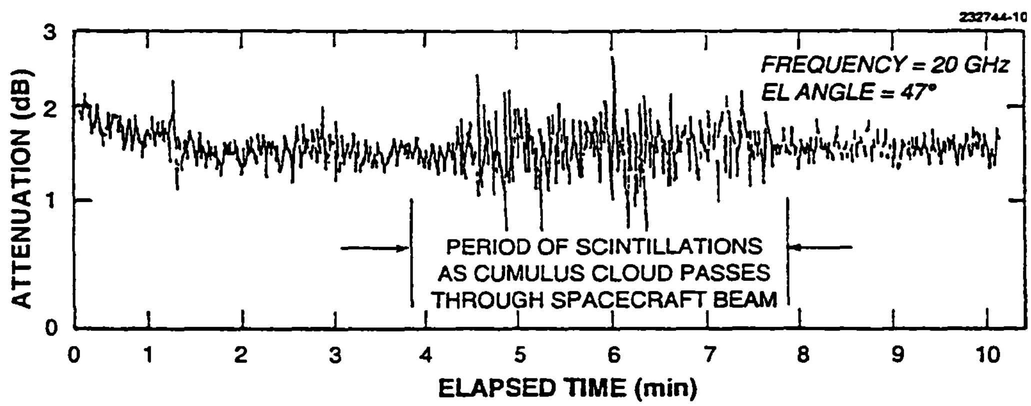


Figure B-7: Predicted Scintillation (20 GHz and 30 GHz)



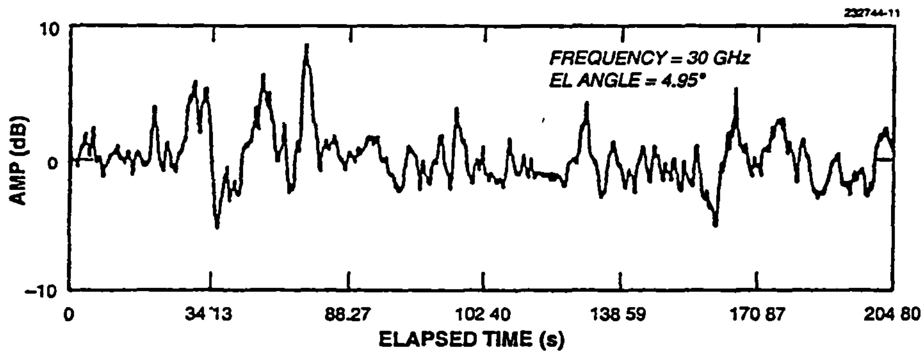


Figure B-8: Measured Scintillation at 20 GHz (top) and 30 GHz (bottom)

B.3 Technology Assessment

A typical measure of merit for a transmitting terminal is its EIRP while the corresponding measure for a receive terminal is its G/T. These translate to the considerations of (1) antenna, (2) power amplifiers, and (3) low noise amplifiers (LNAs). The general result is that lower frequency devices are more mature and have better performance.

B.3.1 Antenna Technology

For a given frequency, as the antenna size increases, the antenna gain increases and the antenna beamwidth decreases. Likewise, for a fixed antenna beamwidth, the antenna size decreases with increasing frequency. Thus, use of a higher frequency has the desirable effect of allowing use of smaller antenna to achieve the same gain. Alternatively, if the size is kept constant, increasing the frequency will result in an increased antenna gain and smaller antenna beamwidth.

However, a reduction in the antenna beamwidth has consequences in terms of more accurate control and tracking. There is also is an antenna surface tolerance requirement which is a typically 1/10 wavelength, and is thus more difficult with increasing frequency (and increasing antenna size). For example, the antenna rms surface tolerance is ±1 mm (±0.040 in) at 30 GHz, but is 5 times greater , or ±5 mm at 6 GHz. With present day technology, even an 2.4-m (8-ft) reflector at 44 GHz that results in 58 dB gain could be manufactured to meet the tolerance requirement. However it becomes increasingly difficult to manufacture antennas with still higher gain.

For ground antennas, those that operate at higher frequencies possess the advantages of small size and less torque required for driving the antenna. Those at lower frequencies with wider beamwidths are easier to manufacture and control.

B.3.2 Transmitter Technology

Ground transmitter and spacecraft transmitters are discussed separately

B.3.2.1 Ground Transmitters

S-band transmitters in the 2.5-kW range are readily available, and combining four of them yields a ground transmit power of 10 kW. Transmitters in the same output range are also available in the 8 GHz frequency band. Commercial off the shelf 15-GHz transmitters can reach to the 400-W level and can be combined to produce a power output of over 1 kW. Due to the fewer number of users, equipment in the 30-GHz band is less developed. In the 44-GHz range, traveling wave tube amplifiers (TWTAs) with outputs in the 600 W range are available.

B.3.2.2 Spacecraft Transmitter

Due to the power and mass restrictions on the spacecraft and the need for high efficiency, space transmitters have much lower output powers. TWTAs are favored for their high efficiency (60%), but may need 2-dB to 4-dB backoff if operated with multiple carriers. This favors use of communication system designs with single TDM carriers on the downlink. TWTA power (saturated) ranges up to 100-W at Ku-band (FSS), and somewhat less at Ka-band. SSPAs may have 20-W linear power at C-band and X-band. Multiple TWTAs are ganged together to make 200-W transponders for Ku-band BSS applications.

B.3.3 Low Noise Amplifier Technology

Performance of the receiver's dynamic range is bounded at the low end by the noise floor and at the high end by the output at the gain compression or intercept point. Practical considerations dictate a receiver operational margins above the noise floor and back off between 10-dB to 20 dB below the output intercept point.

The critical component responsible for the receiver performance is the front end low noise amplifier. **Table B-5** [1] summarizes the status of low noise transistor development in various frequency bands. The trends in the table show that the overall noise figure increases with frequency. Apparently, device physics favors low end frequency performance. The lower LNAs should continue to perform better than those at higher frequencies.

Table B-5. Low Noise Transistor Development

Device	Frequency (GHz)	Noise Figure, F (dB)	Gain, G (dB)	F00 (dB)
0.25 mm	8	0.4	15.2	0.41
Standard	18	0.8	10.4	0.87
HEMTs	30	1.5	10.1	1.64
	40	1.8	7.5	2.11
0.25 mm	8	0.8	15.0	0.82
MESFETs	18	1.4	10.0	1.53
	50	2.0	7.8	2.31
	40	2.6	6.9	3.07

HEMT is the high electron mobility transistor

MESFET is the metal-semiconductor field effect transistor

$$F_{00} = F + \frac{F-1}{G-1} = \frac{FG-1}{G-1}$$

B.4 Conclusions

SOW Task 4. Choice of frequency band of operation (C, Ku, and Ka-bands)

a. Determine what frequency bands are favored in different regions of the world in terms of interference from existing terrestrial or VSAT systems.

b. Determine the impact of rain attenuation in different regions of the world. Can quality of service objectives be met.

c. Determine which regions are more favorable for different technologies.

For FSS band, the choice is between C, Ku, and Ka-bands. As seen from the summary in **Table B-1**, the higher frequency bands tend to have more spectrum and orbital slots available, but more expensive technology and higher rain margin. The conclusion is to use the lowest frequency that can supply the service, possibly using both C and Ku-band transponders on the same satellite if more capacity is required Use of Ka-band would require special circumstances such as need for narrow spot beams and/or large bandwidths for high data rates.

B.4.1 Impact of Interference from Existing Systems

The impact of interference from existing communications systems and industrial operations is likely to be less in developing countries. In particular, terrestrial microwave relays may not exist, and thus will not place restrictions on ground terminal locations. Thus, a general conclusion is that C-band and Ku-band may be more generally available. However, the situation may change rapidly if the local government decides to open up a frequency band for terrestrial use, such as Ka-band LMDS for TV distribution.

B.4.2 Impact of Rain Attenuation in Different Regions of World

The impact of rain attenuation is different in different regions of the world, particularly the wet tropical areas. Unless satellite EIRP and ground station size is adjusted, quality of service will suffer in these regions. The primary factor to suffer will be the availability of service during times of heavy rain. C-band service will have few problems; Ku-band service will have moderate loss in availability; and Ka-band service will have significant drop in availability (98% availability is likely design point) and will require use of larger terminals.

B.4.3 What Regions are More Favorable for Different Technologies?

Tropical regions are more favorable for C-band and Ku-band services, and temperate regions for Ka-band services. Double hop (conventional) VSAT services at Ku and Ka-bands are to be avoided in regions of high rainfall.

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Appendix C

Antenna Technologies

This appendix examines the use of multiple beam and active antenna technology. It specifically attempts two answer the two questions from the statement of work: (1) Is multiple beam antenna technology necessary? and (2) Is there a net benefit from the use of active antenna technology? This section is organized in four parts:

C.1 Introduction

Space Systems/Loral uses many different technologies such as shaped reflectors, receive and transmit phased arrays, multibeam antennas, and conventional gimbaled dishes, to meet its customers needs. A comparison of these different approaches are shown in **Table C-1**.

Table C-1: Comparison of Antenna Technologies

	Active	Approaches Utilizing TWTAs		
Figure of Merit	Phased Array	Multibeam	Shaped Refl.	Gimbal dish
No. of independent beams	≤6	many	1	<4 typical
Reconfigure beam?	over earth disc	limited region	no	no
Movement	electrical	no	no	motor
Shape	arbitrary	combination of beams	fixed	ellipse
Zoom	to min. bw	n/a	n/a	n/a
Scanning	fast	one beam at a time	n/a	slow
Power	No of elements	constrained by TWTA	constrained by TWTA	constrained by TWTA
Efficiency	25%	60%	60%	60%
Thermal	heat pipes	heat pipes	passive	passive
Size	determined by min. beamwidth	determined by minimum bw	determined by minimum bw	determined by minimum bw
Shroud area	horn height	hinged	hinged	unfurl
Deployment	none	offset feed	offset feed	boom

C.2 Multiple Beam Antennas

SOW Task 5a: Determine if multiple beam antenna technology is necessary or would a shaped antenna coverage suffice. For example multibeam coverage is often necessary for Ka-band due to the need for high gain antennas to combat rain fades and the need for wide geographic coverage. Arid areas may be suitable for simple coverage in Ku or Ka-bands if there is a significant market.

Multi-beam antennas are used in applications that cover areas that may employ frequency reuse or complicated patterns. Satellites manufactured at SS/L use combinations of shaped reflectors and multibeam antennas to achieve coverage. Although complicated to shape and manufacture, shaped antennas are the lightest weight of the options. Of course simple elliptical or circular patterns can be generated with parabolic dishes. The basic difference between a multibeam antenna and a phased array is the coverage of a single element. A multibeam antenna element is synonymous with a spot on the ground. **Figure C-1** shows an example of how a 10 element, 1.55° beam, multibeam antenna could be used to achieve three times frequency reuse over the continental United States. One disadvantage is that a single element failure produces a "blind spot" in the overall antenna.

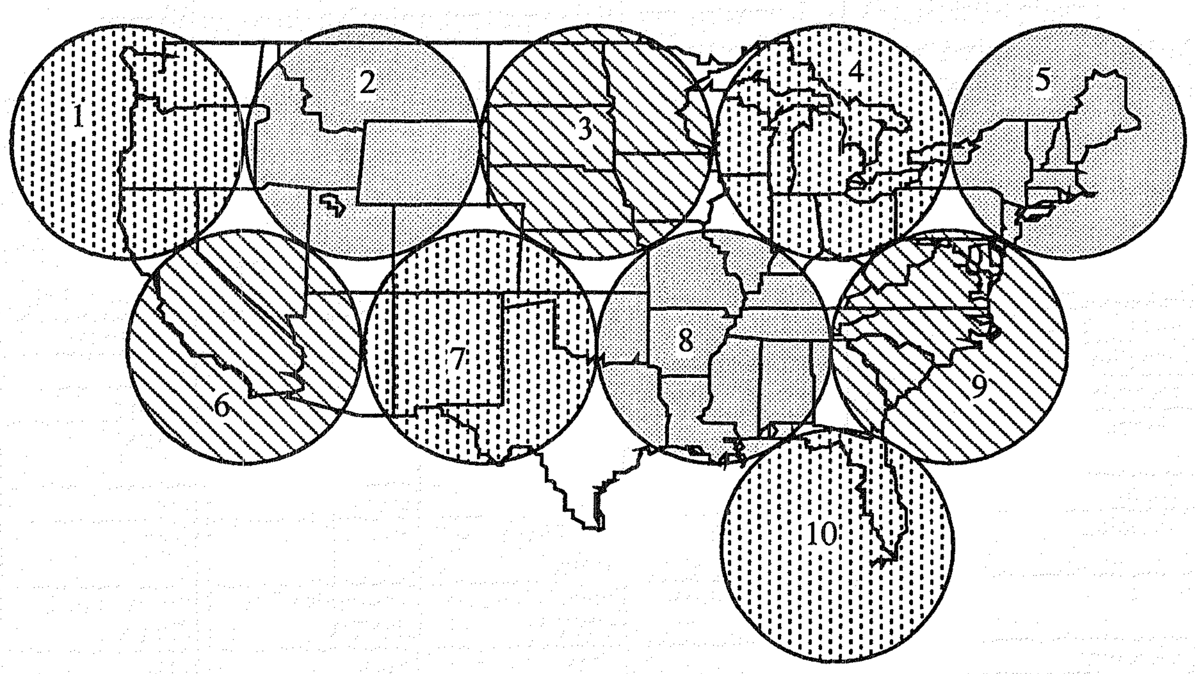

Figure C-1 Multibeam Antenna Covers CONUS with 10 beams of 1.55°

On the other hand phased arrays are designed so that their elements cover an entire geographic area, usually the earth disc from geosynchronous orbit. Arbitrary patterns are generated by combining the individual radiation patterns of the elements in space.

The advantage to multibeam antennas is that the gain is higher than a phased array and the shaping algorithms are relatively simple, when compared to phased arrays. Another advantage is that multibeam antennas are usually driven by traveling wave tube high power amplifiers, which are very efficient. **Figure C-2** is a block diagram of the payload showing how TWTAs are utilized for the patterns shown in **Figure C-1**.

Multibeam coverage is often necessary for Ka-band due to the need for high gain antennas to combat rain fades and the need for wide geographic coverage. Arid areas may be suitable for simple coverage in Ku or Ka-bands if there is a significant market.

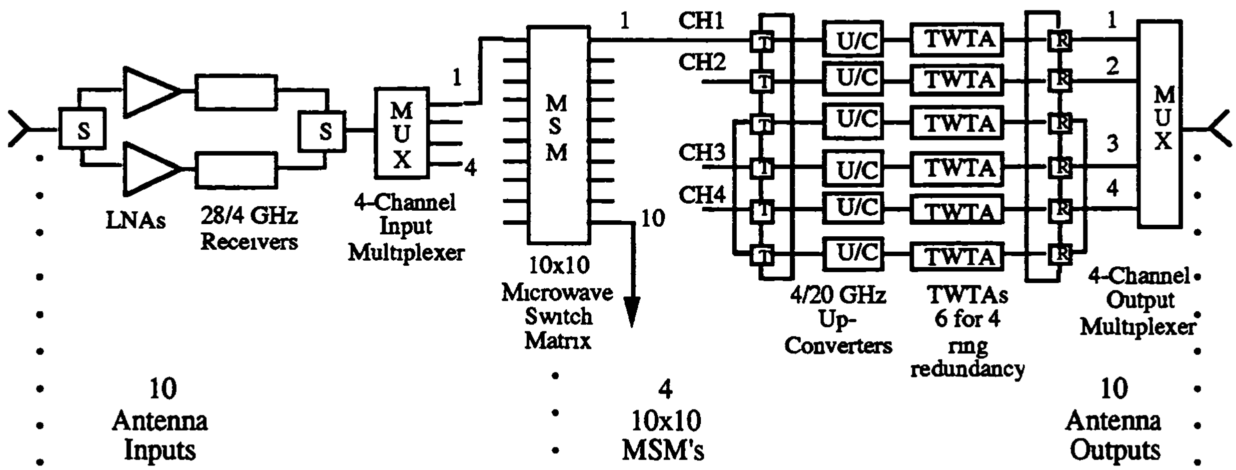

Figure C-2 Block Diagram of a Payload with Multiple Beam Antennas

C.3 Active Antennas

SOW Task 5b. Determine ıf there a net benefit from the use of active antenna technology such as the active transmit phased array. For example the increased complexıty of the active antenna is offset by its superior reproducibility and adjustability which reduce manufacturing and testing expenses. In addition, one antenna design can be used for multiple applications, thus reducıng development expense. The user benefits from havıng the flexibility to change beam coverage shapes during service.

An active phased array (APA) antenna consists of the MMIC electronics and control circuitry to both transmit and receive signals, as shown in **Figure C-3**. It can replace the conventional linearizers, TWTAs or SSPAs within a transponder, the antenna, including all reflectors, gimbals, and any other structure required to support and/or point the reflector. Since an APA can perform the receive function also, any low-noise amplifiers and receivers may also be replaced. There will be some reduction in interconnect waveguide as the APA interface is simpler and more compact than disparate, decentralized antennas.

The major advantage of phased array technology is the ability to re-configure on orbit. Tradeoff must be made to determine whether the on-orbit flexibility for a commercial application is worth the potential weight and power penalty of implementing the array. Commercial requirements for the different applications of along with an assessment of whether or not the requirements can be met with a phased array are shown in **Table C-2**.

Another potential benefit is that the increased complexity of the active antenna is offset by its superior reproducibility and adjustability which reduce manufacturing and testing expenses. In addition, one antenna design can be used for multiple applications, thus reducing development expense. The user benefits from having the flexibility to change beam coverage shapes during service.

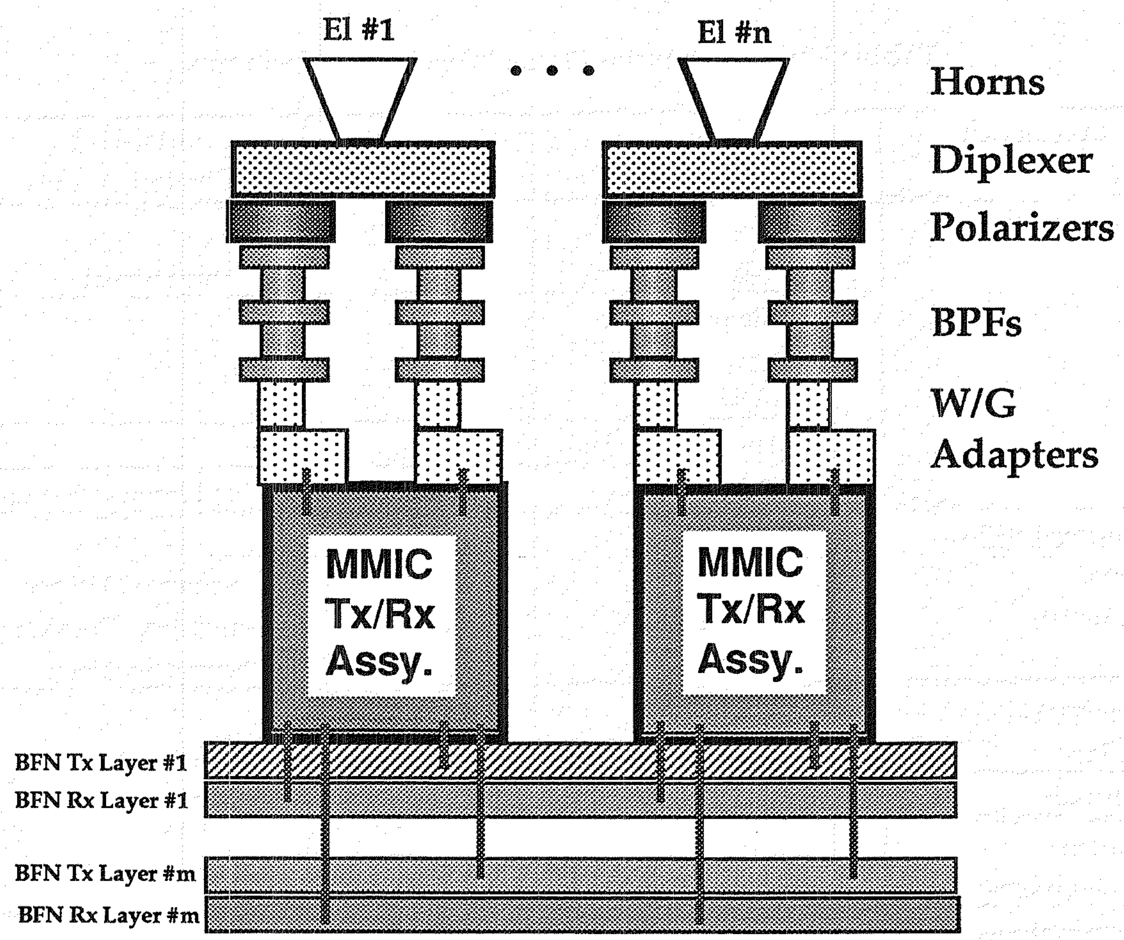

Figure C-3: Artist's Conception of Phased Array Element

Table C-2: Commercial Phased Array Requirements

Spacecraft Application	Requirement	Value	Satisfied by Phased Array?
Commercial FSS			
	1. Fixed beam positions		Yes, conventional
	2. Variable position & shape (e.g. Superbird, Orion, GE Americom)		Yes
	3. No. of individual beams	≤6	Yes
	4. 24-48 transponders	45 dBW EIRP	Yes for beamwidth < 1.5°
Commercial BSS			
Tempo, PanAmSat	No. channels RF power per channel	> 16 > 100 W	No Requires 20 W per amplifier. Potential thermal problems
Commercial MSS			
Teledesic	Many beams in LEO	60 supercells	Yes (only way)
Globalstar	Fixed beams in LEO	16 (1,6,9)	Yes, with fixed phases
Advanced			
Scanning beams	Fast switching	microseconds	Yes
Incremental coverage	Reconfigurable on orbit	1.5° beamwidth	Yes
Sat. News Gathering	Moveable beams	>second	Yes
Disaster recovery	Arbitrary beam shape	1.5° beamwidth	Yes

The parameters of an APA are shown in **Table C-3**. Note that we have selected the power per element so that the EIRP of the antenna is approximately 32 dBW in the earth coverage mode (specifications for Intelsat-VIIA). The size of the array is determined by the wavelength and, thus, the frequency (see **Figure C-4**). Besides aperture size, parameters are dependent on the number of elements and are independent of frequency.

Thus if a coverage area is specified, this determines the resolution in a rough way, which then drives the number of elements required. **Figure C-5** shows the coverage in California and China for approximate beamwidths of 1° and 4°. The EIRP is then determined by multiplying the power per element times the elements gain times the number of elements.

Table C-3: Antenna Parameters for an Active Phased Array in Geosynchronous Orbit

Minimum Circular Beamwidth	Number of Elements	Power per Element (W)	Maximum EIRP (dBW)	Earth Coverage EIRP (dBW)
8.0°	7	4.0	38.4	31.4
6.0°	19	2.0	44.1	33.0
5.0°	37	1.0	46.9	33.8
4.0°	61	1.0	51.2	35.7
3.0°	91	1.0	54.7	35.6
2.0°	127	0.5	54.6	34.3
1.5°	169	0.5	57.1	35.5
1.0°	396	0.1	57.5	32.4

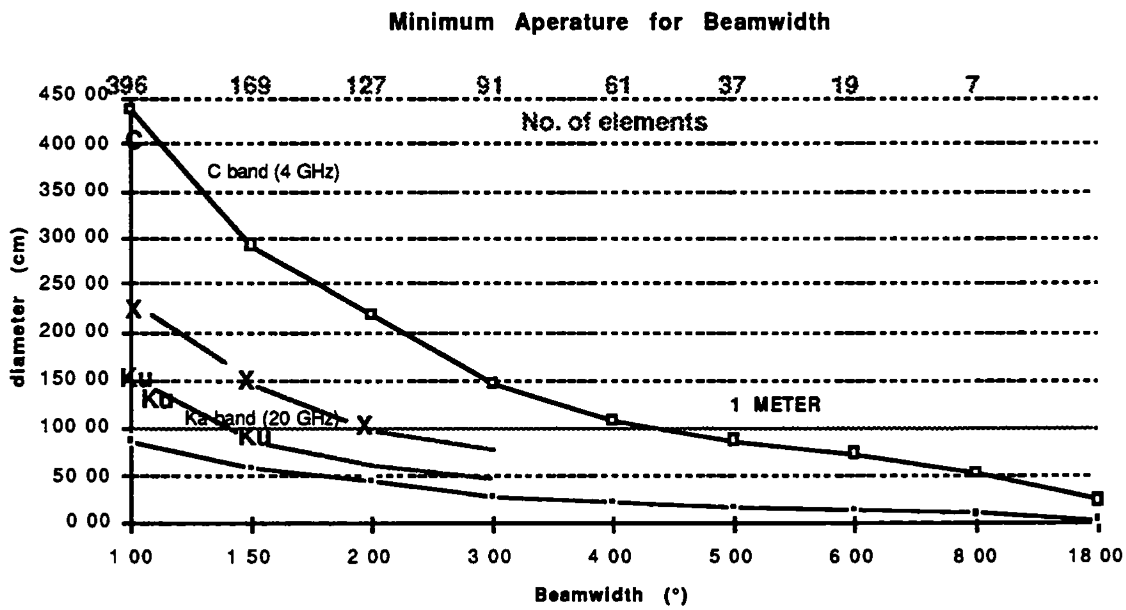

Figure C-4: Size of the Phased Array vs. Frequency

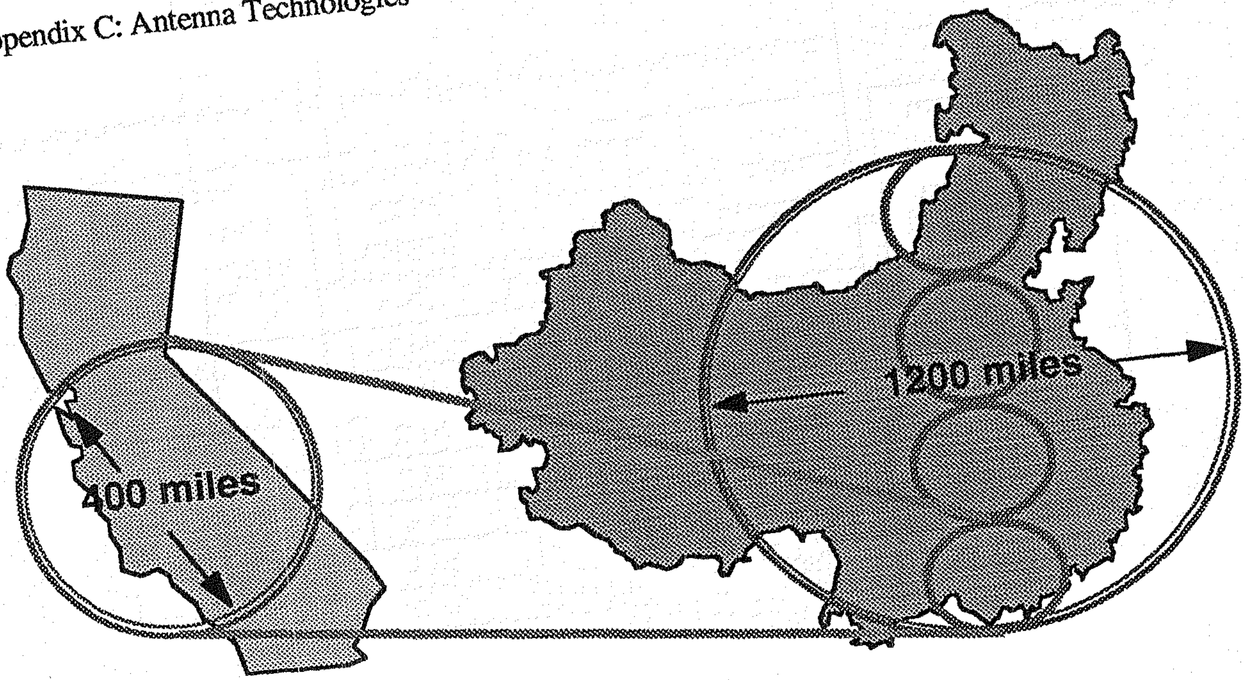

Figure C-5: Beam size and Coverage

C.4 Summary and Conclusions

SOW Task 5. Use of multiple beam and active antenna technology

a. *Determine if multiple beam antenna technology is necessary or would a shaped antenna coverage suffice. For example multibeam coverage is often necessary for Ka-band due to the need for high gain antennas to combat rain fades and the need for wide geographic coverage. Arid areas may be suitable for simple coverage in Ku or Ka-bands if there is a significant market.*

b. *Determine if there a net benefit from the use of active antenna technology such as the active transmit phased array. For example the increased complexity of the active antenna is offset by its superior reproducibility and adjustability which reduce manufacturing and testing expenses. In addition, one antenna design can be used for multiple applications, thus reducing development expense. The user benefits from having the flexibility to change beam coverage shapes during service.*

Satellite manufacturers are using shaped-beam instead of multiple-beam antenna technology for fixed coverage area applications such as DBS over CONUS or Intelsat-type hemi and zone beams. There are several advantages with shaped beam technology:

- There are much fewer feed horns and beamforming network complexity is reduced. Thus, antenna hardware cost is somewhat reduces.
- The computer program design for the antenna is extremely good, and thus antenna range testing can be eliminated with confidence. This results in a very large savings in manufacturing cost. The multiple beam antenna requires range testing for adjustment of the complex beamforming network.

Multibeam antennas are still necessary for applications which require multiple beams to achieve higher gain, either via fixed or scanning beams. Service examples include high data rate point-to-point service, or use of high gain to reduce user terminal size and cost.

Current communication satellite payloads are generally not using active phased array antenna technology due to cost and performance issues. Both low efficiency and thermal dissipation are technical barriers to implementation of transmit phased arrays. Present technology may incur weight and power penalties. Phased arrays show promise for advanced applications where the flexibility to reconfigure on orbit is a benefit, and in low earth orbits where beamwidths are wider, and gain requirements are less. Satellite manufacturers, together with Government agencies, are spending considerable R&D in developing active antenna technology for use with advanced communications system concepts such as Iridium and Teledesic.

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Appendix D

Use of Intersatellite Links

The impact and desirability of using Intersatellite links (ISLs) between two satellites which must cover a large geographic region (such as Brazil, Canada, or the former CIS) are evaluated in this appendix. A qualitative description of ISLs is given in terms of advantages and disadvantages, and the use of ISLs is described. Descriptions of baseline RF (60 GHz) and optical systems are then given. Summary and conclusions are presented. The discussion is organized as follows.

D.1 Description of Intersatellite Links
D.2 Use of Intersatellite Links
D.3 60 GHz ISL System
D.4 Optical ISL System
D.5 Summary and Conclusions

D.1 Description of Intersatellite Links

There are two fundamental methods of covering a large geographic region (which cannot be covered by a single satellite antenna footprint): (1) via a ground station to relay traffic from one satellite to the other, or (2) via dedicated communication links (ISLs) between the spacecraft. **Table D-1** qualitatively describes the advantages and disadvantages of each implementation. In general, use of ISLs is preferred for satellites with OBP and digital switching, provided there is sufficient ISL traffic and that there is not unused capacity on the satellites for up/down link relay via ground station. ISLs will most likely be a burden on conventional transponder satellites.

The assumptions made in defining the RF and optical ISL systems are listed in **Table D-2**. Two link sizes are considered; 100 Mb/s and 1 Gb/s data rates. A 60° separation in longitude in the GEO arc is assumed. The best RF implementation is judged to be at 60 GHz, and it is compared with a coherent detection optical ISL.

Table D-1: Qualitative Comparison of ISL vs. Ground Based Systems

ISL Implementation	Ground Based Implementation
Delay due to double hop avoided -- a significant issue with voice.	Additional double hop delay as signals propagate from spacecraft to ground station and back to second spacecraft
Additional mass and power required to support ISL system on spacecraft. Additional hardware costs to spacecraft as well as in integration and test.	No additional mass or power impact to spacecraft from ISL hardware. Spacecraft capacity (power and spectrum) is used by uplinks from and down links to the ground relay station.
ISL traffic switching and routing burden placed on spacecraft. This is trivial for an OBP satellite with digital switching, but may be difficult for flexible IF switch on satellite. Minor additional complexity in ground operations in setting the appropriate spacecraft routing switches.	Switching and routing complexity placed at the ground station to relay signals back to second spacecraft. Ground station must have two antennas to point at two different spacecraft, and be able to "see" both satellites from the same location.

Table D-2: Overall ISL System Parameter Assumptions

Parameter	Value	Units	Comments
Data rate	100 1000	Mb/s Mb/s	Evaluate both data rates
Link range	42,239	km	60° separation in GEO arc
RF aperture size	90	cm	Maximum diameter of dish
RF Frequency	60	GHz	TWTA operable bandwidth is approx. 5 GHz at RF
Optical aperture size	25	cm	Maximum diameter of telescope aperture
Optical wavelength	850	nm	TerraHertz of bandwidth available in the optical domain

D.2 Use of Intersatellite Links

SOW Task 6. Use of intersatellite links.

a. Determine if intersatellite links (with multiple satellites) are necessary for large geographic areas (such as Brazil, Canada, or the former CIS).

b. Determine the cost-benefit tradeoff of intersatellite links.

D.2.1 Are Intersatellite Links Necessary for Large Geographic Areas?

The use of multiple satellites may be necessary to cover the geographical area of a large country due to reasons of single satellite capacity and better elevation angle in the sky as viewed from the user locations. Countries may cover 60° or more in longitude (east – west), and large countries or regions linked by language can cover 100° or more in longitude. The availability of orbital slots, or interference issues may favor satellites being located even beyond the geographical longitude extent of the country.

In general, intersatellite links are to be avoided since they impose additional mass and power penalties on the satellite, and thus reduce the remaining payload capacity to carry uplink and downlink traffic. In addition, there must be a router on the satellite to separate out and recombine ISL traffic from the up/downlink traffic streams. This is relatively easy for a satellite with OBP and switching, but imposes additional cost and complexity on a conventional satellite design.

However, if there is traffic that must be transmitted to/from a neighboring satellite, there is less impact on the satellite to use an intersatellite link versus uplinks and downlinks passing through a ground installation. There are several reasons:

- There is no atmosphere to pass through for the intersatellite link, and thus link performance is improved.
- Separate frequency bands (for intersatellite links) are used which do not subtract from the available uplink and downlink spectrum which could be used to provide revenue producing traffic.

A single ground control location in the center of most countries can see a considerable section of the geosynchronous arc. For example, 160° of arc is covered by locations on the equator, down to 10° elevation angle. (Less of the arc is covered as ground station latitude increases.) This is greater than the longitude covered by most countries or regions, provided the latitude is not too high. Thus a single ground location could pass or interchange information to all satellites via different interconnected ground terminals.

The conclusion is that a developing country using conventional satellites does not need ISLs. Any interconnections between satellites can be accomplished via ground links. If advanced satellites are used, ISLs are a better way to carry traffic between satellites, providing their is sufficient traffic. Thus, the use of ISLs depends on the volume of traffic and the existence of satellites with OBP.

D.2.2 Cost – Benefit Tradeoff of Intersatellite Links

It is apparent that ISLs offer significant advantages in terms of minimal propagation delay in voice as well as flexibility onboard the spacecraft at the cost of additional mass, power, and additional costs; both in space qualified hardware and integration and test at the spacecraft level. A detailed cost/benefit analysis of implementing the ground based (costs of additional ground station, ground hardware, maintenance, etc.) versus ISL solution would need to be performed for the particular system under consideration.

D.3 60 GHz Intersatellite Link System

The description of the 60 GHz ISL system is given along with link closure analysis and mass and power estimates.

D.3.1 RF System Description

A 60 GHz RF ISL system is functionally represented in **Figure D-1**. The ISL system features beam waveguide assembly to transfer the received and transmit energy over the orthogonal azimuth and elevation gimbal axes, 2:1 redundant LNAs, a down-conversion assembly which converts the incoming 60 GHz to a 12 GHz IF, amplifies it, and passes this IF on to the transponder for connection to the appropriate downlink. Similarly, the IF signals from the uplink beams of the transponder are up-converted to 60 GHz and transmitted via HPAs and the 1.5 meter aperture.

To accommodate the higher (1,000 Mb/s) data rate, the minimum required IF bandwidth would be 1,000 MHz. Since this is a significant percentage of the IF center frequency (12 GHz), it is recommended that the high data rate traffic be channelized into two or three bands. Thus, both the upconversion and downconversion assemblies are either 3:2 or 4:3 redundant, respectively, with the appropriate multiplexing and redundancy switching.

In addition, the narrow bandwidth of the 60 GHz ISL beam mandates a closed loop tracking system on-board. The proposed system features pseudomonopulse autotracking whereby error-off-axis signals are generated via a multi-mode tracking coupler, and the difference signal is sequentially phase shifted in 90° increments and coupled back to the main beam, thus forming an AM signal whose amplitude is proportional to the error-off-axis A (redundant) tracking receiver deciphers the AM error component and is passed through the autotrack processor, generally part of the payload or spacecraft computer, and is used to drive azimuth - elevation gimbals which reorient the reflector on target. The autotrack processor uses the tracking receiver outputs to initially scan and acquire the transmitted signal (through some cooperative protocol) and then hold lock.

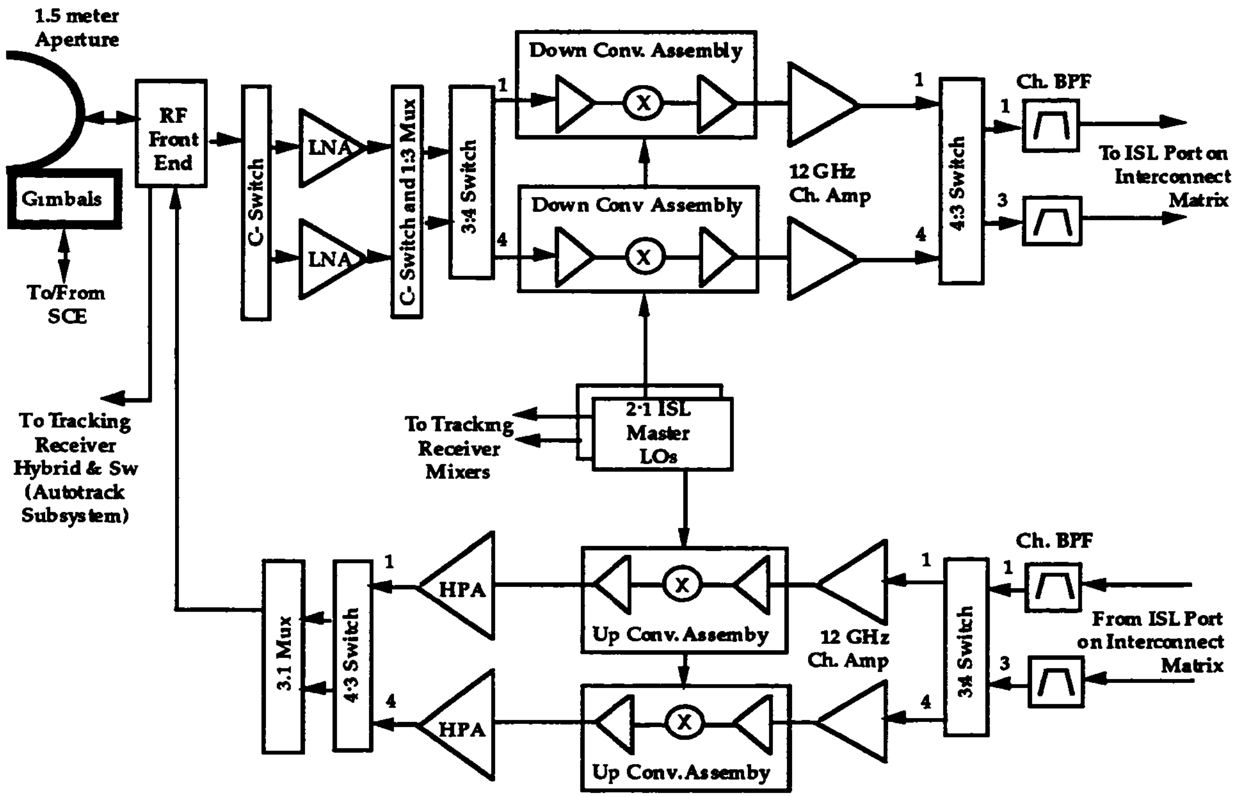

Figure D-1: Functional Diagram of 60 GHz RF Intersatellite Link System

D.3.2 RF ISL Link Closure Analysis:

Table D-3 illustrates the link closure analysis for the RF ISL at 100 Mb/s and 1000 Mb/s. For the 1,000 Mb/s case, the data rate is set up as two independent channels at 500 Mb/s each, or, as three independent channels at 333 Mb/s each. The following link and device assumptions were used in this analysis.

- 0.9-m aperture size for both transmit and receive ISL systems
- BER of 10^{-10}, modem loss of 2 dB, system margin of 3 dB, and Viterbi FEC coding (rate 1/2, constraint length 7) gain of 5.7 dB

- Receiver NF of 4 dB and G/T of 23.7 dB/K

The HPA power required to close the link was evaluated. **Figure D-2** illustrates this result. Note that with a 0.9 meter antenna on both the receive and transmit terminals, 10.4 W and 34.5 W HPAs are required to close the link for the 100 Mb/s and each of the three 333 Mb/s links. The required HPA power to close the link for each of the two 500 Mb/s links is 51.7 W.

Table D-3: Link Closure Analysis for 100 Mb/s RF Link

Parameter	Crosslink	Units	Remarks	
Data Bandwidth	1000 00	MHz		
Carrier Frequency	60 00	GHz		
Transmit Power	17 14	dBW		
HPA Backoff	0.00	dB		
Transmit Feed/Line Loss	1 50	dB		S/C EIRP (dBW)
Transmit Ant Gain	52 46	dBi	**51.71**	S/C HPA (Linear, W)
Operating EIRP	68 10	dBW	0 90	S/C T/X Ant diam (m)
D/L Edge of Cov. Loss	0 00	dB	55 00	Surface Efficiency(%)
EIRP (/Carrier) @EOC	68 10	dBW		S/C T/X Ant Gain (dBi)
Free Space Loss	220 53	dB	60 00	Angular Separation (deg)
Atmospheric Loss	0 00	dB	42239 00	D/L Range (km)
Rain Margin	0.00	dB		
Ptg/Pol//Trk Loss	0 50	dB		
Net Path Loss	221 03	dB		
Receive Ant. Gain	52 46	dBi		
Feed/Line Loss	1.50	dB		
U/L Edge of Cov. Loss	0 00	dB		
Sys Temp(Rec Input)	27 24	dB-K		
Effective G/T	23.72	dB/K		
Rec'd Carrier Level	-101.97	dBW		
Boltzmann's Constant	-228 60	dBW/Hz-K		
Rec'd Noise Density, No	-201 36	dBW/Hz	0 90	S/C R/X Ant diam (")
Spec'd X/L C/I	30 00	dB	55 00	Surface Efficiency(%)
Spec'd X/L Int'f Density, Io	-221 97	dBW/Hz	10 00	Antenna temp (K)
Total Noise Dens, No+Io	-201 32	dBW/Hz	290 00	Feed/Line Temp (K)
Received C/(No+Io)	99 35	dB-Hz	4 00	Rec. NF (dB)
			438 45	Receiver Temp (K)
	End-to-End	**Link**	530 22	System Temp (K)
Composite C/(No+Io)	99 35	dB-Hz		
Modem Impl. Loss	2 00	dB		
System Margin	3 00	dB		
Coding Gain	5 70	dB	Rate 1/2, k=7	
Req'd Eb/No	13 06	dB	1E-10	QPSK BER
Available Data Rate	86 99	dB-Hz	500 00	Mb/s

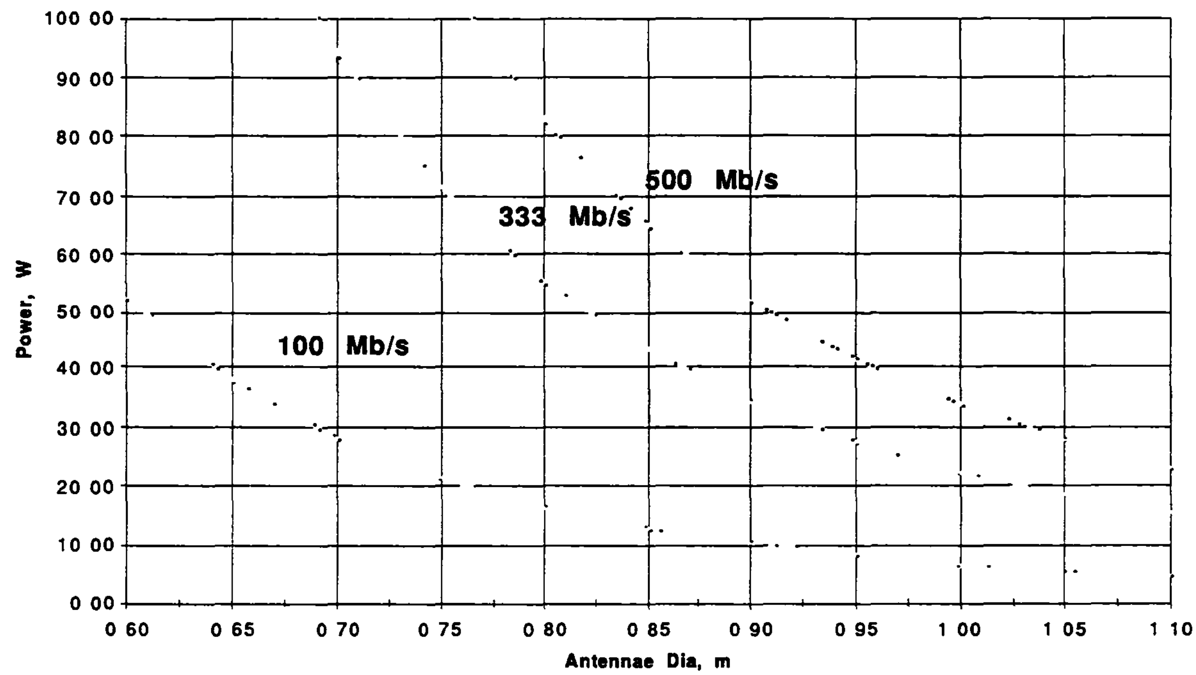

Figure D-2: HPA Power Required for RF ISL

D.3.3 RF ISL Mass and Power Estimates:

Tables D-4, D-5, and **D-6** itemize the mass and power for each of the three implementations.

1. 100 Mb/s RF link **(Table D-4)**
2. 1 Gb/s RF link; 3 channels @ 333 Mb/s **(Table D-5)**
3. 1 Gb/s RF link; 2 channels @ 500 Mb/s **(Table D-6)**

TWTAs with 30% to 35% efficiencies are assumed, and a hardening mass margin of 5% and overall mass margin of 15% is assumed. A 10% power margin in also assumed. The basis of these estimates are the various R&D projects and 60 GHz proposals performed at SS/L over the past few years. In summary, the mass and power characteristics are given by **Table D-3**. The following comments are applicable to these implementations.

- All implementations require TWTAs as the required HPA power levels are beyond the capability of SSPAs. However, 5-W SSPAs are currently available at 60 GHz, and it is conceivable that space qualified 10 W versions will be available in the 2000 time frame. Thus, the 100 Mb/s version could employ SSPAs if their lifetime is also enhanced (up to the typical 15 years).

- The 2-channel x 500 Mb/s is less massive and power consumptive than the 3-channel x 333 Mb/s implementation, but the availability is 50 W plus of TWTA power at 60 GHz is a real concern. Therefore, the 3-channel x 333 Mb/s implementation is recommended, despite its weight and power disadvantage.

Table D-4: Overall RF ISL System Characteristics

Implementation	Req'd HPA Power (W)	Reference Table No.	Mass (lb)	Mass (kg)	Power (W)
100 Mb/s	10.43	D-4	160.32	72.86	118.7
3-channel x 333 Mb/s	34.50	D-5	215.96	98.16	541.4
2-channel x 500 Mb/s	51.70	D-6	189.28	86.03	528.4

Table D-5: Mass and Power – 100 Mb/s RF Link

60 GHz ISL ITEM	Qty	Unit Mass (lbs)	Total Mass (lbs)	Qty ON	Unit Power (W)	Total Power (W)	Comments
Antenna	1	7 00	7 00				9 m, IR&D/60 GHz Prop
Beam Waveguide (Optics)	1	4 00	4 00				IR&D/60 GHz Prop
RF Front Ends (see below)	1		3 15	1		1.2	IR&D/60 GHz Prop
Autotrack S/S (see below)	1		54 00	1		27.0	IR&D/60 GHz Prop /N-Star
LNA	2	2 00	4 00	1	1 5	1.5	IR&D/60 GHz Prop.
C Sw	2	0 00	0 00				
Input 1.2 MUX	0	0 50	0 00				
2 3 Red Sw	0	0 60	0.00				
Down Conv Assy	2	5.00	10.00	1	4.0	4.0	IR&D/60 GHz Prop
12 GHz Channel Amp	4	2 50	10 00	2	1 0	2.0	IR&D/60 GHz Prop
3.2 Red Sw	0	0 60	0 00				
12 GHz Channel Filter	2	0 30	0 60				IR&D/60 GHz Prop
Up Conv. Assy	2	4 00	8.00	1	4.0	4 0	IR&D/60 GHz Prop
HPA (10.34W, 35% Effic)	2	6 00	12.00	1	29 5	29.5	IR&D/60 GHz Prop
Output 2:1 Mux	0	0 50	0.00				
ISL Master LO	2	10.00	20.00	1	25.0	25.0	IR&D/60 GHz Prop
Subtotal			132.75			94.2	
Integration Hardware			6 64			4 7	5% Assumed
Margin			20 9			19 8	15% Mass Margin
							20% Power Margin
TOTAL			**160.30**			**118.7**	
Total Mass (kg)			**72.86**				
RF Front-Ends							
Multi-Mode Trk Cplr	1	1 00	1 00				
Polarizer	1	0 30	0.30				
SCM Cplr	1	0.30	0.30				
SCM Converter/Driver	1	1 00	1.00	1	1.2	1 2	
OMJ	1	0 25	0.25				
Cplr	1	0 30	0.30				
TOTAL			3 15			1 2	
Autotrack Subsystem:							
Tracking Receiver	2	10.00	20.00	1	7.0	7.0	
Gimbal Assy	2	17.00	34.00	2	10.0	20.0	Incl Actuators, encoders,
TOTAL			54 00			27.0	and structure BWG
							given separately above

Table D-6: Mass and Power – 1 Gb/s RF Link, 3 channels @ 333 Mb/s

60 GHz ISL ITEM	Qty	Unit Mass (lbs)	Total Mass (lbs)	Qty ON	Unit Power (W)	Total Power (W)	Comments
Antenna	1	7 00	7 00				9 m, IR&D/60 GHz Prop
Beam Waveguide (Optics)	1	4 00	4 00				IR&D/60 GHz Prop.
RF Front Ends (see below)	1		3 15	1		1 2	IR&D/60 GHz Prop.
Autotrack S/S (see below)	1		54 00	1		27 0	IR&D/60 GHz Prop /N-Star
LNA	2	2.00	4.00	1	1.5	1 5	IR&D/60 GHz Prop.
C Sw	2	0 00	0 00				
Input 1 3 MUX	1	0.75	0 75				
3·4 Red. Sw	2	0 85	1.70				
Down Conv. Assy	4	5.00	20 00	3	4.0	12.0	IR&D/60 GHz Prop.
12 GHz Channel Amp	8	2.50	20 00	6	1.0	6 0	IR&D/60 GHz Prop
3 4 Red Sw	2	0 85	1 70				
12 GHz Channel Filter	6	0 30	1 80				IR&D/60 GHz Prop.
Up Conv. Assy	4	4 00	16 00	3	4.0	12 0	IR&D/60 GHz Prop
HPA (34.5W, 30% Effic)	4	6 00	24 00	3	115.0	345 0	IR&D/60 GHz Prop.
Output 3.1 Mux	1	0 75	0 75				
ISL Master LO	2	10.00	20 00	1	25.0	25 0	IR&D/60 GHz Prop.
Subtotal			178.85			429 7	
Integration Hardware			8.94			21.5	5% Assumed
Margin			28 2			90 2	15% Mass Margin
							20% Power Margin
TOTAL			**215.96**			**541.4**	
Total Mass (kg)			**98.16**				
RF Front-Ends							
Multi-Mode Trk Cplr	1	1 00	1 00				
Polarizer	1	0 30	0.30				
SCM Cplr	1	0 30	0 30				
SCM Converter/Driver	1	1 00	1.00	1	1 2	1 2	
OMJ	1	0 25	0 25				
Cplr	1	0 30	0.30				
TOTAL			3 15			1 2	
Autotrack Subsystem:							
Tracking Receiver	2	10 00	20 00	1	7 0	7 0	
Gimbal Assy	2	17 00	34 00	2	10 0	20 0	Incl Actuators, encoders,
TOTAL			54 00			27.0	and structure BWG
							given separately above

Table D-7: Mass and Power – 1 Gb/s RF Link, 2 channels @ 500 Mb/s

60 GHz ISL ITEM	Qty	Unit Mass (lbs)	Total Mass (lbs)	Qty ON	Unit Power (W)	Total Power (W)	Comments
Antenna	1	7.00	7 00				9 m, IR&D/60 GHz Prop
Beam Waveguide (Optics)	1	4.00	4 00				IR&D/60 GHz Prop
RF Front Ends (see below)	1		3.15	1		1 2	IR&D/60 GHz Prop
Autotrack S/S (see below)	1		54 00	1		27 0	IR&D/60 GHz Prop /N-Star
LNA	2	2 00	4 00	1	1 5	1 5	IR&D/60 GHz Prop
C Sw	2	0.00	0.00				
Input 1 2 MUX	1	0 50	0 50				
2:3 Red Sw	2	0 60	1.20				
Down Conv Assy	3	5.00	15 00	2	4 0	8.0	IR&D/60 GHz Prop
12 GHz Channel Amp	6	2.50	15.00	4	1 0	4 0	IR&D/60 GHz Prop
3:2 Red Sw	2	0 60	1.20				
12 GHz Channel Filter	4	0 30	1 20				IR&D/60 GHz Prop
Up Conv Assy	3	4.00	12.00	2	4.0	8.0	IR&D/60 GHz Prop.
HPA (51.7W, 30% Effic)	3	6.00	18.00	2	172 3	344 7	IR&D/60 GHz Prop
Output 2 1 Mux	1	0.50	0 50				
ISL Master LO	2	10.00	20 00	1	25 0	25 0	IR&D/60 GHz Prop
Subtotal			156.75			419 4	
Integration Hardware			7 84			21 0	5% Assumed
Margin			24 7			88 1	15% Mass Margin
							20% Power Margin
TOTAL			189.28			528.4	
Total Mass (kg)			86.03				
RF Front-Ends							
Multi-Mode Trk Cplr	1	1 00	1 00				
Polarizer	1	0.30	0.30				
SCM Cplr	1	0.30	0.30				
SCM Converter/Driver	1	1 00	1.00	1	1 2	1 2	
OMJ	1	0 25	0 25				
Cplr	1	0 30	0.30				
TOTAL			3.15			1.2	
Autotrack Subsystem:							
Tracking Receiver	2	10 00	20.00	1	7 0	7 0	
Gimbal Assy	2	17 00	34.00	2	10 0	20 0	Incl Actuators, encoders,
TOTAL			54 00			27 0	and structure BWG
							given separately above

D.4 Optical Intersatellite Link System

The potential advantages of an optical ISL system is a lower mass and power impact on the spacecraft with greater capacity (multi-Gb/s). The disadvantages include state of maturity of space qualified hardware, low power optical transmit sources, survivability of the various optical hardware (in terms of out gassing, alignment and maintenance of the alignment due to thermal variations) and the problem of acquiring and maintaining lock on the extremely narrow optical beamwidth.

MIT/Lincoln Laboratories has made significant advancements in developing high power laser diode arrays, acquisition and tracking via a nutating fiber (similar to monopulse tracking techniques at RF), and complete optical transceiver systems as part of the NASA/LeRC ACTS satellites. Although the optical package was deleted from the ACTS spacecraft, MIT/LL has continued its efforts in the optical ISL area, and the following baseline system is derived from their program.

D.4.1 Optical System Description

Figure D-3 is a block diagram of the proposed system based on 1995 technology and derived primarily from MIT/Lincoln Laboratories work. This proposed system features:

- Duplex 1 Gb/s link with polarization diversity to discriminate transmit and receive. Both 100 Mb/s and 1000 Mb/s data rates are evaluated here.
- 1 Watt laser diode array operating at 850 nm wavelength.
- Non-coherent, heterodyne, 4-FSK, injection current modulation of the laser diode array. Heterodyne detection can provide up to 10 dB better sensitivity when operating with a bright background; the cost of which is maintaining phase lock between the incoming signal and the local oscillator laser source.
- Fiber optic coupling of the energy from the telescope to the electronics. Fiber optic coupling eliminates the need to employ heavy bulk optics with their concomitant alignment and temperature sensitivities as well as launch survivability issues.
- Active tracking achieved by nutating the fiber at the telescope at audio rates, similar to a monopulse RF tracking system.
- High bandwidth steering mechanism for fine pointing control in the presence of expected spacecraft motion. A CCD array is used for initial acquisition and coarse pointing to the target spacecraft.
- Prime power and all telemetry and command interfaces to the spacecraft are provided via the spacecraft bus.

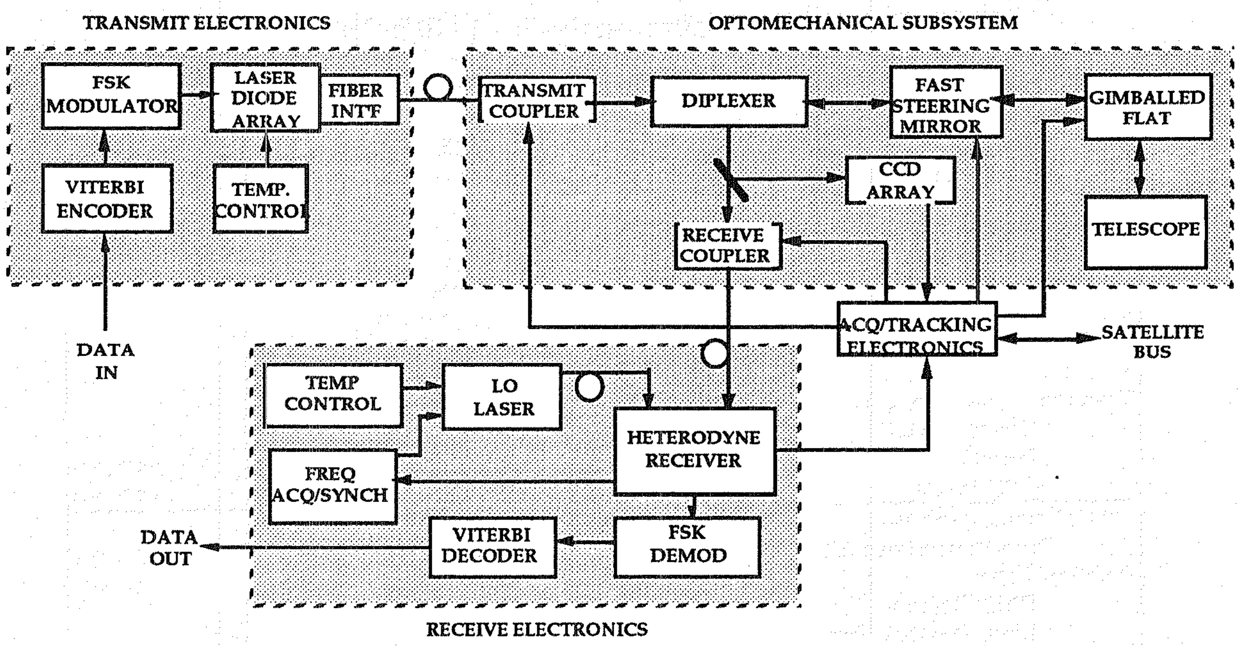

Figure D-3: Functional Diagram of Optical Intersatellite Link System

D.4.2 Optical ISL Link Closure Analysis

Table D-8 shows a sample link closure analyses for a 1,000 Mb/s link, and **Figure D-4** shows the required optical power versus optical diameter for both data rates. The principal parameters used in evaluating link closure are:

- BER of 10^{-10}, modem loss of 3 dB, system margin of 3 dB, and Viterbi FEC coding (rate 1/2, constraint length 7) gain of 5.7 dB
- Aperture and detector efficiencies of 85% and 75%, respectively
- Spectral radiance function of 2,000 W/µm cm^2, dark current of 0.1 nA, equivalent load temperature and resistance of 400 K and 2,000 Ω, respectively.

From **Figure D-4**, to maintain 1-W optical transmit power and a data rate of 1,000 Mb/s, it is apparent that both (on the transmit and receive terminals) the apertures must be at least 22 cm in diameter. To operate at 100 Mb/s, the laser power could be reduced to 0.1 W at the same aperture, or conversely, the aperture could be reduced to 13 cm while maintaining 1-W transmit power.

Table D-8: Link Closure Analysis – 1 Gb/s Optical Link

Parameter	Value (Scaler)	Value (dB)
Laser Wavelength (nm)	850	
Laser Transmit Power (W)	1 00	0 00
Max Norm Linewidth	0.24	
Max. Linewidth (MHz)	120.00	
Detection Method	Heterodyne Norcoherent	
Modulation Format	4-FSK	
Modulation Index	1 00	
Transmit Optical Path Loss		5 00
Transmit Aperture (m)	0 22	
Efficiency (%)	85	
Transmit Gain (dBi)		117 50
EIRP (dBW)		112 50
Link Distance (Mm)	42 24	
Free Space Loss (dB)		295 91
Pointing Loss		4 00
RMS Pointing Error (urad)	0 33	
Max Pointing Error (urad)	2 26	
Total Path Loss (dB)		299 91
Receive Optical Loss		5 00
Receive Aperture (m)	0 22	
Receive Field of View (urad)	500	
Efficiency (%)	85	
Receive Gain (dBi)		117 50
Receive Signal Level (W)	3 22E-08	-74 92
Receive Photoelectron Counts/sec	1 38E+11	
Local Osc Power (W)	1 00E-03	
Local Osc Photoelectron Counts/sec	4 28E+15	
LO Mixing/Alignment Loss		1 50
LO Phase Noise Loss		0 50
Detector Efficiency Loss (%)	75 00	1 25
Detected Signal Counts/sec	6 52E+10	
Signal Level (dBW)		-78 17
Average Detector Gain	1 000	
Detector Gain Variance	0.000	
Excess Noise Factor	1 000	
Receive Filter Bandwidth (um)	0 002	
Spectral Radiance Function (W/um cm^2)	2000 000	
Bac Background Power (W)	2 25E-05	
Background Noise Counts/sec	9 64E+13	
Dark Current (A)	1 01E-10	
Dark Current Noise Counts/sec	6 27E+08	
Equiv. Load Temperature (K)	400	
Equiv. Load Resistance (ohm)	2,000	
Thermal Noise Counts/sec	2 15E+14	
Available SNRo (dB-Hz)	3 04E+10	104 83
Data Rate (Mb/s)	1,000 00	90 00
Modem Loss		3 00
Available Eb/No (dB)		11 83
Interference Degradation (dB)		0 00
Coding Gain (dB)		5 70
Required BER	1 00E-10	
Required Eb/No (dB)		14 50
System Margin (dB)		**3.03**

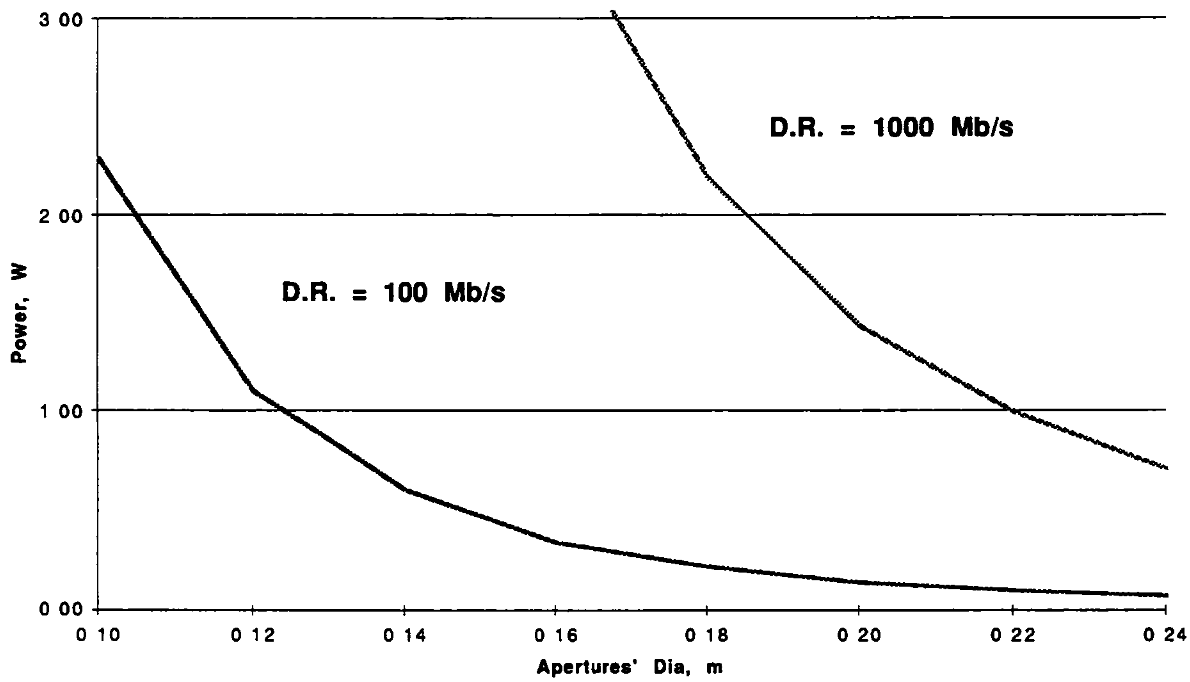

Figure D-4: Optical Power versus Aperture Size

D.4.3 Optical ISL Mass and Power Estimates

Table D-9 itemizes the mass and power of the proposed optical ISL system. Note that the same transmit power of 1 W is assumed for both cases, and the optical size is reduced (linearly) for the 100 Mb/s case down to 13 cm. A hardening mass margin of 5% and overall mass margin of 15% is assumed. A 10% power margin in also assumed in these calculations. The basis of these estimates are, as previously stated, MIT/Lincoln Laboratories work. In summary, the mass and power of the proposed optical ISL system are by **Table D-9.**

Table D-9: Mass and Power Details of Optical Link

Item	Mass (lbs.)	Power (Watts)	Mass (lbs.)	Power (Watts)	Comments
	D.R. = 1000 Mb/s		D.R. = 100 Mb/s		
Optomechanical Subsystem					
Telescope	6 6		3 9		22 m for 1 Gb/s, 13 m for 100 Mb/s
Gimballed flat/driver	4 4		2.6		Weight scaled linearly to size of aperture
Fast steering mirror/driver	2 2	2 0	1 3	2 0	Weight scaled linearly to size of aperture
Nutating coupler/driver	3 3	1 0	3 3	1.0	
Diplexer	1 1		1.1		
Transmit Electronics					
Laser diode array	0 4	8 3	0.4	8 3	1W, 12% efficiency for 1 both cases
Modulator/driver	3 3	3 0	3.3	3 0	(Aperture reduced for lower data rate)
Viterbi encoder	1 1	8 0	1 1	8 0	
Temp control	4 4	5 0	4 4	5 0	
Receive Electronics					
L O Laser/Het Rec'r	4 4	3 0	4 4	3 0	
Viterbi decoder	1 1	8 0	1.1	8 0	
Temp control	4 4	3 0	4 4	3 0	
Acq/Tracking Electronics	1 1	3 0	1.1	3 0	
Subtotal	*37 8*	*44 3*	*32 4*	*44 3*	
Hardenig Margin	1 9		1.6		5% of subtotal
Design Margin	5 7	4 4	4.9	4 4	15% of subtotal for mass
					10% of subtotal for power
Total	**45.4**	**48 8**	**38.9**	**48.8**	

Table D-10: Mass and Power Summary of Optical Link

Optical ISL Data Rate	Mass (lb)	Power (W)	Comments
1,000 Mb/s	45.4	48.8	1-W laser array, 22 cm aperture
100 Mb/s	37.3	48.8	Same laser source, smaller telescope (13 cm). Thus, power remains unchanged.

D.5 Summary and Conclusions

The use of multiple satellites may be necessary to cover the geographical area of a large country due to reasons of single satellite capacity and better elevation angle in the sky as viewed from the user locations. The availability of orbital slots, or interference issues may favor satellites being located even beyond the geographical longitude extent of the country.

In general, intersatellite links are to be avoided since they impose additional mass and power penalties on the satellite, and thus reduce the remaining payload capacity to carry uplink and downlink traffic. However, if there is significant traffic that must be transmitted to/from a neighboring satellite, there is less impact on the satellite to use an intersatellite link versus uplinks and downlinks passing through a ground installation.

The conclusion is that a developing country using conventional satellites does not need ISLs. Any interconnections between satellites can be accomplished via ground links. If advanced satellites are used, ISLs are a better way to carry traffic between satellites, providing their is sufficient traffic. Thus, the use of ISLs depends on the volume of traffic and the existence of satellites with OBP.

If ISLs are chosen as the optimal approach, an optical ISL solution will offer greater mass and power savings over an RF ISL solution. However, optical technology growth needs to occur before an optical system is deemed as feasible. An RF solution (at 60 GHz) is already flight proven on many military missions, and the technology and space qualified components currently exist.

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13. ABSTRACT (*Maximum 200 words*)

This study examines the potential use of satellites to augment the telecommunications infrastructure of developing countries with advanced satellites. The study investigated the potential market for using satellites in developing countries, the role of satellites in national information infrastructures (NII), the technical feasibility of augmenting NIIs with satellites, and a nation's financial conditions necessary for procuring satellite systems. In addition, the study examined several technical areas including on-board processing, intersatellite links, frequency of operation, multibeam and active antennas, and advanced satellite technologies. The marketing portion of this study focused on three case studies—China, Brazil, and Mexico. These cases represent countries in various stages of telecommunication infrastructure development. The study concludes by defining the needs of developing countries for satellites, and recommends steps that both industry and NASA can take to improve the competitiveness of U.S. satellite manufacturing.

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E.1 Economics of Satellite Communications

A discussion of the economics of satellite systems is given in order to allow an assessment of the impact of different technologies on user cost. The discussion is divided into three subsections: (1) Breakdown of LCC by system segment; (2) Categories of user costs; (3) Factors that influence user costs; and (4) Conclusions of Satcom Economics.

E.1.1 Breakdown of LCC by System Segment

Table E-1 gives the breakdown of life cycle cost (LCC) for a proposed government FSS satellite system. The LCC is dominated by the ground terminal costs. The satellite payload cost is approximately 7% of the total LCC. The total space segment cost (satellite, spacecraft control, and launch) is 36%. Higher payoff technologies will be those that reduce ground terminal costs, even at the expense of increased satellite costs. The relative importance of ground segment costs is expected to be similar for a variety of systems that have large numbers of ground terminals.

- Direct broadcast satellite systems such as DirecTV are each expected to have more than 3 million user terminals at a unit cost of $700 (initial) or $500 average. User terminals consist of 0.45-m (18-in) antennas, RF receive-only electronics, and digital codecs.
- Worldwide MSS systems such as Globalstar, Iridium, Odyssey, and Inmarsat P are expected to each have millions handsets at a cost of $500 (Globalstar) to $3,000 (Iridium). User handsets are likely to be dual or triple mode, operating with satellite or terrestrial wireless systems. User handsets will resemble cellular phones.
- Mesh VSAT systems such as Spaceway suggest 600,000 users for a 2-satellite system (FCC filing, 12/3/93). User terminals (0.7-m to 2-m) could cost an average of $5,000.

In all of these cases, the total price of ground terminals or handsets is several billion dollars, and is equal to or greater than the space segment costs (satellites plus launches). Ground terminal operation and maintenance is reduced by increased automation.

Table E-1: Relative Segment Costs of Satellite Communications System

System Segment	Percent of Total Cost	Space Segment	Ground Segment
Satellite (bus and payload)	18%	18%	
Launch (of satellites)	13%	13%	
Control (spacecraft and network)	10%	5%	5%
Ground terminal development and production	35%		35%
Ground terminal operation and maintenance	24%		24%
Totals	100%	36%	64%

E.1.2 Categories of User Costs

User costs can be divided into two categories:

- User equipment costs (handset or ground terminal). There may be other costs implicit in the supply of the service (e.g., the existence of electricity, terrestrial phone lines, personal computer, or television receiver). These other items could be most significant in an undeveloped region.
- System use charges (cost per minute, cost per packet, etc.) for a given type of service. Service could be priced according to data rate, number of packets sent, time of day, quality of service, etc. Each user also has a monthly charge for accounting services.

Sometimes the system provider may supply the user equipment free (e. g. cellular phones) in return for a commitment to a specified amount of system use. For simplicity, this discussion assumes that the costs are separate.

Table E-2 shows how the number of users is expected to increase as the user equipment cost decreases. The numbers are based on costs ($1995) for U. S. consumers. A number of conclusions can be made. (It is assumed that reasonable system use charges or the unavailability of alternate systems gives the incentive for user purchase.)

- Purchases of user equipment rises dramatically as user equipment costs drops below $500. The reason is that even small users with small telecommunications expenditures can justify the purchase. As seen with cellular phones and to a lessor extent with DBS receivers, a "fad" effect occurs and everyone in a particular group must have one.
- The acceptable cost of user equipment is related to the user's anticipated system use cost. User equipment costs in excess of 1 or 2 year's anticipated use charges are likely to be unacceptable, except in the case of mitigating factors such as personal safety, plant security, primary communications system backup, etc.

Table E-2: Number of User Terminals vs. User Equipment Cost and System Use

	Small Users (<$300/yr) (Number = 90X)	Medium Users ($500–$1000/yr) (Number = 9X)	Large Users (>$2,000/yr) (Number = 1X)	Relative Number of User Terminals
Low cost user equipment (<$300)	Small users will buy	Medium users will buy	Large users will buy	100X
Medium cost user equipment ($500 to $1000)	Few small users will buy	Medium users will buy	Large users will buy	20X
High cost user equipment (>$2000)	Small users will not buy	Few medium users will buy.	Large users will buy	2X

The system architect tries to minimize user costs, both user equipment costs and system use charges. This will most probably require a tradeoff between increasing user equipment size and cost in order to increase system capacity and hence lower system use charges. Alternately, the satellite EIRP could be increased, resulting in less system capacity, but reducing user ground terminal size and cost. The existence of large numbers of users pushes the result towards lowering the cost of the ground terminals at the expense of higher system use charge

The optimum solution can be calculated using minimum LCC as the performance criteria, if the user parameters are known (i. e., number of users, user data rates, system utilization, etc.).

- For the MSS systems currently under construction, the FCC filings have given estimates of numbers of users and the expected financial performance of the systems. It is interesting that financial viability is demonstrated for systems with a range of user equipment and user access charges (Globalstar, $0.60/min and $700 handset; Iridium, $3.00/min and $3,000 handset). The key design constraint for the MSS systems is the user handset omni-directional antenna. These systems are designed to accommodate millions of users world wide, and their economic success depends on the number of actual users. MSS systems have a system design limit to number of users over a given geographic region; for example, 5,000 4.8-kb/s duplex circuits over the continental United States.

- DBS (BSS) systems have the interesting feature that there is no limit to the number of users in a given geographic region, since DBS is receive only (with perhaps provision for a low capacity order wire). Thus the cost tradeoff favors lowering the cost of user equipment at the expense of increased space segment cost. For example, DirecTV has user equipment (0.45-m dishes plus receiver and codec) that currently is priced at $700. (The user also needs a conventional TV set which costs $200 or more, but most users in developed countries already a TV.) Competition from additional manufacturers is expected to reduce equipment to $500 or less. The break-even point for DirecTV is 3,000,000 users in the United States, and they are significantly ahead of schedule in reaching this figure.

- FSS systems such as Spaceway are harder to optimize the relationship between user equipment cost and system use charges since the business plan may encompass users with different traffic volumes (i. e., business with 40 hr/week communications versus home with 1 hr/week. A flexible system design could allow for a mix of ground terminal sizes for different data rate users, but still has to target a particular traffic volume user.

  A typical Atlas IIAS class GEO FSS satellite has 4 Gb/s simplex capacity. This is allows 2,600 1.5-Mb/s or 62,500 64-kb/s simultaneous one-way circuits. Depending on use patterns, 10 to 100 times as many users could share this capacity.

E.1.3 Factors that Influence User Costs

Table E-3 lists a number of factors that influence user costs. Factors are classified as system, user preference, technical, and cost factors.

- System factors are functions of the system architecture. An example is "system utilization" which depends on the network control system, user access method, and communication protocols. Use of reconfigurable antennas could allow the beams to follow-the-sun and improve utilization. Use of switching on the satellite could avoid double hop connections. Use of ATM protocols could more efficiently fill channels with packets.
- User preference factors depend on user preferences, and may have different impacts than with terrestrial systems. Examples are data rate, availability, mobility, and location.
- Technical factors relate to the technical details of the system implementation. A given of this study is to consider satellite systems. Usually technical factors are of no interest to the user except insofar as they influence user costs. (An exception can be user equipment size for mobile or transportable systems.) Examples of technical factors are antenna sizes and transmitter powers.
- Cost factors are the cost of selected pieces of the satellite system. Examples are launch costs and user equipment cost. The LCC breakdown given in **Table E-1** showed that user equipment cost was the largest segment of the LCC.

Table E-3: Factors that Influence User Costs

Factor	Influence of Factor on User Equipment Cost	Influence of Factor on System Use Charge
System capacity (for a fixed size and cost satellite)	None	Directly related
System utilization	None	Directly related
User data rate	Increases somewhat for higher data rates	Directly related
Service availability requested by user	Large increase for high rain regions	Large increase for high rain regions
Satellite antenna gain (transmit and receive)	Decreases somewhat with increased antenna gain	Decreases somewhat with increased antenna gain
Satellite transmit power	Decreases with increased satellite transmit power	Increases somewhat with higher transmit power
Ground terminal size (power and diameter)	Directly related (significant for larger sizes)	Inversely related
Mass of satellite hardware (bus and payload)	None	Directly related since capacity is directly related to mass
Cost of launch service	None	Small increase with increasing launch cost
Frequency band of operation	Varies with service	Higher for UHF, L-band, and EHF
User mobility	Lower for smaller user antennas. Higher for transportable antennas	Higher for lower gain user antennas, much higher for omni user antenna
User geographical location	Higher for high rain regions or high latitudes using GEO satellites	Higher for high latitude locations using GEO satellites
Standards and protocols for interoperability	Complexity of user equipment interfaces	Overhead traffic May improve utilization.

E.1.4 Conclusions of Satcom Economics

Satellites are favorable for developing nations in order to enable the rapid establishment of communications infrastructure without have to lay copper wire, cable, or fiber optics to a dispersed population. Thus the satellite communications scenarios might consists of the following cases:

FSS Many (100,000) small users (64 kb/s or less) interconnected with duplex circuits; or a moderate amount (3,000) of villages interconnected at medium rates (2 Mb/s).

BSS DBS (6 Mb/s TV) and/or DAR (384 kb/s audio) direct broadcast to the home or village; possibly with order wire (<1 kb/s). Millions of simultaneous users are envisioned.

MSS Regional mobile service to handhelds and village phone booths (4.8 kb/s to 64 kb/s duplex links). 100,000 simultaneous circuits shared by several million users is possible.

Within this service context, the satcom economics conclusions are as follows.

- Technology applications should be judged on a systems level, with impact on user equipment cost and system use charge.
- Ground terminal costs are the largest component of the overall system LCC. In a developing nations context, additional ground support costs may be required (e. g., electricity supply, computer, television.).
- Relatively large, high power satellites are favored in order to reduce user terminal costs.
- Technologies that increase system capacity or system utilization have a direct impact on the system use charge.
- Satellite technologies are constrained by mass, in addition to cost and performance. Mass is typically a "zero sum" game on the spacecraft, considering use of a given size launch vehicle.
- Satellites must be able to interconnect without adverse cost impacts with terrestrial wired and wireless networks. International standards and protocols should accommodate satellite as well as terrestrial communication links without prejudice to the satellite user equipment or system architecture.

E.2 System Design to Reduce User Costs

There are a number of ways to reduce user costs, ranging from incremental improvements to complete redesign of system function.

1. Reduce cost and mass of existing hardware by incorporating evolutionary technology advances. In the time period from 1996 to 2000, reductions of 50% may be feasible for the space segment, which could translate into 25% user cost savings.
2. Improve the utilization of the system (MSS and FSS systems). The typical satellite communications system design is based on meeting peak traffic requirements, and achieves a 15% overall utilization (actual average traffic versus theoretical maximum traffic). Since utilization is directly related to user cost, there is considerable potential for cost reduction (50% user cost savings if utilization is doubled). Systems with flexible architectures (e. g., reconfigurable antennas, on board switching) are more likely to achieve high utilizations.

3. Improve the efficiency of transport by minimizing overhead bits. This is unlikely to occur since the trend is to put more intelligence in the network, which results in more signaling and control bits being embedded in the communications traffic. This trend may indirectly improve utilization, but by itself slightly increases user costs.
4. Transmission capacity improvement has the greatest potential to reduce user costs for satellite communication systems. Spacecraft power is the limiting resource, and the user equipment needs a minimum W/m^2 to close the link. If the coverage area (e. g., CONUS) is fixed, the required transmit power is fixed. This is typically the case for broadcast systems with many users. However, for point-to-point communications, power can be reduced by shortening the range (GEO to MEO to LEO) or using a larger gain antenna (larger size or higher frequency). Potential cost reduction could be 90% on the satellite via a 10-times increase in capacity. The uplink from user to satellite also requires a large antenna on the satellite.
5. User equipment (ground terminal) cost can be reduced via use of small handsets with omnidirectional antennas. As noted in point (4) above, this requires high power and/or large antennas on the satellite, and/or shortened range. The new LEO MSS systems (e. g., Globalstar, Iridium, Odyssey) use L/S-bands, and are able to service a small number (600 per satellite) of 4.8 kb/s circuits by using LEO orbits.

   Small user terminals at higher frequencies could have autotracking phased arrays to improve link performance on the forward and return links. The satellite also would have a large receive antenna (high G/T) to enhance the user to satellite link.

New system architectures can be envisioned that use a very high gain steerable beam to transmit individual user traffic at high data rates, or multiple steerable beams at lower data rates. Use of Ka-band is one approach, and use of optical frequencies would be even better for making a limited number of point-to-point connections. Digital beam forming could be used to obtain multiple beams from one aperture.

E.3 Technologies that Influence User Costs

User costs have been differentiated by user equipment costs and system use charges. This subsection discusses the trends in satellite communication systems, services, and technologies. Finally the technologies that are expected to have the most influence on user costs are identified.

E.3.1 Trends in Satellite Communication Systems

A number of trends have developed through the 1970's and 1980's such as use of larger, more powerful GEO satellites. However, the 1990's have brought some paradigm shifts such as the use of proliferated, smaller satellites. Trends are listed below.

1. GEO orbit has been the preferred location for communications satellites due to the advantages of (1) continuous coverage of a large region from a single satellite and (2) the ability to use non-tracking ground terminals. Even worldwide systems such as Intelsat and Inmarsat used the GEO orbit. Only in the 1990's have non-GEO orbits (NGO's) such as LEO and MEO been proposed for worldwide systems. An exception has been the Russian use of highly elliptical orbits (Molniya orbits) for satellite communications to high latitude locations. The trend is now to choose the orbit that gives the best and lowest cost service to users.

2. Larger and more powerful satellites are being used in order to increase capacity and minimize impact on ground terminals. Larger satellites can support larger antennas and higher power transmitters. Economies of scale also come into play. However, size is constrained by capacity of launch vehicles, about 1,900 kg wet mass for a GEO satellite with the Atlas IIAS or Ariane.

3. Constellations of smaller satellites are being proposed for worldwide systems in LEO or MEO orbits. The minimum size of these satellites is constrained by antenna size requirements and traffic capacity requirements. Within limits of budgets, required traffic capacity, and available spectrum, these satellites may also push the launch vehicle size envelope.

4. Payload mass fraction (proportion of communications payload mass to total satellite mass) is rising due to advances in materials and component designs. This allows smaller satellites with the same capacity or more capacity from the same size design.

5. Satellites are having higher power capacities. Current DBS satellites have prime power capacities up to 8 kW. Planned satellites (Atlas IIAS class) have up to 15 kW capacity. The combination of high power and digital compression allows a DBS satellite to have enough capacity (100 channels) to be economically viable.

6. Antenna sizes are becoming larger within the constraints of launch vehicle envelope size. Designs have been made for large, unfurlable antennas such as on TDRS and AMSC.

7. Processors continue to have increased speed, reduced cost, and reduced size. The existence of high performance processors allows automatic control of ground terminals, automatic network control, and digital processing of communication signals e. g., coding, compression, beam forming). All of this reduces costs and allows new services.

7. Networks are using higher speeds (e. g., terrestrial networks using ATM/BISDN). Switching is being proposed on the satellite in order to enhance connectivity (Iridium MSS system under construction and Teledesic proposed FSS system).
8. User equipment has tended to become smaller and less costly (VSATs), even collapsing into handsets for low data rate MSS service (Globalstar, Iridium, Odyssey, Inmarsat P).

E.3.2 Trends in Satellite Communication Services

Communication satellites are (1) carriers of the services offered to users by terrestrial communication networks; (2) suppliers of separate "bypass" or backup communication networks; and (3) suppliers of unique services such as GPS time and position service and GOES meteorological mapping service.

In the 1970's and early 1980's, communication satellites were simply used to relay terrestrial communications via large trunking terminals. Thousands of voice circuits were multiplexed together and relayed from one office switch to another. Single television channels used entire transponders and CONUS coverage for distribution of network feeds to remote affiliate stations. There were few individual users with enough traffic to occupy an entire transponder and rich enough to afford 10-m ground terminals (e. g., Dow Jones used satellites to distribute the "Wall Street Journal" to remote printing sites).

In the 1980's, VSATs (very small aperture terminals used with a large hub) allowed private networks to be established independent of the terrestrial communications infrastructure. These spread very rapidly due to favorable economics. Even though the VSAT equipment cost $5,000 to $10,000 or more, the circuit costs (lease of transponder) were greatly reduced compared to terrestrial for a network of many nodes over a large geographical area. Examples of private networks include banks (ATM transactions) and stores for inventory control (Wallmart). The TVRO (TV receive only) video pirates emerged in this time frame, with millions of C-band dishes being sold to those people beyond the reach of terrestrial TV, and to people avoiding local cable television fees. Worldwide mobile satellite service emerged via the Inmarsat system, using GEO satellites and small steerable antennas on ships.

In the 1990's, a number of satellite unique services have emerged in addition to the previously existing services.

- GPS supplies time and position information to users via $500 handsets.
- GOES takes pictures of Earth and relays processed weather maps to users.
- Worldwide mobile satellite service (MSS) was improved via smaller "briefcase size" Inmarsat terminals that are easily transportable and set up in minutes.

- Direct broadcast satellite service (BSS) was established with DirecTV to provide television service direct to the user via $700 ground terminals. In contrast to the "pirates" of the 1980's, DirecTV (and the soon to be launched Tempo) are designed to provide TV-on-demand and pay-per-view direct to the user.
- Regional paging systems using satellites cover large areas such as CONUS or Europe.

Another trend is the use of terrestrial communications standards and protocols to allow interoperability between satellite and terrestrial systems, and to transport traffic conforming to such standards. Examples include MPEG video standards, and ATM/B-ISDN network standards. A significant problem is that these standards have not necessarily been developed to accommodate satellite transmission, and may need to be modified to allow efficient use by satellite transmission networks.

The future holds more innovations such as worldwide mobile satellite service via handheld sets that are dual mode, using the satellite system when no terrestrial cellular relay exists (Globalstar, Iridium, and Odyssey systems are under construction with goals of 1998 service). The proposed Orbcomm system would supply worldwide message service. The proposed GEO Spaceway system will supply switched, fractional T-1 service worldwide for business services such as videoconferencing and document transfer. The proposed Teledesic system would provide 16 kb/s and higher links for e-mail, Internet connection, and other interactive services. Another need is for a regional and world wide (including polar) air traffic control and routing system.

E.3.3 Trends in Satcom Technologies

Satellite communications has benefited from the general advance of terrestrial as well as aerospace technologies. Specific items relating to the communications payload and user equipment are discussed below.

1. Antenna sizes are limited by the frequency band of operation and the required coverage area and gain. Satellite manufacturers have expended large amounts of effort to minimize antenna losses, costs, and mass, with considerable success. Current efforts are focusing on active antenna designs such as direct radiating phased arrays with active elements (phase shifters, power dividers, amplifiers, LNAs) in the antenna assembly. The promises of such designs are ease of integration and test (reduces cost) and operational flexibility (allows greater system utilization which reduces cost, or allows new services).
2. Power amplifiers have advanced in capacity and efficiency, and followed the trend to higher frequencies (C-band to Ku-band to Ka-band, and even 60 GHz for intersatellite links). Efficiencies have made dramatic advances, particularly TWTAs (tubes and power conditioner units) which now exceed 60% at lower frequencies. MMIC device efficiencies have also been

improving, but are typically half that of TWTAs for the devices available. This is adversely affected the development of active transmit phased array antennas.

3. On board processing technology has been slow to develop for satellite applications due to its mass and power consumption, which detracts from payload capacity. ACTS and Milstar have make first steps. Some commercial systems (Iridium, Spaceway, Teledesic) are now proposing to use on board processing (demodulation, digital switching, remodulation) to facilitate networking.
4. Intersatellite links (ISLs) have not been used (except on some military systems) due to their impact on satellite capacity. (The mass of the ISL reduces the mass available for the other communications payload.) Some new systems (e. g., Iridium, Teledesic) propose to use ISLs to facilitate networking.
5. User equipment (ground terminals) have been reduced in size, primarily due to higher EIRP and G/T on the satellites. More capable, lower cost processors have allowed the automation of user terminal functions, thus reducing operations and maintenance costs, and hence user equipment cost.
6. Processors are being used in transmitters and receivers for source coding (compression and security) and channel coding (forward error correction). This allows cost reduction for supplying the service and the supplying of new services (pay-per-view) by eliminating signal piracy and theft of passwords.
7. Packaging and design for manufacturability is becoming important for cost reduction of multiple satellite systems such as Globalstar (48 + 8 satellites) and Iridium (66 + 11 sats.).

E.3.4 Technologies that Influence User Costs

This subsection takes the trends discussed above and lists technologies, roughly in order of impact on economics, that have the potential to influence user costs (user equipment and system use charges). There are three classification; most important, important, and other. Technologies in the "other" category are believed significant, but relative importance was not able to be assessed.

Most important technology areas

- Standards and protocols that are "satellite friendly" and allow seamless, low cost interoperability with terrestrial wired and wireless networks.
- New system architectures to meet user needs via new services. System architectures that lower user costs. Hybrid space–terrestrial communication system architectures.
- On board processing and switching with low mass and power consumption.

- Active antenna technology for spacecraft, gateways, and user equipment. Spacecraft active antennas require high efficiency MMIC HPAs, packaging to reduce cost, and integrated thermal control. Gateways for LEO systems require multiple beams (at least two beams for hand-offs) with wide field-of-view (down to 10° elevation angle). User equipment (at Ka-band) could use a small phased array to track the satellite(s) (to obtain higher gain).
- User equipment (ground terminals and handsets) that is compact, transportable, and/or unobtrusive. Lower cost user equipment is required.

Important technology areas

- Higher EIRP and G/T on the satellite to decrease size of user terminal, or to increase user data rate for a given user terminal size. Use of larger satellite antennas, higher frequency bands, and higher power amplifiers are possible technologies.
- Power generation and storage which is more efficient in terms of mass required for a given capacity
- Launch vehicles with lower cost and higher reliability.
- Network control technologies to manage a number of satellites with interconnected communications services (e. g. Spaceway with 10 or more GEO spacecraft; Globalstar with 48 LEO spacecraft interconnected through gateways; Iridium with 66 LEO spacecraft interconnected via intersatellite links; and Teledesic with even more links).

Other technology areas

- Laser links offer the highest EIRPs and hence potentially best performance. How to use laser links for satcom through the Earth's atmosphere?
- Intersatellite links with minimum mass and power impact on host satellite.
- Technical support for U. S. positions on international spectrum and orbital assignments. Tools to enable timely analysis and resolution of inter-system interference issues.
- Security of transmissions. U. S. source of encryption devices for foreign use.
- Design for manufacturing of satellites, for systems with many satellites.
- Technologies for efficient orbit and spectrum utilization.

E.4 Specific Recommendations for Technologies

This section gives specific recommendations for technologies that have significant potential to lower user costs (cost of user equipment or cost of system use). Three tables are presented for FSS, BSS, and MSS satellite communication systems, including hybrid space-ground systems in these categories.

Table E-4 lists recommended technology developments for fixed satellite service (FSS) systems. The listing is not in any prioritized order. Items not on the list are judged to be less important, or else being developed as a matter of common practice by Industry. The FSS satellite for the year 2002 is envisioned to have beginning-of-life mass of 2,000 kg and power of 12 kW, with 700 kg payload capacity. Major challenges are to have a flexible system architecture.

Table E-4: Technology Developments for FSS Systems

Technology	Rationale
Standards and protocols for interoperability with terrestrial wired and wireless	Satellite must operate with terrestrial networks.
Flexible system architecture in assignment of resources (beams, bandwidth, power)	Improve utilization of satellite capacity
High EIRP and G/T satellites	Allows higher capacity systems or lower cost ground terminals
Optical communications between satellite and earth (>500 Mb/s) (far term application)	Allows high data rate communication links to be established via satellite
Active phased array antennas with low cost and good efficiency (satellite)	Flexibility for reconfiguration on-orbit Potential cost savings in integration and test
High efficiency power devices for active array antennas	Low efficiency of active phased arrays is factor limiting their use
Thermal control of phased arrays	Critical technology for feasibility
High power, high efficiency, low mass SSPAs (L-band to Ka-band)	Multiple carrier systems require linear power amplifiers
High data rate (1 Gb/s) optical cross link	Network of GEO or MEO satellites
High data rate (1 2 Gb/s) up/down links	Relay of high data rate terrestrial links
On board switching with low mass and power consumption	Interconnections among multiple beams without double hop time delay
Autotracking Ka-band user handsets	Low cost, transportable user equipment
Position location of FSS users.	Security and control of service
Wide angle electronic scanned user terminal 1.5 Mb/s and 6 Mb/s	Fixed and transportable (SNG) applications

Table E-5 lists recommended technology developments for broadcast satellite service (BSS) systems. . The BSS satellite for the year 2002 is envisioned to have beginning-of-life mass of 2,000 kg and power of 15 kW, with 600 kg payload capacity. Major challenges are the high power capacity; the transmission of many channels at one time; the establishing of an order wire for remote users; and low cost user terminals.

Table E-5: Technology Developments for BSS Systems

Technology	Rationale
Low cost implementation of low rate order wire (<1 kb/s) with position location	Remote user can order pay for view video. Position is determined for content control
Reconfigurable beam shaping of coverage area	Flexibility in positioning and use of satellite.
Provision for local advertising to be inserted into nationwide programming (TV and radio)	Greatly increases value and appeal of service to resellers. Potentially reduces user cost.
Technologies for low cost user equipment	Lower cost of user equipment
Provision for multiple language "dubbing" of video presentations	Wider customer appeal

Table E-6 lists recommended technology developments for mobile satellite service (MSS) systems. These systems have many satellites (e. g., 12 MEO; 48 or 66 LEO) that function in a coordinated manner to provide communication services to a wide area. A challenge is the control of interference, and the ability to operate in an interference environment (e. g., MSS to MSS; LEO to MEO to GEO).

Table E-6: Technology Developments for MSS Systems

Technology	Rationale
20-m deployable spacecraft antenna for high power use at L or S bands	High EIRP required for GEO satellite to service handheld user terminals.
Moderate data rate (5 Mb/s) ISLs with low mass and low power consumption	Each MSS satellite has 4 or more ISLs (intersatellite links)
Method to synchronize transmissions from user handsets	Allow more efficient use of spectrum with synchronous multiple access schemes
Multicarrier demux and demod for CDMA and FDMA signals (low power & mass)	Allows switching on satellite with minimum mass and power penalties
Baseband switch (64x64) with 10 Mb/s capacity Minimize mass and power	Allows switching on satellite for improved connectivity
Wide angle, multiple beam scanning antenna for gateway (C-band and Ka-band).	Easier hand-offs
Wide angle electronic scan antenna for user (Ka-band MSS only)	Higher gain allows higher data rate user links Mobile antennas require constant steering.
Digital beam forming of multiple beams	Each user can have optimized beam
Standards and protocols for interconnection with terrestrial wired and wireless	Interoperability with terrestrial networks
Analysis and control of inter-system interference	Self interference limits capacity
Bandwidth efficient systems	Limited MSS bandwidth
Design for manufacturing of multiple satellites	Cost reduction Competitiveness with terrestrial wireless services

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13. ABSTRACT ***(Maximum 200 words)***
This study examines the potential use of satellites to augment the telecommunications infrastructure of developing countries with advanced satellites. The study investigated the potential market for using satellites in developing countries, the role of satellites in national information infrastructures (NII), the technical feasibility of augmenting NIIs with satellites, and a nation's financial conditions necessary for procuring satellite systems. In addition, the study examined several technical areas including on-board processing, intersatellite links, frequency of operation, multibeam and active antennas, and advanced satellite technologies. The marketing portion of this study focused on three case studies—China, Brazil, and Mexico. These cases represent countries in various stages of telecommunication infrastructure development. The study concludes by defining the needs of developing countries for satellites, and recommends steps that both industry and NASA can take to improve the competitiveness of U.S. satellite manufacturing.

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