(NASA-TM-795:2) FORECAST OF SPACE SHUTTLE FLIGHT REQUIREMENTS FOR LAUNCH OF COMMERCIAL COMMUNICATIONS SATELLITES (Future Systems, Inc., Gaithersburg, Md.) 126 p HC A07/MF A01 CSCL 22A G3/12

N78-26159

Unclas 24363

Future Systems Incorporated

4 Professional Drive, Suite 141
Gaithersburg, Maryland 20760 U.S.A.

FORECAST OF SPACE SHUTTLE FLIGHT REQUIREMENTS FOR LAUNCH OF COMMERCIAL COMMUNICATIONS SATELLITES

Prepared for the
National Aeronautics and Space Administration Headquarters

September 6, 1977

by

Future Systems Incorporated
4 Professional Drive, Suite 141
Gaithersburg, Maryland 20760 U.S.A.

(301) 840-0320

TABLE OF CONTENTS

SECTION 1
EXECUTIVE SUMMARY

The purpose of this study was to prepare a forecast of Space Shuttle flight requirements in support of the launch of commercial communications satellites. The study was prepared for NASA Headquarters by Future Systems Incorporated.

The forecast for the number of communications satellites which have to be launched is based on a 25-year traffic forecast which was prepared by Future Systems Incorporated. It is important to note that this study covers only commercial communications satellite requirements, which constitute only one part of the satellites which will be launched by the Space Shuttle.

Table 1-1

Scope of Forecast

Systems Which Are Included in the Forecast
1. Domestic and regional commercial communications satellite systems
2. Video conferencing satellite systems
3. Direct TV broadcast satellite systems
4. The INTELSAT System
5. Maritime and aeronautical communications systems
Examples of Systems Which Are Not Included in the Forecast
1. Government communications satellite systems, military operational and experimental
2. Earth sensing satellite systems, Landsat, meteorological programs
3. Scientific experiments
4. Search and rescue, navigational, tracking data relay satellites, etc.

One of the inputs to the traffic forecast is a set of demographic data for world model zones containing countries of similar political and economic characteristics. Demographic data including forecasts for future population and GNP was taken from a variety of future oriented information sources which are referenced in an Annex to this report. Highlights of the demographic data are shown in Table 1-2.

Table 1-2
Highlights of Demographic Data
(GNP in 1977 Dollars)

	North America	Asia*	World Total
1977 GNP/Capita (Dollars)	8,000	240	1,600
2002 GNP/Capita (Dollars)	13,000	570	2,700
2002 Population (Millions)	290	2,100	6,000
2002 GNP ($Billions)	3,800	1,200	16,000

*Excludes Japan and China

The traffic forecast for domestic and regional satellite communications includes the following categories:

- Telephony Traffic, including Telegraphy and other low speed data
- New Data Services
- TV Distribution
- Video Conferencing
- Direct TV Broadcast
- Aeronautical and Maritime Services

Since there is extensive background of conventional telephony transmission, the model for telephony satellite traffic is based on correlation factors which have been derived from historical data, and which are applied to forecasts of future population and GNP numbers.

The forecast for new data services is based on a market study by Satellite Business Systems (SBS) which was filed with the FCC in 1976. The SBS data traffic forecast which covers only the USA has been applied to other countries and future years by scaling in proportion to each country's GNP.

Video conferencing is another rapidly emerging new service which will be further stimulated by the depletion of the world's oil reserves and rising travel costs. Current satellite and terrestrial transmission facilities are totally inadequate for the high capacity requirement of video conferencing systems, since one video channel is equivalent to about 300 voice channels. New special purpose high capacity satellite systems will furnish this service.

A summary of the total world traffic is shown in Table 1-3.

Table 1-3

Summary of Commercial Satellite Communications Traffic

For the Year 2002

(Excluding INTELSAT)

Traffic Category	Quantity	Unit
Telephony, Telegraphy	2,700	Reference transponders*
New Data Services	800	Reference transponders
TV Transmission	145	Reference transponders
Video Conferencing	160	1,000 two-way video circuits**
Direct TV Broadcast	140	Video channels
Maritime Communications	720	Voice circuits
Aeronautical Communications	18	Ground-to-air voice channels

*A reference transponder has a bandwidth of 36 MHz, an EIRP of 33 dBW and carries 1,000 one-way voice channels.

**A two-way circuit is equal to two one-way channels.

Future communications traffic will be transmitted over advanced technology satellite transmission systems. Such systems will provide spacecraft with multiple spot beams to permit frequency re-use in all satellite communications bands including 18/30 GHz. Interconnection of spot beams will be accomplished by satellite-switched TDMA. Future high capacity satellites will include the equivalent capacity of 200 reference transponders.

Lower capacity satellites operating exclusively at C-band will continue to be used for domestic and regional communications for developing countries. Technology improvements will emphasize spacecraft antenna sidelobe control to permit re-use of the same orbital position by satellites which provide coverage to different zones. For example, the same orbital location may be used for satellites providing coverage to a South American country and to an African country. Improvements in coding techniques will permit operation at lower carrier-to-noise ratios at little loss in capacity, which will make the signals more immune to interference.

New video conferencing satellites will be designed with capacities of about 8,000 two-way video circuits in conjunction with special bandwidth compression techniques for video conferencing.

The INTELSAT System will continue to evolve along the trend set since the start of Early Bird operations in 1965. In six successive generations of satellites deployed over a period of 15 years, the capacity per satellite has risen from 240 circuits of Early Bird to 12,000 two-way telephony circuits of INTELSAT V which is to be launched by 1979 or 1980. The spacecraft weight in orbit increased from 38 kg for Early Bird to 967 kg for INTELSAT V. The system will continue to grow, primarily by phasing in higher capacity satellites.

Domestic and regional systems will grow in a similar fashion. As capacity requirements increase, systems will go from one to two and then to three operating satellites. As capacity requirements increase, new generations of spacecraft will be deployed with higher capacity. This leads to a gradual increase of spacecraft weight from the Delta class to the Atlas class of spacecraft, and finally to a spacecraft which requires the total capability of the Space Shuttle.

The first domestic system was that of Telesat which became operational in 1972. In the 5-year period since 1972, six domestic systems have been established with a total of 15 satellites in orbit.

Because of improved technology including the availability of convenient, low cost reliable launches, the introduction of domestic systems will accelerate. This trend will be reinforced by oil shortages and consequent increases in travel costs. By the year 2002 we expect that a total of 67 separate satellite communications systems will be in operation, plus the INTELSAT System and a maritime/aeronautical communications satellite system. Table 1-4 shows the distribution of these systems.

Table 1-4

Satellite Systems Distribution

Communications Satellite Systems		
Regional	10	
Domestic	28	
Total		38
Video Conferencing Systems		
Regional	7	
Domestic	5	
Total		12
TV Broadcasting Systems		
Regional	9	
Domestic	8	
Total		17
INTELSAT		1
Aeronautical/Maritime		1
Grand Total		69

The rate at which new systems are added will rise to four per year in the mid 1980's and will then taper off to one per year around the year 2000.

In developing a count of Space Shuttle flight requirements, we have excluded the launch requirements for the USSR and for Eastern Europe, since these satellites will be launched by Russia. For the remaining systems, the occasional use of expendable launch vehicles will only have a minor impact on Shuttle flight requirements. The Space Shuttle will be less expensive and more reliable as well as more readily available on short notice than expendable vehicles. Nevertheless, there will probably be some launches of communications satellites by Ariane and by Japanese launch vehicles. These will have to be relatively low capacity satellites.

China will have a large requirement for satellite launches, and the use of launch facilities will be a political decision. We have assumed that 50 percent of the Chinese satellites will be launched on the Space Shuttle.

Table 1-5 shows the summary of satellites in orbit, excluding satellites for the USSR and for Eastern European requirements.

Based on past history of replacement of satellites in orbit and on the trend of improved spacecraft reliability, we used an average of 6 years as the satellite replacement cycle. This includes replacement due to failures and system obsolescence. Excluding the USSR and East European requirements, 92 percent of all satellites will be launched by the Space Shuttle. Launch reliability will be improved as the result of the Shuttle use, but a failure rate of 9 percent for SSUS, AKM or IUS as applicable was assumed in calculating total launch requirements.

Based on the above considerations, numbers of annual spacecraft launches have been determined as shown in Table 1-6. These launch requirements have been translated into Shuttle flight requirements by assuming a 100 percent fill factor for all Shuttle flights. We find that Shuttle flight requirements rise from five per year in the early 1980's to 10 per year in the mid 80's. They level off at around 17 per year in the mid 1990's. As stated earlier, these requirements include only commercial communications satellites; they exclude government communications satellites and many other satellite categories.

Table 1-5
Total In-Orbit Requirements
For All Services
Year 2002

Service Type	Satellite Size* A	B	C
INTELSAT, communications and video conferencing			15
Maritime and aeronautical	9		
Domestic and regional communications	38	36	15
Domestic and regional video conferencing			23
Direct TV broadcast		22	
Total	47	58	53
Grand Total - All Sizes		158	

*A = Delta equivalent, B = Atlas Centaur equivalent
C = IUS equivalent

Table 1-6

Satellite Launch and Shuttle Flight Requirements

Year	Satellite Launched Size* A	B	C	Number of Shuttle Flights
1982	8	4	1	5.00
83	10	7	0	6.00
84	9	8	2	8.25
85	11	7	1	7.25
86	10	9	3	10.00
87	11	8	5	11.75
88	11	9	3	10.25
89	11	9	5	12.25
1990	10	10	6	13.50
91	11	10	6	13.75
92	10	11	7	15.00
93	10	9	6	13.00
94	9	11	9	16.75
95	8	11	9	16.50
96	9	11	9	16.75
97	8	9	9	15.50
98	5	10	11	17.25
99	8	8	9	15.00
2000	6	9	11	17.00
2001	8	8	11	17.00
2002	7	8	12	17.75
Total	190	186	135	275.50
Average Per Year	9.05	8.86	6.43	13.12

*A = Delta equivalent, B = Atlas Centaur equivalent
C = IUS equivalent

SECTION 2
INTRODUCTION

This forecast of Space Shuttle Flight Requirements for Commercial Communications Satellites has been prepared for NASA Headquarters by Future Systems Incorporated (FSI) under Order No. W14.367. The Order date was August 9, 1977, and the required completion date is September 7, 1977.

The forecast of the number of Space Shuttle flights which will probably be required for the launch of commercial communications satellites is based on a 25-year traffic forecast for domestic and regional satellite communications, which had previously been prepared as an FSI funded project. The results of this forecast are also documented in this study report.

It is important to note that commercial communications satellites constitute only one part of the communications satellites which will be launched by the Space Shuttle. The study does include international, regional and domestic communications satellite requirements, fixed and mobile applications, as well as special purpose satellite systems such as direct TV broadcast systems and video conferencing systems. It does not include, however, the important categories of government communications satellite systems, both military and experimental, earth sensing satellite systems such as LANDSAT and meteorological satellite systems, scientific experiments, search and rescue satellites, navigational satellites, tracking data relay satellities, etc.

The present forecast is therefore addressed only to a portion of the total requirements for Space Shuttle flights in support of satellite launches. The methodology, which has been developed during the course of this study, is, however, equally applicable to the generation of similar forecasts for Space Shuttle flight requirements in support of the launch of the other satellite categories.

Initial plans were to develop a computer program for delivery to NASA which would compute probable Shuttle flight requirements as a function of time, using the methodology described in Section 3 of this report. Such a program can also be extended to include all types of satellite missions instead of only commercial communications satellites. The advantage of such a program would be the ability of entering new information as it becomes available, and thus maintaining an accurate estimate of Shuttle flight requirements in light of the latest developments.

For example, in 1976 the government of Brazil announced firm plans to construct its domestic satellite system starting in 1977. Representatives of Telebras/Embratel held exploratory talks with NASA concerning the procurement of launch vehicles in support of the program. In May of 1977, however, it was announced that the Brazilian communications satellite program had been indefinitely deferred. On the other hand, the INSAT Program, which was in the planning stages for a long time and whose implementation was in doubt until recently, was approved by the Indian Government in June of 1977. The availability of a computer program would facilitate convenient and quick updating of the total Shuttle flight estimates whenever new program decisions are announced. However, because of the short time that was available for the preparation of this report, it was not possible to include the computer program with this study.

SECTION 3
METHODOLOGY

This section provides a brief description of the methodology which was used in deriving forecasts of Space Shuttle flight requirements.

3.1 Traffic Forecasts

The first step is the determination of forecasts of communications traffic that will likely be handled by commercial communications satellites. To develop such forecasts we look into the past to see what we can learn from historic developments in the telecommunications area in order that we can extrapolate into the future. We also look at other predictions for future developments in order to evaluate how the extrapolations of past trends will be modified by expected developments in other areas.

Many factors contribute to the shaping of commercial satellite communications systems of the future, including:

Requirements
Technology
Economics
Regulation

New technology will both stimulate requirements as it permits the introduction of new services and make it possible to satisfy these requirements economically. Shortage of fossil fuels will increase travel costs temporarily which will stimulate the partial substitution of communications for travel, thus increasing communications requirements. Improving economic conditions will increase the demand for communications services. Policy makers will plan ahead and make those regulatory changes which will be required to meet increased satellite communications requirements economically with new technology.

For a 25-year traffic forecast for telephony requirements we considered it appropriate to review 25 years of the history of telecommunications. From this review we developed certain correlation factors which were then applied to predict future traffic.

One very useful correlation factor was found to be the measure of GNP per telephone. It was found that this factor generally converges to similar numbers, as each country progresses in its economic and technological development. Another important factor is the ratio of long distance telephone calls per telephone. Finally, we used the ratio of long distance calls per unit GNP as another correlation factor.

Using these factors for predictions of future traffic requires assumptions regarding certain demographic data of the future. Specifically, we require estimates of future GNP and population in the countries or world regions under study. Fortunately, a suitable range of these numbers is well documented and generally agreed upon by a variety of sources. Literature references to these forecasts are given in Annex A to this report. Using these demographic forecasts and the correlation factors which were developed from historic telecommunications statistics, we predicted future long distance telephone traffic. Number of calls were translated into a required number of trunks by the use of information on the average call duration, number of channels per trunk and a desired grade of service.

Next it was necessary to determine the percentage of the total traffic that would likely be transmitted via satellites. This is a matter of economics and depends also on the extent of development of the terrestrial network. For example, in the USA the economic break-even point between terrestrial and satellite transmission is about 500 miles. This means that communications of over 500 miles are cheaper via satellite. Communications between two points which are less than 500 miles apart are generally cheaper via terrestrial facilities. This is a typical figure which varies with a variety of assumptions. In developing countries, especially in the tropics, the terrestrial transmission facilities are much less developed, and where they exist they are more costly. In such countries the break-even distance is smaller, and a larger percentage of the traffic can be expected to be carried via satellites. Based on these considerations the total telephony traffic estimates were developed.

Extrapolation of historic data leads us only to a traffic estimate for the types of traffic which has been carried in the past. New technology and other changing conditions lead to the introduction of new services for which traffic estimates must be based on market forecasts and other considerations. One major category of new services is the type of data communications traffic which is the target of Satellite Business Systems (SBS). Our forecast for this type of service is based on the SBS market survey, which was described in a 1976 FCC filing. A variety of other forecasts and considerations led to the generation of a traffic model for other new services.

3.2 Technology Development

If we translate the total communications traffic requirements for the year 1990 or 2000 into satellite requirements based on present technology satellites, we find that the equatorial arc would quickly become saturated. This would be a very expensive solution and would inhibit the growth of satellite traffic. In order to make a realistic forecast of satellite requirements, it is necessary to predict technology advances which will be introduced during the period of time under study. These technology advances will permit the construction of higher capacity satellites than are existing or are being planned today.

Technology advances can also improve the satellite life. Longer satellite life means fewer failures and therefore fewer replacement launches.

For these reasons a technology forecast has been made to form an input to the construction of satellite systems models from which the number of launch requirements can be determined.

3.3 The INTELSAT System

The INTELSAT System has carried traffic since 1965, a 12-year period. INTELSAT has also made estimates of future traffic which would be carried by the system. We have not attempted to duplicate these estimates, but rather we have extrapolated the available INTELSAT data to develop a model for future launch requirements.

INTELSAT has also entered the business of leasing transponders for domestic communications. If INTELSAT pursues this business opportunity vigorously, domestic traffic may become a large portion of its total traffic. However, since INTELSAT has not yet announced its policy in this respect, we have not included new domestic traffic in the INTELSAT systems model.

3.4 Domestic and Regional Systems

The traffic models which were generated in Section 5 show the satellite communications traffic that can be expected if satellite systems are constructed to satisfy the particular traffic. Section 8 provides a review of the general conditions in each region under study and identifies specific systems and their likely date of introduction and subsequent development. Thus, satellite systems models are generated from which launch requirements can be derived.

3.5 Expendable Launch Vehicles

In Section 9 a discussion is given as to which systems are likely to use expendable launch vehicles instead of the Space Shuttle.

3.6 Space Shuttle Flight Requirements

Based on the work in the preceeding sections, in Section 10 we have generated requirements for Space Shuttle flights in support of the launch of commercial communications satellites on a year by year basis. The launches are those required for the initial introduction of each system, those for replacement satellites for in-orbit failures and finally for the replacement of obsolete satellites by a new generation.

SECTION 4
DEMOGRAPHIC DATA

Certain demographic data is needed for the forecasting of communications requirements. These are, namely, GNP and population for different world regions as a function of time.

In global forecasting it is standard practice to segregate countries into world model regions of similar political and economic characteristics. For the FSI model we have segregated the world into two major groups as follows:

Group I	North America Western Europe USSR Eastern Europe Japan
Group II	Latin America Middle East China Asia Africa
Other Countries	Those not covered in Groups I and II

In this model North Africa has been included in the Middle East Group. Japan and China have been excluded from the Asia Group, and the Africa Group excludes South and North Africa.

The Edison Electric Institute prepared a 25-year forecast for the electric power companies. Similarly, the FAA is working on a 25-year forecast for the aviation environment. (See Annex A for both references.) In the FSI traffic model we have also selected a 25-year period as the range for our forecast. The basic demographic data that was used in this forecast is listed in Table 4-1.

Table 4-1

Demographic Data

Region	1977 GNP/Cap. (Dollars)	GNP Growth Rate (%/Y)	2002 GNP/Cap. (Dollars)	2002 Population (Mill.)	2002 GNP ($ Bill.)
Group I					
North America	8,000	2.0	13,000	290	3,800
Western Europe	6,000	2.0	9,800	400	3,900
USSR	3,300	2.3	5,800	340	1,980
Eastern Europe	3,000	2.3	5,300	125	660
Japan	4,800	2.5	9,000	130	1,150
Total			9,000	1,285	11,500
Group II					
Latin America	800	3.5	1,900	450	850
Middle East*	1,100	3.0	2,300	300	690
China	300	5.0	1,000	1,200	1,210
Asia**	240	3.5	570	2,100	1,200
Africa***	210	3.5	500	500	250
Total			900	4,550	4,200
Other	1,500	2.5	2,800	110	310
World Total			2,700	6,000	16,000

*Includes North Africa
**Excludes Japan and China
***Excludes South Africa and North Africa

The starting point is the 1977 GNP per capita. One will find that these numbers are higher than those usually shown in financial statistics. This is due to the fact that they are expressed in 1977 dollars, while many other statistics use dollars of earlier years as a reference.

The GNP growth rates from 1977 to 2002 and the population by the year 2002 are based on a consolidation of estimates and forecasts given in various references listed in Annex A. Current and historic data was also derived from various references in Annex A. It should be noted that all figures are rounded to avoid giving the impression of a higher degree of precision than is warranted. For this reason the totals in each column do not add up precisely.

Some of the highlights of the forecast of demographic data are summarized in Table 4-2. (Figures are rounded.)

Table 4-2
Highlights of Demographic Data
Year 2002

Population	Developed countries	20% of world population
	Developing countries	80% of world population
GNP	Developed countries	75% of world total
	Developing countries	25% of world total
GNP Per Capita	Developed countries	$9,000
	Developing countries	$ 900

Thus, even 25 years from now the disparity between the average developing countries and developed countries is still a factor of 1 to 10 in GNP per capita. However, if we compare North America with Asia and Africa, the differential is even larger, as shown in Table 4-3.

Table 4-3
North America Compared With Asia and Africa
Year 2002

	North America	Asia and Africa (average)	Ratio
1977 GNP Per Capita	8,000	230	35
2002 GNP Per Capita (in 1977 Dollars)	13,000	550	25

SECTION 5
TRAFFIC FORECAST

FSI has developed a 25-year traffic forecast for domestic and regional satellite communications. This forecast includes conventional telephony traffic, new data services, TV distribution, video conferencing and direct TV broadcast traffic. For the purpose of estimating Space Shuttle flight requirements in support of the launch of commercial communications satellites, we have also included an estimate of aeronautical and maritime service requirements. Launch requirements for the INTELSAT System are derived separately, as described in Section 7.

5.1 Telephony Traffic

Since there is extensive background of conventional telephone telecommunications, the model for telephony satellite traffic is based on correlation factors which have been derived from historical data, and which are applied to forecasts of future population and GNP numbers.

Table 5-1 summarizes the derivation of transponder requirements for a simplified world model. Transponders are expressed in terms of typical domestic C-band transponders with an EIRP of about 33 dBW and a bandwidth of about 36 MHz and being able to carry about 1,000 multiple access one-way telephone channels as a weighted average for domestic applications. This measure was chosen merely as a convenient reference with which everyone is familiar. Actual domestic satellite systems of the future will use a variety of other arrangements.

The following correlation factors were found to be useful in deriving the traffic model:

GNP Per Telephone
Long Distance Calls Per Telephone
Long Distance Calls Per $1,000 Dollars GNP

These factors vary from country to country and with time, but they follow a general trend. Detailed information on these factors is shown in Annex B of this report, where curves are plotted for 17 representative countries.

In estimating domestic traffic requirements, the so-called regional system requirements have been included. For example, the European traffic that will be carried on ESA's ECS satellites which will follow OTS is considered European domestic traffic. Likewise, the traffic on the Arab regional system, on the ANDEAN and the ASEAN Systems, etc., is lumped in the domestic category. This is not to say that such traffic could not be carried on the INTELSAT System. It may well be included in part in the INTELSAT System through transponder lease or as regular traffic, if INTELSAT implements a distance-dependent rate.

This inclusion permits us to construct a model in which the size of a country is not important. A large country like the USA has very little international traffic, when such traffic is expressed as a percentage of the total traffic. Smaller countries, such as those of Europe, have a much larger percentage of international traffic since by nature of their size they found it beneficial to establish close relations with their neighbors. Similar relationships will grow in developing countries. Thus, large countries have their proper domestic satellite traffic while small countries require regional systems to benefit from the same economies, and the traffic of these systems is included in the model presented in this report.

Figure 5-1 is a summary of the GNP per telephone correlation factors. North America has the most advanced telephone network, which is expected to bottom out at $10,000 GNP per telephone. Japan is about to overtake Western Europe, while Russia and Eastern Europe are lagging behind. The Middle East is expanding its telephone network rapidly, and Asia and Africa are making rapid relative progress.

Figure 5-2 shows the number of long distance calls per $1,000 GNP. The real cost of long distance calls is dropping rapidly, and the number of calls per $1,000 GNP is therefore increasing. By the year 2002 most countries will have between 10 and 15 long distance calls per $1,000 GNP.

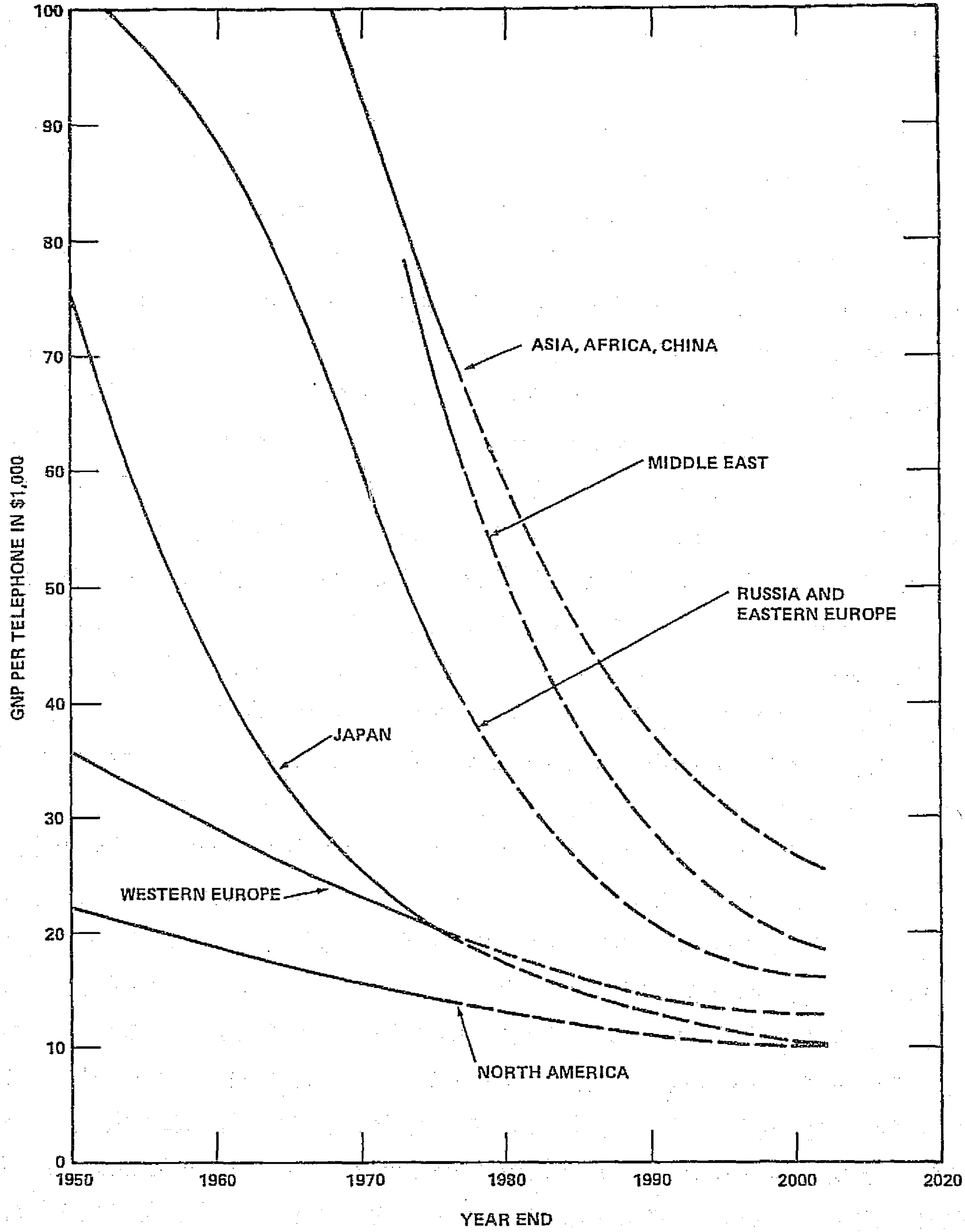


FIGURE 5—1
GNP PER TELEPHONE

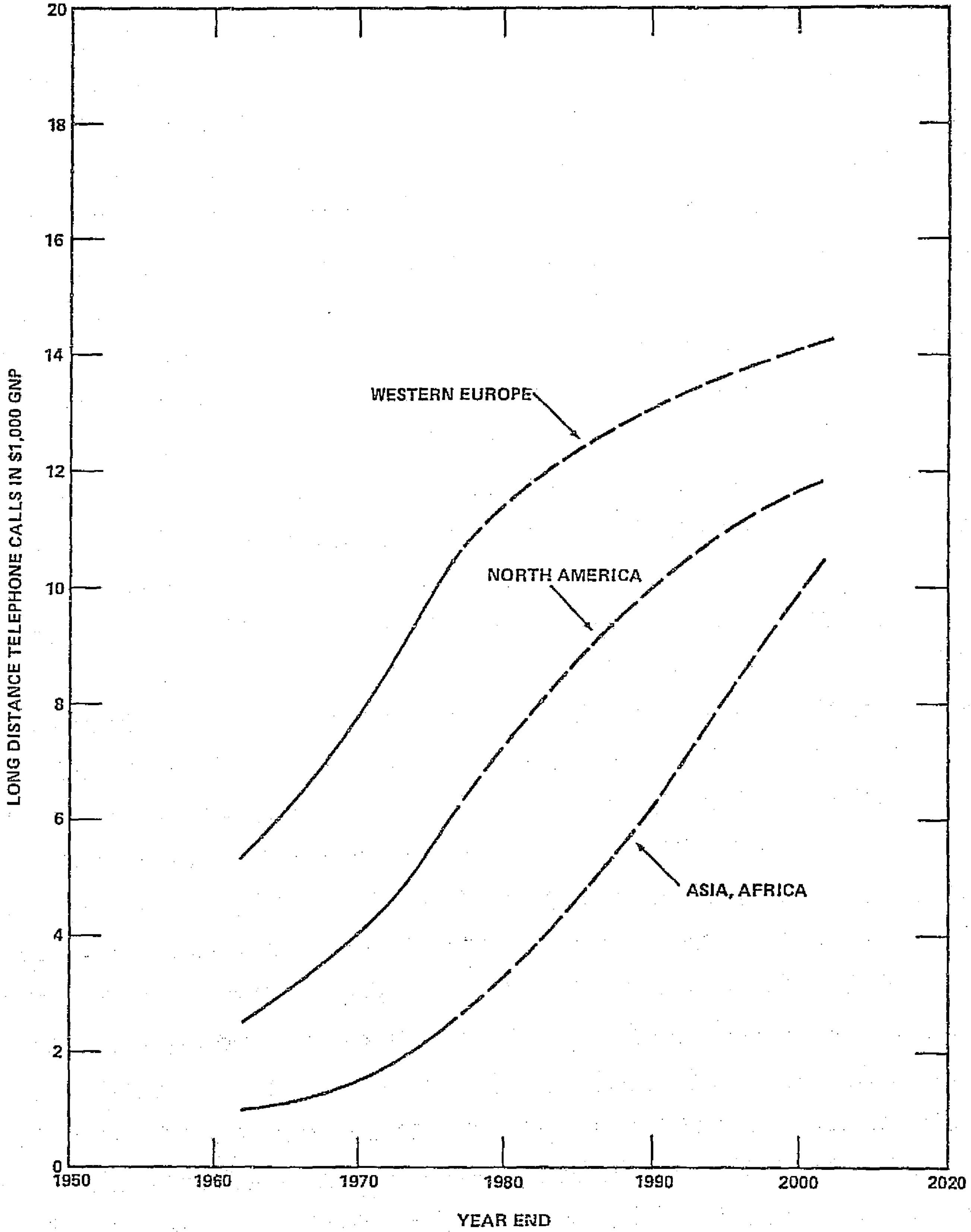


FIGURE 5–2
LONG DISTANCE TELEPHONE CALLS PER $1,000 GNP

The extrapolated figures of GNP per telephone for the year 2002 are taken from Figure 5-1 and listed in Table 5-1. Although these figures are not used directly in the generation of the traffic model, they are used as a check on the reasonableness of the model.

The present telephone density in the USA is about 70 telephones per 100 population. In some cities the density is already above 100. In our model the total number of telephones per 100 population for the developed countries in the year 2002 is 75, slightly higher than in the USA today. The total world average by the year 2002 is 20 telephones per 100 population, compared to about 10 today. This implies an annual growth of 4.7 percent for the world's telephones, while the world population will grow at an average rate of 1.6 percent per year.

The extrapolated values of long distance calls per $1,000 GNP from Figure 5-2 are also listed in Table 5-1. These figures, together with the GNP forecast, are then converted into transponder requirements.

Table 5-2 provides another cross-check on the correlation factors. It is found that the long distance calls per telephone range from 120 to 250 per year. This is quite reasonable, since the number of long distance calls per telephone for Sweden and Germany have already exceeded 200 per year in 1975.

The next step in generating transponder requirements as shown in Table 5-1 consists of translating long distance calls into satellite call minutes. An average call duration of 9 minutes was used for this calculation, which was based on a summary of international statistics. Furthermore, it was assumed that from 5 to 15 percent of all long distance traffic by the year 2002 would be suitable for transmission via satellite. This percentage varies with the region and is dependent on the extent of the terrestrial transmission facilities presently existing.

At present the break-even distance for satellite and terrestrial communications in the USA is about 500 miles. In the USA at present, only about 5 percent of the total long distance traffic would be suitable for transmission via satellite. This follows from an FCC filing by AT&T of the distribution of route miles of leased lines. In the future, however, long distance transmission costs will continue to drop, and there will be a shift of long distance traffic to longer distances.

Already today, the packet communications network of Telenet offers data communications with distance independent rates. A Washington to Los Angeles connection costs no more than a Washington to Baltimore connection. A similar trend will be experienced with telephony transmissions in the future. This will increase the portion of traffic which can best be carried by satellites.

In developing countries the expansion of the terrestrial network is more expensive than in Europe and the USA, because the repeater stations for the microwave links would be inaccessible and would be difficult to maintain. For these reasons, developing countries will opt to expand the transmission facilities with communications satellites to a greater extent than the already developed countries. As the result of these considerations we have selected the following percentages of total long distance traffic as being suitable for satellite transmission:

Western Europe	5%	Western Europe has a very well developed terrestrial network and the PTT's are in part opposed to domestic and regional satellite communications. Germany, for example, is said to be opposed to the satellite system because it would lose transit revenues for traffic that would otherwise be transmitted through the country.
Japan	6%	Japan also has a very well developed terrestrial system but has nevertheless already started to implement domestic satellite communications. One of the alleged reasons for this system is the objective of technology advancement.
North America	8%	In spite of the well developed terrestrial system, there are already three domestic satellite systems in operation (not counting American Satellite Corporation, which leases transponders from Western Union), and a fourth system (SBS) will probably start construction in the near future.
Developing Countries	15%	For all developing countries we have assumed that 15% of the long distance traffic will be suitable for satellite communications.

As the final step, satellite call minutes are translated into transponder requirements as follows:

a. It was assumed that the total traffic is distributed over the equivalent of 2,400 busy hours per year. On this basis the Erlang load is calculated as:

   1 billion call minutes/2,400 hours x 60 = 6,944 Erlangs

b. The trunk distribution and grade of service are such that the required ratio of Erlangs to circuits is 0.8. Therefore, 1 billion call minutes per year requires 8,680 circuits.

c. One reference transponder handles 1,000 one-way channels or 500 two-way circuits. Therefore, 1 billion call minutes per year requires 17.4 transponders.

Table 5-1

Transponder Requirements Based on Extrapolation of Present Services

GNP in 1977 U.S. Dollars

Region	GNP/ Tele. ($k)	Tele- phones (Mill.)	Tele- phones /100 Pop.	Calls Per $1000 GNP	Billion LD Calls Per Year	Percent Satellite Traffic	Billion Satellite Call Min. Per Year	Trans- ponder Req.
Group I								
North America	10	380	130	12	45	8	32	560
Western Europe	13	300	75	14	55	5	25	435
USSR	16	125	40	12	24	10	22	380
Eastern Europe	16	40	30	12	8	7	5	85
Japan	10	115	90	14	16	6	9	155
Total		960	75	13	150		93	1,600
Group II								
Latin America	12	70	15	12	10	15	14	240
Middle East*	18	40	13	12	8	15	11	190
China	15	50	4	10	12	15	16	280
Asia**	25	50	2	10	12	15	16	280
Africa***	25	10	2	10	3	15	4	70
Total		220	5		45	15	61	1,060
Other	15	20	20	12	4	10	4	70
World Total	13	1,200	20	12	200		158	2,700

*Includes North Africa
**Excludes Japan and China
***Excludes South Africa and North Africa

Table 5-2

Summary of Correlation Factors for Year 2002

(Figures are rounded)

Region	GNP Per Telephone $1,000	LD Calls Per Telephone Per Year	LD Calls Per $1,000 GNP
Group I			
North America	10	120	12
Western Europe	13	180	14
USSR	16	190	12
Eastern Europe	16	190	12
Japan	10	140	14
Total			13
Group II			
Latin America	12	140	12
Middle East*	18	210	12
China	25	250	10
Asia**	25	250	10
Africa***	25	250	10
Other	15	180	12
World Total	13	160	12

*Includes North Africa
**Excludes Japan and China
***Excludes South Africa and North Africa

As a result we find that the world total requirement for the year 2002 is 2,700 transponders.

For those who have previously not looked at long range forecasts in telecommunications, this result may appear staggering. Let us check whether it is reasonable.

The only domestic satellite communications system which has reached relative maturity is the Telesat System. Canada has presently a population of about 23 million people, and there are 14 million telephones in the country. Canada also has two Anik A satellites in operation, each with 12 transponders. Anik B with increased capacity is being built by RCA Astro-Electronics, and Anik C was just contracted to Hughes Aircraft Company.

Assuming that the Telesat System at present uses only 12 transponders for telephony transmission, we find a situation where 23 million people use 12 transponders, or 2 million people per transponder. If the world average would use satellite communications as extensively by 2002 as Canada does today, the world's 6 billion inhabitants would require 3,000 transponders. This compares reasonably well with the 2,700 transponders of our model.

It is important to remember that the reference transponder equivalent to 1,000 one-way channels was used only as a convenient measure for traffic; the actual implementation of domestic systems by the year 2002 will rely on more advanced high capacity satellites, as described in Section 6.

5.2 New Data Services

Advances in computer technology and application have introduced new data transmission services which will be in extensive use by the year 2002. These services will require space segment capacity in addition to that which has been extrapolated from the historical use of the telephone system.

In an FCC filing of April 1976, SBS shows that 415 major U.S. corporations create a market for 90,000 voice circuits and data requirements equivalent to 100,000 circuits for transmission via satellite by 1985. At 1,000 one-way channels, this corresponds to 200 equivalent C-band transponders. SBS states that the market is further increased by requirements from smaller corporations and from government agencies. To be conservative, we have cut this forecast in half and applied it to each country or region in proportion with the GNP.

In our model the 1985 GNP of the USA expressed in 1977 dollars is 2,020 billion dollars. Therefore we allocate one transponder per 20 billion GNP.

The resulting transponder requirements are shown in Table 5-3. The world total for 2002 is 800 transponders.

5.3 TV Distribution

Satellites are ideal for the transmission of network TV to affiliated stations throughout the country. Such services are already carried, and more extensive use will be made in the future. Considering the various networks and the impact of the time zones in the USA, as well as requirements for CATV program distribution, Home Box Office, etc., it is estimated that the U.S. requirement in 2002 will be 60 TV channels which can be carried on 30 transponders. In the absence of another measure, we have tied this requirement again to GNP, which results in one transponder for each 110 billion dollars GNP.

However, for real widespread use the capacity of the present terrestrial transmission system is wholly inadequate. Likewise, the capacity of any of the current or planned communications satellite programs is insufficient. For example, a TDRSS type satellite would provide capacity for only 56 two-way video circuits of good transmission quality. The reason for this low capacity is the fact that one TV channel requires the equivalent capacity of about 300 voice channels. This ratio varies, depending on the coding and transmission quality used.

Table 5-3

Total Transponder Requirements for Telephony, Data and TV Distribution

(Equivalent C-band Transponders, 33 dBW, 35 MHz, 1,000 Channels)

(Figures are rounded)

Region	Telephony (from Table 5-1)	New Data Services	TV Transmission	Total
Group I				
North America	560	190	35	765
Western Europe	435	195	35	665
USSR	380	100	20	500
Eastern Europe	85	33	5	125
Japan	155	60	10	225
Total	1,600	575	105	2,200
Group II				
Latin America	240	43	8	290
Middle East*	190	35	6	230
China	280	61	11	350
Asia**	280	60	11	350
Africa***	70	13	2	85
Total	1,060	210	38	1,300
Other	70	16	3	90
World Total	2,700	800	145	3,600

*Includes North Africa
**Excludes Japan and China
***Excludes South Africa and North Africa

In order to permit the widespread use of video conferencing, special high capacity satellites will have to be developed. We believe that NASA should develop such a high capacity video conferencing system and we have proposed that NASA conduct preliminary studies towards the implementation of this system. The description of this system is reproduced in Annex C of this report. The proposed satellite design, in conjunction with special picture coding to be developed for video conferencing, will have a capacity of 8,000 voice circuits. We expect that three such satellites will be carrying operational traffic for the USA in the year 2002. Similar satellites will be used in Europe, and other smaller capacity video conferencing satellites will be used by other countries and also for international video conferencing. The latter feature will be provided by INTELSAT.

In terms of developing a traffic estimate, we have assumed that the world total for TV distribution is 145 transponders.

Telephony, TV and data transmission will use the same types of transponders. The total requirements for these three services can therefore be summed, as shown in Table 5-3, to obtain total transponder requirements. The world total is 3,600 transponders for the year 2002.

5.4 Video Conferencing

As the world's oil reserves near depletion, oil prices will continue to increase and we will face sharply increased air travel costs. Eventually there will be developments of non-petroleum energy sources suitable for air transportation, but in its 25-year forecast the FAA states that it is not likely that such systems will be available during the current century. For this reason we expect that there will be a growing desire and necessity to replace some travel by telecommunications. The result will be increased use of video conferencing.

Several organizations including NASA are already operating video conferencing facilities. ERDA has a video link between its Germantown and Washington offices, and in April 1977 AT&T started to offer video conferencing services between Washington, San Francisco, Chicago and New York. AT&T plans to expand this service to eight more cities in January 1978. In spite of the relative inconvenience (conferences have to be booked a day in advance and both parties have to go to the video conference room, which in the case of Washington is in the C&P building at 17th and H Streets) and of the high cost (almost $400 per hour for a Washington-San Francisco conference), the use of the system is growing rapidly.

Video conferencing would replace about 15 percent of the air travel. In addition, video conferencing will be used as a new and improved service for applications for which no travel would have taken place in the absence of the video conferencing system.

Based on calculations shown in Annex C, a capacity of 16,000 circuits is required to replace 20 percent of the U.S. air travel for 1974. The FAA study assumes that air travel will increase by up to a factor of 4 between 1974 and the year 2000. Based on the conservative assumption of doubling the air travel, a 15 percent replacement requires a capacity of 24,000 circuits, or three operating satellites. A fourth operating satellite is assumed for service applications, which are not substitutions for travel. Total video conferencing capacity is then 32,000 circuits.

To find a measure for estimating the requirements for other countries, we have again tied this service to GNP. The 2002 GNP for the USA is about 3,400 billion dollars (in 1977 dollars). This results in about one video circuit per 100 million dollars GNP. The resulting video conferencing traffic model is shown in Table 5-4.

Table 5-4

Video Conferencing Traffic Model

Region	2002 GNP ($ Bill.)	Number of Video Conferencing Circuits (1,000's)	Number of Operating Video Conferencing Satellites
Group I			
North America	3,800	38	6
Western Europe	3,900	39	5
USSR	1,980	20	3
Eastern Europe	660	7	1
Japan	1,150	12	2
Total	11,500	115	17
Group II			
Latin America	850	9	2
Middle East*	690	7	2
China	1,210	12	2
Asia**	1,200	12	2
Africa***	250	3	1
Total	4,200	42	9
Other	310	3	1
World Total	16,000	160	27

*Includes North Africa
**Excludes Japan and China
***Excludes SouthAfrica and North Africa

5.5 Direct TV Broadcast

Direct TV broadcast will be of great interest for educational and other purposes to many countries. We expect that by 2002 it will be in use by many of the countries which we now call developing. (By 2002 many of those countries will be developed by today's standards.) However, plans for direct TV broadcast are also being made by developed countries. Examples are the Canadian TV broadcast satellite and NORDSAT, a direct TV broadcast satellite for the Scandinavian countries. The latter is foreseen to provide about 20 TV channels already in the mid 1980's.

The recently approved INSAT System includes a direct TV broadcast facility, and Japan has a system under construction. There is some uncertainty about the speed of implementation, since the East Block countries object to spill-over of the antenna patterns into their territories.

An estimate of direct TV broadcast channel requirements is shown in Table 5-5. The world total for the year 2002 is 140 direct TV broadcast channels.

5.6 Aeronautical and Maritime Services

One commercial maritime system, the MARISAT System, is now in operation. The European MAROTS System is planned for implementation, and there is an international conference aimed at the establishment of INMARSAT, an international organization for providing maritime satellite service, similar to INTELSAT for fixed services. (The charter of INTELSAT permits it to provide maritime communications services, and INTELSAT has from time to time studied the possibility of providing such services.)

AEROSAT was intended to provide experimental aeronautical satellite communications service. It was intended as a joint venture by COMSAT General and ESA, with some Canadian participation. In early 1977 this program was indefinitely deferred due to lack of funding.

Table 5-5

Direct TV Broadcast Services

Region	2002 GNP/Cap. (Dollars)	2002 Population (Mill.)	2002 GNP ($ Bill.)	Direct TV Broadcast (Channels)
Group I				
North America	13,000	290	3,800	10
Western Europe	9,800	400	3,900	30
USSR	5,800	340	1,980	20
Eastern Europe	5,300	125	660	5
Japan	9,000	130	1,150	5
Total		1,285	11,500	70
Group II				
Latin America	1,900	450	850	20
Middle East*	2,300	300	690	10
China	1,000	1,200	1,210	5
Asia**	570	2,100	1,200	15
Africa***	500	500	250	15
Total		4,550	4,200	65
Other	2,800	110	310	5
World Total	2,700	6,000	16,000	140

*Includes North Africa
**Excludes Japan and China
***Excludes South Africa and North Africa

In May 1977 Mr. Pritchard of Satellite Systems Engineering and Mr. Stamminger of Future Systems Incorporated completed a study of the technical and economic aspects of combining maritime and aeronautical communications satellite services for the years 1985 to 2000. This study was prepared for the OTP and includes traffic estimates for the time frame through the year 2000. The same traffic estimates will be used for the present NASA study on Shuttle launch requirements.

As a starting point for the generation of the maritime traffic requirements model, the traffic estimates developed by the IMCO Panel of Experts* was used. The Panel of Experts had assumed that ships with over 10,000 grt would provide most of the market for ship terminals. It then estimated a number of paid minutes per ship per day and assumed that the busy hour traffic would be twice the average traffic for 330 days per year. The number of voice channels was then determined based on the Erlang statistics with 5 percent probability of call blocking.

The study report for the OTP used the IMCO forecast for maritime traffic through the early 1990's and extended it to the year 2000 by assuming growth rates of 10 percent, 15 percent and 20 percent. This traffic model includes telephony and telegraphy as well as other low speed data. In addition, it is assumed that requirements for higher speed data transmission will develop which are not included in the voice/telegraphy data. This higher speed data transmission requirement will result largely from the exploration for undersea minerals and petroleum and from the inclusion of off-shore platforms in the maritime communications system.

One example for this data transmission requirement is the "Brightspot" technique of ocean floor mapping that is used to determine likely locations of oil. At present, large amounts of data are recorded on tape for computer analysis some weeks later. It would be desirable to transmit this information via satellite to a computer for real time processing. With increasing shortages of natural resources, we expect that ocean floor exploration will intensify over the next 2 decades. Accordingly, a data traffic model has been generated, starting with 500 kBps in 1985 for the Atlantic and growing at 15 percent per year.

---

*IMCP Panel of Experts on Maritime Satellites. Report to the International Conference on the Establishment of an International Maritime Satellite System. September 1974.

The Pacific and Indian Ocean traffic requirements are generally about half of those for the Atlantic. Traffic is summarized in Table 5-6.

Table 5-6

Estimate for Voice and Data Traffic for Maritime Communications

(Equivalent Voice Circuits - Year 2000)

Area	Voice Circuits	Data Traffic in Equivalent Voice Circuits	Total Equivalent Voice Circuits
Atlantic Ocean	240	120	360
Indian and Pacific Ocean, Each	120	60	180

Aeronautical communications requirements were derived from an ARINC research report prepared for the FAA*. The report bases its traffic forecast on "peak instantaneous aircraft in the gap (PIAG)" estimates. For 1975 the Atlantic PIAG was 150. The Year 2000 estimates range from 250 to 360, corresponding to annual growth rates of 2 to 3.6 percent.

* A Study of Communications Requirements for a 1985 to 2000 Operational Aeronautical Satellite System, Volume I, May 1975 and Volume II March 1976. Prepared for the U.S. Department of Transportation by ARINC Research Corporation. Report No. FAA-RD 75-80.

Different values of traffic are found depending on the operating discipline used. For the year 2000 estimate of foreward channels (ground to aircraft) which are the most demanding on spacecraft power, the estimates range from 6 to 12 channels. The 13-channel estimate results from so-called "undisciplined voice" which is the most desirable mode of operation.

It is also possible that a requirement will develop for public correspondence channels on aircraft. At present, the aeronautical frequency band cannot be used for this type of service, but it is possible that the ITU frequency allocations will be changed to permit this use. With present frequency allocation rules, public correspondence traffic from aircraft could be provided in the maritime frequency band, but this would result in technical difficulties causing interference in the maritime systems due to the large power differences which are required. For this reason, we have not included an estimate for public correspondence traffic in our model.

A summary of the ARINC estimates is shown in Table 5-7.

Table 5-7
Year 2000 Traffic Estimates By ARINC

Ocean Area	Forward Channels	Return Channels
Atlantic	6	9
Pacific	7	8
Indian	5	8

SECTION 6
TECHNOLOGY DEVELOPMENT

6.1 General Areas of Development

The use of the Space Shuttle will provide much lower launch costs than would result from the use of conventional launch vehicles. It will be possible to design spacecraft with more redundancy and higher reliability and with longer in-orbit lifetimes. The longer life coupled with lower launch costs and higher capacity will reduce annual costs per channel.

Ion engines will form the primary means of station-keeping propulsion. Solar cell efficiencies will be increased, and the weight efficiency of power generation equipment including solar cells, cover glass and back-up structure will be increased from 15 W/kg to 35 W/kg. Nickel-hydrogen batteries will be used with a storage capability of 40 watt hours per kg instead of present day nickel-cadmium batteries with 14 watt hours per kg. The increased weight efficiencies will permit higher satellite EIRP, which can be translated into lower cost earth station antennas.

Advances will be made in baseband processing which will permit transmission of a given quality at fewer bits. At the same time there will be advances in the low cost implementation of error control codes which permit operation at lower carrier-to-noise ratios. An improvement of 5 dB will be practical in each of these two areas. This will be important especially for mobile transmission applications.

6.2 Multi-beam Satellite-Switched TDMA Systems

The major advance in technology which will have a great impact on future domestic satellite systems will be the use of high-speed satellite-switched TDMA with multiple spot beam antennas.

To meet the traffic requirements of the year 2002 and still leave room for growth it will be desirable to illuminate the coverage area of a given domestic or regional system by multiple spot beams.

Multiple spot beams offer the following advantages:

Multiple spot beams permit frequency re-use

Spot beams increase the satellite transmit EIRP and receive G/T.

Interference from adjacent beam sidelobes will make operation at low C/N ratios desirable, perhaps calling for rate 7/8 or rate 3/4 error coding, which reduces C/N requirements by 3 and 4 dB respectively, relative to uncoded transmissions. These low operating C/N ratios will also make the system less sensitive to interference from adjacent satellites, thus permitting smaller satellite separations.

Spot beams make the system less sensitive to interference from terrestrial sources. The reduced earth station transmit EIRP reduces interference into other systems.

Satellite-switched TDMA provides a flexible means of interconnecting multiple spot beams. With 4-phase PSK, 8 percent guard bands between TDMA carriers, 8 percent frame efficiency and rate 7/8 coding, the useful communications bit rate for each 500 MHz band is 640 MBps. With 64 kBps PCM this results in a capacity of 10,000 one-way channels per 500 MHz frequency band. With six times frequency re-use, the k-band capacity of a single satellite is 60,000 channels. The practical usable capacity is 40,000 channels.

6.2 Systems Operating By The Year 2002

6.2.1 High Density Routes

High density routes will be served by satellites operating in the 18/30 GHz bands with space diversity to reduce propagation outages and satellite diversity to avoid sun outages.

The total bandwidth of 2,500 MHz will be re-used perhaps six times. Considering practical traffic distributions, some beams will saturate earlier than others, and the usable bandwidth will be about 10,000 MHz. The corresponding usable capacity is 200,000 one-way channels. This corresponds to 200 equivalent C-band transponders as postulated in the traffic model in Section 2.

6.2.2 Medium and Low Density Routes

Satellites at these frequencies will also employ multiple spot beams for area coverage. For medium density routes, satellite-switched TDMA will be employed, and for low density routes there will be a trade-off between satellite-switched TDMA and SCPC. The latter is cheaper to implement on the ground but imposes a greater beam distribution problem on the satellite. The usable capacity is 40,000 channels per satellite.

These satellites will also provide C-band transmission with wider area coverage with a single-shaped beam. The C-band will be used for multi-destination traffic, such as TV distribution. In developed countries, currently established earth stations at C-band will continue to operate at these frequencies; new stations will become progressively more difficult to implement because of frequency coordination difficulties.

6.2.3 C-band Satellites

C-band satellites will be used primarily in developing countries in tropical zones where K-band transmission outages without diversity would be objectionable. The satellites will use multiple transponders, but probably wider than the present 36 MHz. They will be used with SCPC for light route demand-assigned traffic and with TDMA and DSI for medium density routes. The capacity is 10,000 one-way channels per beam without DSI and correspondingly higher when DSI is used. Dual polarization can double this capacity.

A single satellite may provide several spot beams to widely separated areas. This will be efficient and cost effective, but it may be difficult to implement because of ownership and control problems. It will be an obvious solution for those cases where INTELSAT will furnish transponder lease services. Each beam can have the above-mentioned capacity.

6.2.4 TV Broadcast Satellites

TV broadcast satellites will operate at K-band and at 2.5 GHz. The former will be preferred where large numbers of channels are required; the latter will be used by developing countries where the simpler receiver is important. A single K-band broadcast satellite will typically have a capacity of about 20 TV channels.

6.2.5 Video Conferencing Satellites

Video conferencing satellites will be specially designed for high capacity. They will operate in the 18/30 GHz frequency bands in the developed country zones, where traffic requirements are especially high and where the temperate rain climate makes the rain attenuation at these frequencies acceptable. They will also operate at 12/14 GHz and at 4/6 GHz for lesser traffic requirements and for higher continuity of service in areas of tropical rain.

A detailed description of a video conferencing satellite system is given in Annex C to this report.

SECTION 7
THE INTELSAT SYSTEM

7.1 Historical Data

The INTELSAT System has been in operation since the launch of Early Bird in April 1965, over 12 years ago. Because of this extensive history it is reasonable to use historical data for the prediction of future launch requirements.

A substantial planning effort is underway at INTELSAT for the prediction of future traffic and for estimates of future launch requirements. Even though INTELSAT V is not scheduled for launch until 1979, there are already plans for an INTELSAT VI generation. However, at this stage INTELSAT's plans are confidential, and we have therefore based assumptions for future launches on published information and on an extrapolation of past data.

To date, INTELSAT has attempted the launch of 24 satellites. Of these launch attempts there were three launch vehicle failures and two apogee motor failures. A total of 19 satellites were successfully injected into orbit. More detailed information on the history of the INTELSAT satellites is shown in Annex D of this report.

Table 7-1 shows the distribution of launches over time. An analysis of the information in this Table shows that the 24 launch attempts over 12½ years averaged at 1.9 launch attempts per year. Furthermore, the launch frequency was higher in the first 6-year period than in the subsequent period. For the first 6 years the launches averaged 2.2 per year, and this figure dropped to 1.7 for the second period.

The reason for the higher launch frequency in the earlier years is the shorter lifetime of the earlier satellites. The average lifetimes of the INTELSAT series are as shown in Table 7-2.

Table 7-1

INTELSAT Launches Versus Time

Year	Number of Launches	Launch Vehicle
65	1	Thor Delta
66	1	Thor Delta
67	3	Thor Delta
68	2	Thor Delta
69	3	Thor Delta
70	3	Thor Delta
71	2	Atlas Centaur
72	3	Atlas Centaur
73	1	Atlas Centaur
74	1	Atlas Centaur
75	2	Atlas Centaur
76	1	Atlas Centaur
77 (mid-year)	1	Atlas Centaur
Total	24	
Average	1.9 per year	

Table 7-2

Average Lifetimes of the INTELSAT Series

Satellite Type	Design life in Years	Actual life in Years
INTELSAT I/II	1½/3	4.1
INTELSAT III	5	3.0
INTELSAT IV	7	7.0

INTELSAT V is considerably more complex than INTELSATS IV and IV-A, and it is also designed for a 7-year life. Longer life than 7 years is not considered to be very useful, since traffic grows so quickly and technology changes. A satellite program becomes obsolete after 5-7 years, even if the satellite lifetime is longer. For this reason, we have assumed that INTELSAT will continue to work with 6-year mean mission cycles for the rest of this century.

7.2 Future INTELSAT System Configurations

The INTELSAT Systems concept started with a single operating satellite in each ocean area, each protected by an in-orbit spare. When the time arrived where a single satellite could not carry the entire traffic of the Atlantic Ocean area, a system with two operating satellites was implemented. In order to minimize requirements for second antennas, only earth stations with large traffic requirements were assigned traffic in the second satellite, thus the name "Major Path" satellite. Full connectivity between all countries was maintained through the "Primary" satellite.

For the next 25 years, there will be a minimum of three operating satellites and one space in the Atlantic area, two operating and one spare in the Indian Ocean area, and one operating with one spare satellite in the Pacific area. In addition, there will be special transponder lease satellites in the Atlantic and Indian Ocean areas, although with increased satellite reliability some of the transponder lease traffic will be carried on the spare satellites. Table 7-3 lists the countries which lease INTELSAT transponders.

Table 7-3

Countries Which Lease INTELSAT Transponders

Transponder Lease in Service	Algeria Brazil Malaysia Nigeria Norway Spain Nigeria France Saudi Arabia Sudan
Transponder Lease Approved But Not Yet In Service	Zaire Colombia Chile India
Transponder Lease Planned But Not Yet Approved	Philippines Oman Uganda Mauritania

We consider it likely that INTELSAT will provide greatly increased transponder lease services in the future. However, to the extent that INTELSAT provides such services, they will reduce the traffic estimates for the domestic and regional systems shown in Section 5 of this report. Since INTELSAT has not announced a policy decision in this regard, no special satellites for transponder lease service will be included in the launch model.

It is also possible that INTELSAT will provide maritime communications satellite services in the future. To the extent that this is the case, the traffic estimates for maritime traffic in Section 5 will be reduced. Again, since INTELSAT has not announced any policy with respect to maritime traffic, no special satellites have been included in the INTELSAT launch model.

7.3 International Video Conferencing Satellite

International video conferencing will become an important aspect of future INTELSAT business. This is the opinion of FSI and not necessarily that of INTELSAT. We believe that INTELSAT will implement an international video conferencing system based on special purpose high capacity satellites. We have included such satellites in the launch schedule.

SECTION 8
DOMESTIC AND REGIONAL SYSTEMS

8.1 Historic Development of Domestic Systems

Table 8-1 shows the development of domestic satellite communications systems. The first system was the Telesat System of Canada which became operational in 1972. It was followed by Western Union's Westar System in 1974. Two systems were introduced in 1975, RCA's Satcom and Russia's Statsionar System. They were followed by two more systems in 1976, COMSAT's Comstar System and the Indonesian System. A total of six systems with 15 satellites in orbit were introduced in a time span of 5 years.

In addition, during the last 2 years 11 countries started operation of domestic satellite communications on transponders leased from INTELSAT. Four more countries have their transponder lease already approved, and four additional countries are planning to lease INTELSAT transponders. These countries are listed in Table 7-3.

In total, 16 separate systems have started domestic satellite communications during the past 5 years.

Figure 8-1 is a plot of the development of separate domestic satellite systems and of the number of countries which lease INTELSAT transponders. The trendlines show that new systems have been introduced at the rate of approximately one per year, and that countries have started to lease INTELSAT transponders at approximately five per year.

Figure 8-2 shows the number of transponders which were placed into orbit for use in domestic communications satellite systems. Over a period of 5 years, approximately 200 transponders were placed in orbit, and according to reports from Hughes and RCA, none of them have failed yet. (Information on possible failures of transponders in the Statsionar System was not available.) The overall growth of domestic communications satellites transponders in orbit is about 40 per year.

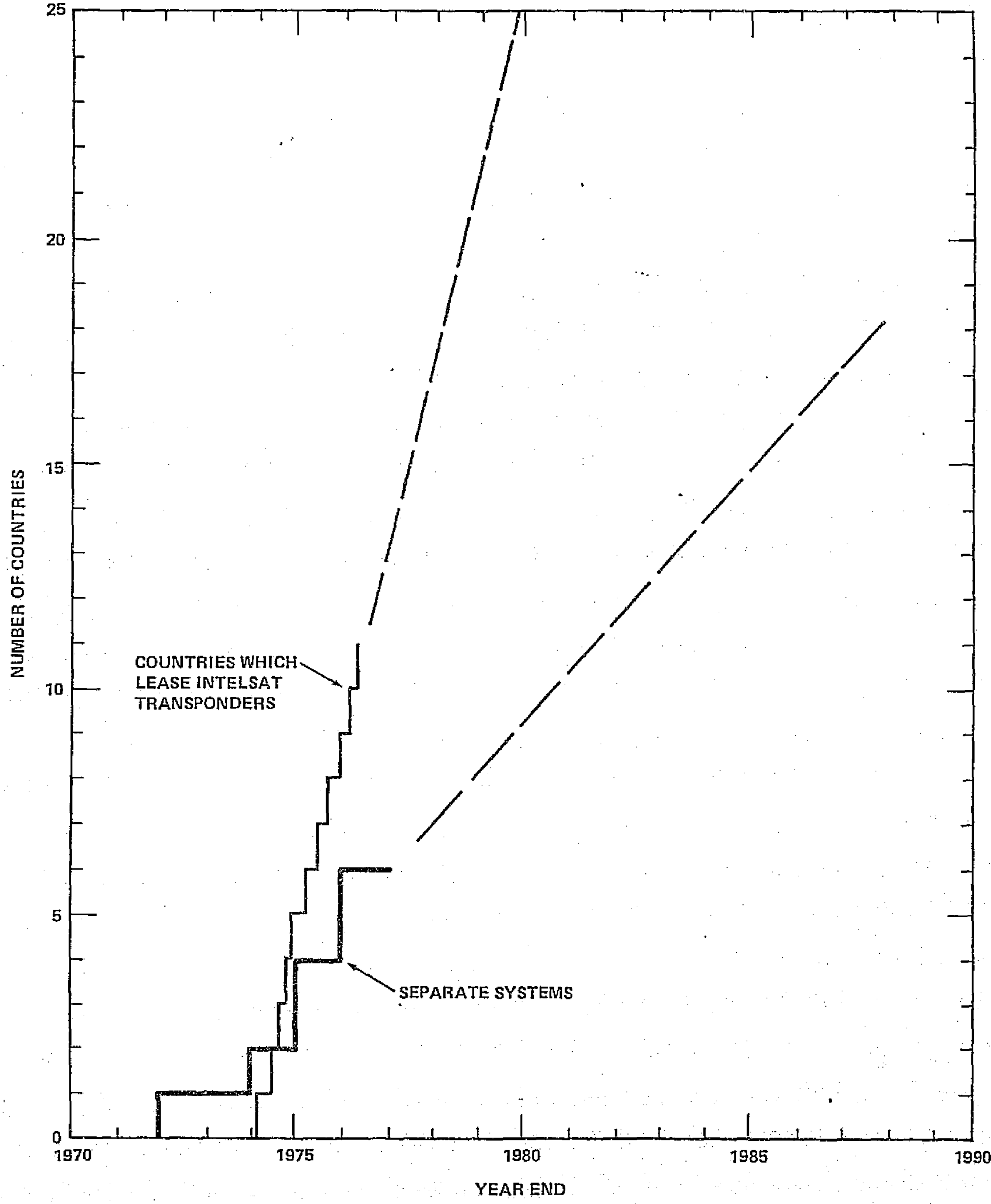


FIGURE 8–1

DEVELOPMENT OF DOMESTIC
SATELLITE COMMUNICATIONS SYSTEMS

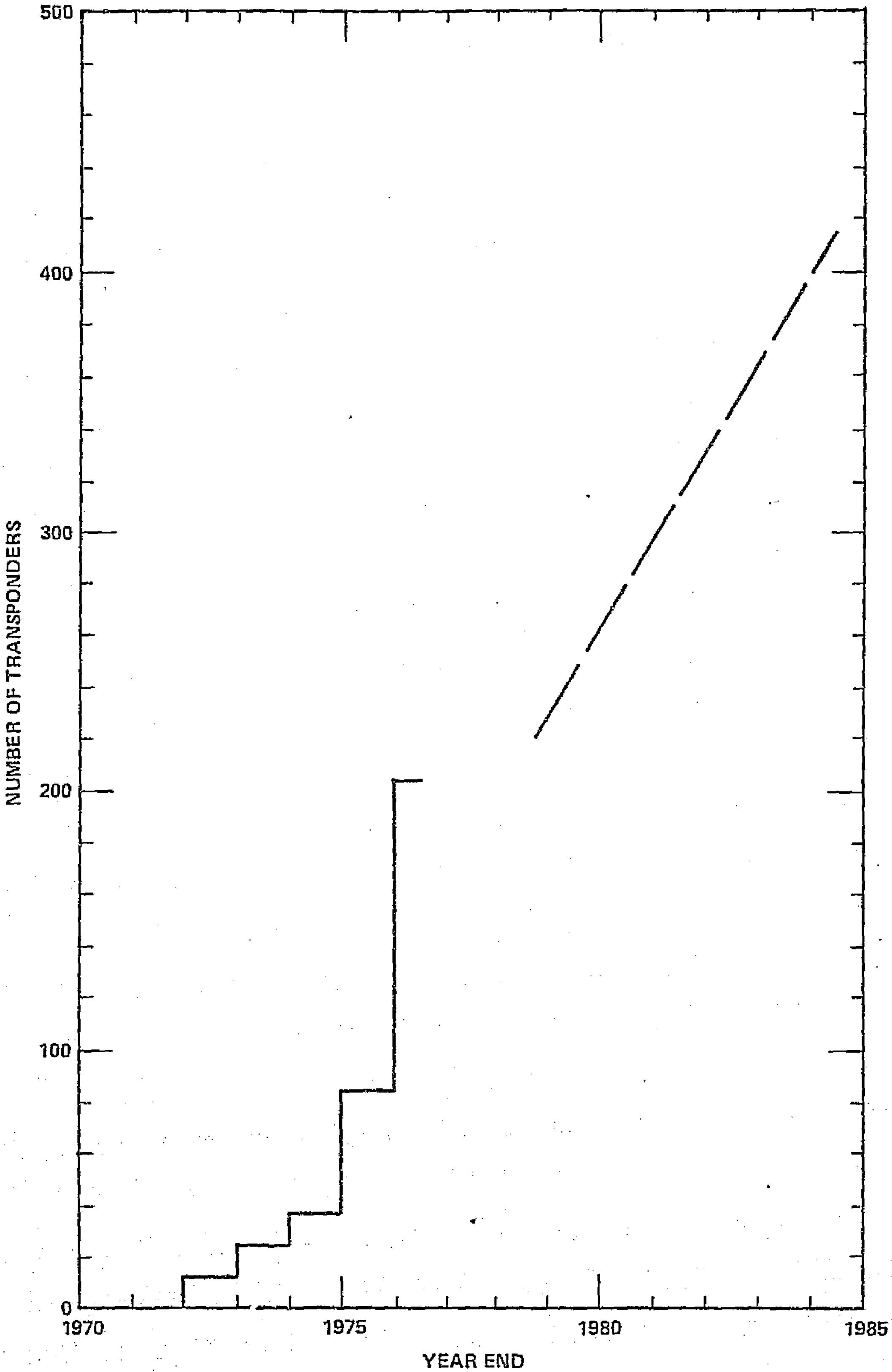


FIGURE 8–2

NUMBER OF TRANSPONDERS IN SERVICE
FOR DOMESTIC SATELLITE COMMUNICATIONS

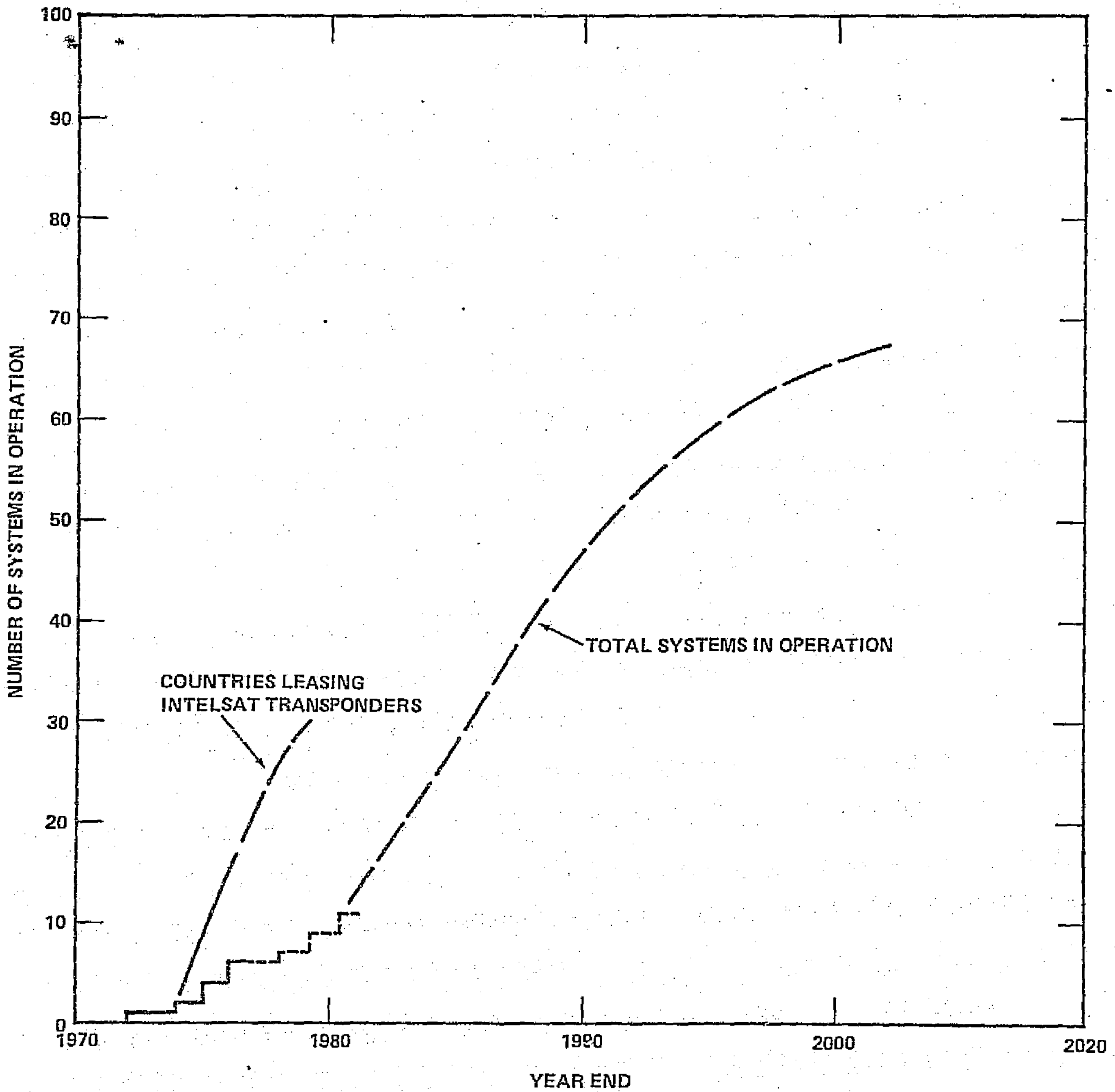


FIGURE 8–3

RATE OF INTRODUCTION
OF DOMESTIC AND REGIONAL SYSTEMS

Table 8-1

Development of Domestic Satellite Systems

System	Date of First Operation	Number of Satellites in Orbit
Telesat - Anik	1972	3
Western Union - Westar	1974	2
RCA - Satcom	1975	2
Russia - Statsionar	1975	4
Indonesia	1976	2
COMSAT - Comstar	1976	2

Total: 6 Systems and 15 Satellites

8.2 Systems in Operation by Year 2002

Table 8-2 lists domestic and regional satellite systems which will probably be in operation by the year 2002. This summary table shows a total of 67 systems, broken down as shown in Table 8-3.

Table 8-2

Domestic and Regional Satellite Systems Summary

World Region	Country or Operating Entity	Communications Satellite System	Video Conferencing System	TV Broadcast System	Total Systems
North America					9
	Canada	X	X	X	
	RCA	X			
	Western Union	X			
	AT&T	X			
	SBS	X			
	Videosat Corporation		X		
	Public Broadcasting			X	
Western Europe					6
	ESA/PTT's - Regional	X	X		
	EBU - Regional			X	
	Nordic Countries - Regional	X		X	
	Denmark	X			
USSR	Statsionar - Regional	X	X	X	3
Eastern Europe	Regional	X	X	X	3
Japan		X	X	X	3

Table 8-2, Continued

Domestic and Regional Satellite Systems Summary

World Region	Country or Operating Entity	Communications Satellite System	Video Conferencing System	TV Broadcast System	Total Systems
Latin America					8
	Brazil	X		X	
	Colombia	X			
	Chile/Argentina	X			
	Regional	X	X	X	
	Mexico/Caribbean	X			
Middle East					7
	Regional Arabsat	X	X	X	
	Iran	X			
	Saudi Arabia	X			
	Algeria	X			
	Lybia	X			
China		X	X	X	3

Table 8-2, Continued

Domestic and Regional Satellite Systems Summary

World Region	Country or Operating Entity	Communications Satellite System	Video Conferencing System	TV Broadcast System	Total Systems
Asia					11
	India	X		X	
	Indonesia	X		X	
	Philippines	X			
	Pakistan	X			
	Regional	X	X	X	
	Thailand	X			
	Malaysia	X			
Africa					8
	Nigeria	X		X	
	Regional I	X	X	X	
	Zaire	X			
	Sudan	X			
	Regional II	X			

Table 8-2, Continued

Domestic and Regional Satellite Systems Summary

World Region	Country or Operating Entity	Communications Satellite System	Video Conferencing System	TV Broadcast System	Total Systems
Other					6
	Australia	X	X		
	South Africa	X			
	South Pacific - Regional	X		X	
	New Zealand	X			
Total		38	12	17	67

Table 8-3

Satellite Systems Distribution

Communications Satellite Systems		
Regional	10	
Domestic	28	
Total		38
Video Conferencing Systems		
Regional	7	
Domestic	5	
Total		12
TV Broadcasting Systems		
Regional	9	
Domestic	8	
Total		17
Grand Total		67

From experience we know that all countries have the desire to control and own the telecommunications facilities which they use. This has led countries to purchase "indefeasible rights of ownership" in submarine cables and INTELSAT earth stations. INTELSAT member countries are also entitled to ownership of a share of the INTELSAT System, the exact amount depending on the degree of utilization. At present, lease of a pre-emptable transponder for domestic communications services does not entitle a country to pro-rata ownership in the INTELSAT System. Therefore, we expect that the following trend will develop.

Countries will initially lease INTELSAT transponders to develop a domestic system. As their traffic grows, there will be a point in time where it becomes economically possible to switch to a dedicated satellite system. At this point many countries will choose to implement their own system. Under present arrangements, the INTELSAT antenna beams are generally not well matched to most countries domestic requirements, and the lease costs are higher than the cost of owning a dedicated system when a country has enough traffic to fill 8 to 12 transponders.

If INTELSAT decides to pursue domestic and regional traffic in a business-like manner, it is clear that INTELSAT will be in a position to provide very efficient service at a lower cost than would result from ownership of a dedicated system. This is the case for all but the largest systems, where INTELSAT could not offer much of an advantage due to economies of scale. For many small and medium size systems, INTELSAT could design more efficient configurations by employing frequency re-use with multiple spot beams and by sharing of spare satellites. For example, the same satellite could provide domestic coverage for an African and a South American country by using separate antenna beams operating in the same frequency bands. Such a dual service satellite is certainly cheaper than two separate satellites. However, outside INTESLAT it would be very difficult, if not impossible, for the two countries to procure and maintain a joint system. In summary, INTELSAT could capture and retain a substantial portion of the domestic and regional satellite systems traffic. However, since INTELSAT has not yet announced a policy to indicate that this course of action will be pursued, we have not included any of the new domestic and regional traffic in the INTELSAT System and have instead assumed all separate systems.

The INTELSAT agreements contain certain clauses concerning the establishment of regional systems by INTELSAT member countries. In summary, such systems are not permitted if their implementation would cause INTELSAT substantial economic harm. Therefore, the INTELSAT members who intend to build regional systems generally take the position that their regional system is intended for traffic that would otherwise not be carried on satellites at all, or that the percent of traffic that will be diverted from the INTELSAT System is so small that it will not cause substantial economic harm. It is generally expected that in the long run the INTELSAT agreements will not prevent the establishment of regional systems.

Technology advances favor the economics of establishing domestic and regional satellite communications systems. The advent of the Space Shuttle is one key element of reduced satellite systems costs. Reduction of mini-computer costs reduces the costs of satellite in-orbit maintenance. Quantity production, which will start in a few years, will reduce satellite costs.

National pride will play a significant role in a country's decision to own its own system. We expect the development of the domestic satellite communications systems to follow the same trend as the development of airlines. The International Air Travel Guide lists over 300 airlines, a large percentage of them flying international routes.

8.3 Rate of Systems Implementation

While it is relatively easy to predict systems which will be operational in 25 years, we consider it impractical to attempt a prediction as to the exact time at which any given system will be implemented. Fortunately, for the purpose of predicting Space Shuttle flight requirements, it is adequate to predict the rate at which systems will be implemented.

It should be noted that the introduction of each new system is not statistically independent from any of the other systems. In fact, we expect a bunching effect, where other countries follow the lead of their neighbors which will speed up the process of systems introduction.

Crowding of the equatorial arc will further contribute to the speedy introduction of systems. Countries will tend to implement a system earlier in order to reserve for themselves one or more slots in the equatorial arc.

The estimate of the rate of systems implementation is given in Figure 8-3. In the mid 70's systems were introduced at the rate of two per year. Now there is a temporary pause in systems implementation, as many countries opted to start their system via the lease of INTELSAT transponders.

Although OTS is labeled as an experimental program, it is intended to be the forerunner of ECS, and we consider it to be the start of the European regional system. Two Japanese systems will also become operational before 1980. None of the other follow-on systems are under contract as yet, but the following entities are planning to have systems operating around 1981:

SBS
India
Arabsat
Colombia
ASETA

From 1982 on we expect systems to grow at about four per year, tapering off to about one per year at the end of the study period. We expect that the systems implementation curve will saturate around 75 systems. Table 8-4 lists the number of new systems to become operational in each of the years past 1980.

Table 8-4

Total Domestic and Regional

Satellite Systems In Operation

Year End	Total Systems In Operation	Systems Added During The Year
1981	12	3
82	16	4
83	20	4
84	24	4
85	28	4
86	32	4
87	36	4
88	39	3
89	43	4
1990	46	3
91	49	3
92	52	3
93	54	2
94	57	3
95	59	2
96	61	2
97	62	1
98	63	1
99	64	1
2000	65	1
2001	66	1
2002	67	1

SECTION 9
EXPENDABLE LAUNCH VEHICLES

The Space Shuttle will be less expensive and more readily available than expendable launch vehicles and will therefore be used for the majority of launches of communications satellites. To prepare an estimate of Shuttle flight requirements, it will be necessary to identify those programs which will not or may not make use of the Shuttle.

Within NASA we expect that expendable launch vehicles will be phased out quickly after the first Shuttle flights are reliably available, and the Shuttle will thereafter be used exclusively for the launch of communications satellites. The rate at which the Delta and the Atlas Centaur vehicles will be phased out is being determined by NASA. For the purpose of this study we have assumed that all NASA launches from 1981 on will use the Shuttle.

The development of a launch vehicle capable of injecting a communications satellite reliably into synchronous transfer orbit is a lengthy and expensive program. For this reason we do not expect any new entries into this field for the remainder of this century.

We expect that all satellites for the USSR and for Eastern Europe will be launched by Russia.

Ariane will not be competitive with the Shuttle with respect to price, availability and reliability. Nevertheless, France will probably insist on the use of Ariane on any program that is controlled by France. On others, France may decide to subsidize the launch in some form in order to get Ariane used. Ariane could thus be competition to the Shuttle on the following programs:

Any of the ESA programs

African programs where France may offer a complete package consisting of spacecraft, launch vehicle and earth stations

We expect that Ariane will be used on some communications satellite launches, but this will not have a major impact on the Shuttle flight requirements. In our satellite systems model we have not included any programs which are controlled by France, and therefore we cannot identify specific programs which will be launched on Ariane. However, to be conservative, we have assumed that 20 percent of the European communications satellite launches will use Ariane.

Japan has developed the N-rocket and NASA has transferred technology to Japan for the construction of an earlier version of the Thor Delta. Japan's first generation communications satellites will all be launched by NASA on the Delta, but some later satellites will undoubtedly be launched by Japanese launch vehicles. Their weight capability will remain to be limited for some time, and therefore all larger Japanese satellites will be launched by the Shuttle. We have assumed that 50 percent of the Japanese satellites will be launched on the Shuttle. We have also assumed that Japanese launch vehicles will not be used for any non-Japanese systems.

China will have substantial requirements for communications satellite launches. We do not believe that China will have its own launch vehicles capable of launching high capacity satellites into synchronous orbit. China has in the past purchased earth stations for operation in the INTELSAT System from the USA. It is therefore possible that China would have some of its satellites launched by NASA. For the purpose of this study, we have assumed that 50 percent of the Chinese communications satellites will be launched on the Shuttle.

SECTION 10

SATELLITES IN ORBIT BY THE YEAR 2002

In this section the Traffic Forecasts of Section 5, the Technology Forecasts of Section 6, and the Systems Forecasts of Sections 7 and 8 are combined into a model of in-orbit satellites for the year 2002.

10.1 INTELSAT, Maritime and Aeronautical Services

INTELSAT V will be introduced in 1979 to 1980, INTELSAT VI will follow in the mid 80's and INTELSAT VII in the mid 90's. From INTELSAT VI on, each satellite launch will exceed the capability of the Atlas Centaur class, and we have assumed that the IUS (or later equivalent) will be used. The totals shown include spares in orbit.

Aeronautical and maritime requirements are relatively modest and can be satisfied with the Delta class satellites. The system could be operated by COMSAT General, Inmarsat or INTELSAT. Each ocean area requires three satellites, two operating satellites for position determination and one spare.

Table 10-1 lists the in-orbit requirements for INTELSAT and for aeronautical and maritime communications.

Table 10-1

In-Orbit Requirements in the Year 2002 for

INTELSAT, Maritime and Aeronautical Services

System	Ocean		Satellite Size* A	B	C
INTELSAT	Atlantic	Communications			4
		Video Conferencing			2
	Pacific	Communications			2
		Video Conferencing			2
	Indian	Communications			3
		Video Conferencing			2
Maritime and Aeronautical	Atlantic		3		
	Pacific		3		
	Indian		3		
Total Number of Satellites			9		15

*A = Delta equivalent, B = Atlas Centaur equivalent, C = IUS equilalent

10.2 Domestic and Regional Communications Services

Requirements for the USSR and for Eastern Europe are not included since these satellites will be launched by the USSR.

Table 10-2 shows the number of satellites required in orbit to satisfy the traffic forecast for the various systems. Spares in orbit are included, but it is assumed that the spare satellites will also carry traffic. Table 10-3 summarizes the total satellite requirements for each of the regions. A total of 89 satellites is required in orbit.

Table 10-2

In-Orbit Requirements in the Year 2002 for

Domestic and Regional Services

Region	Traffic	Systems	Average Traffic* Per System	Satellite Size** A	B	C
North America	765		150			
		Canada			4	
		RCA Satcom			3	
		Western Union				3
		AT&T				4
		SBS			3	
Western Europe	665					
		ESA/PTT's				4
		Nordic Countries			2	
		Denmark		2		
Japan	225				4	
Total Number of Satellites				2	16	11

*Traffic is given in number of reference transponders with a capacity of 1,000 one-way channels.

**A = Delta equivalent, B = Atlas Centaur equivalent, C = IUS equivalent

Table 10-2, Continued

In-Orbit Requirements in the Year 2002 for

Domestic and Regional Services

Region	Traffic	Systems	Average Traffic* Per System	A	Satellite Size** B	C
Latin America	290		60			
		Brazil			3	
		Colombia		2		
		Chile/Argentina			3	
		Regional			3	
		Mexico/Caribbean		2		
Middle East***	230		46			
		Regional Arabsat			3	
		Iran			2	
		Saudi Arabia		2		
		Algeria		2		
		Lybia		2		
China	350					4
Total Number of Satellites				10	14	4

*Traffic is given in number of reference transponders with a capacity of 1,000 one-way channels.

**A = Delta equivalent, B = Atlas Centaur equivalent, C = IUS equivalent

***Includes North Africa

Table 10-2, Continued

In-Orbit Requirements in the Year 2002

Domestic and Regional Services

Region	Traffic	System	Average Traffic* Per System	Satellite Size** A	B	C
Asia***	350		50			
		India			2	
		Indonesia			2	
		Philippines		2		
		Pakistan		2		
		Regional			2	
		Thailand		2		
		Malaysia		2		
Africa****	85		17			
		Nigeria		2		
		Regional I		2		
		Regional II		2		
		Zaire		2		
		Sudan		2		
Other	90		22			
		Australia		2		
		South Africa		2		
		South Pacific		2		
		New Zealand		2		
Total Number of Satellites				26	6	–

*Traffic is given in number of reference transponders with a capacity of 1,000 one-way channels.

**A = Delta equivalent, B = Atlas Centaur equivalent, C = IUS equivalent

***Excludes Japan and China

****Excludes South Africa and North Africa

Table 10-3

Total Number of Communications Satellites

Year 2002

Region	Satellite Size* A	B	C
North America		10	7
Western Europe	2	2	4
Japan		4	
Latin America	4	9	
Middle East**	6	5	
China			4
Asia***	8	6	
Africa****	10		
Others	8		
Total Number of Satellites	38	36	15

*A = Delta equivalent, B = Atlas Centaur equivalent, C = IUS equipment

**Includes North Africa

***Excludes Japan and China

****Excludes South Africa and North Africa

Table 10-4

In-Orbit Requirements for

Video Conferencing Satellites

Year 2002

Region	Traffic*	Systems	Average Traffic Per System	Satellite Size** A	B	C
North America	38					
		Canada				2
		Videosat Corp.				4
Western Europe	39	ESA/PTT's				5
Japan	12					2
Latin America	9	Regional				2
Middle East***	7	Arabsat				2
China	12					2
Asia****	12	Regional				2
Africa*****	3	Regional				1
Other	3	Australia				1
Total Number of Satellites						23

*Traffic is expressed in units of 1,000 two-way video circuits

**A = Delta equivalent, B = Atlas Centaur equivalent, C = IUS equivalent

***Includes North Africa

****Excludes Japan and China

*****Excludes South Africa and North Africa

Table 10-5

In-Orbit Requirements for

Direct TV Broadcast Satellites

Year 2002

Region	Traffic*	System	Satellite Size**		
			A	B	C
North America	10				
		Canada		2	
		Public Broadcasting		2	
Western Europe	30				
		EBU		2	
		Nordsat		2	
Japan	5			1	
Latin America	20				
		Brazil		2	
		Regional		1	
Middle East***	10	Regional		2	
China	5			2	
Asia****	15				
		India		1	
		Indonesia		1	
		Regional		1	
Africa*****	15				
		Nigeria		1	
		Regional		1	
Other	5	South Pacific		1	
Total Number of Satellites				22	

*Traffic is expressed in number of TV broadcast channels.

**A = Delta equivalent, B = Atlas Centaur equivalent, C = IUS equivalent

***Includes North Africa

****Excludes Japan and China

*****Excludes South Africa and North Africa

10.3 Video Conferencing Services

Requirements for video conferencing satellites are shown in Table 10-4. A special purpose, high capacity satellite with 8,000 circuit capability is used for the developed countries. It includes the use of the 12/30 GHz frequency band. Systems operating in zones of high rain rate may be used to operate at lower frequencies only, with reduced capacity.

10.4 Direct TV Broadcast Service

Requirements for TV broadcast satellites are shown in Table 10-5. It was assumed that some of these systems will operate without an in-orbit spare.

10.5 Total Requirements for all Services

Table 10-6 shows the total requirements for all services. A total of 158 satellites will be in orbit, not counting the satellites for the USSR and Eastern Europe.

This large number of satellites will lead to the early congestion of the equatorial arc, at least in some areas of the world. Satisfying the total traffic will require careful intersystem coordination and design. It is expected that the following measures will be taken to permit coexistence of the total number of satellites:

a. Best use will be made of all four frequency bands:

   4/6 GHz, 12/14 GHz, 18/30 GHz and 2.5 GHz

b. Satellite designs for low antenna sidelobe levels will permit multiple use of the same orbital slot at the same frequency band. With this concept, satellites for coverage of North America, South America and Europe could occupy the same slot.

c. Consideration will be given to the allocation of additional frequency bands for satellite communications.

Table 10-6

Total In-Orbit Requirements

For All Services

Year 2002

Service Type	Satellite Size* A	B	C
INTELSAT, communications and video conferencing			15
Maritime and aeronautical	9		
Domestic and regional communications	38	36	15
Domestic and regional video conferencing			23
Direct TV broadcast		22	
Total	47	58	53
Grand Total - All Sizes		158	

*A = Delta equivalent, B = Atlas Centaur equivalent
C = IUS equivalent

SECTION 11

SATELLITE REPLACEMENT AND SYSTEMS GROWTH

In-orbit replacement of satellites is required for two reasons:

a. Replacement of failed satellites
b. Replacement of obsolete satellites

In recent yeears the satellite reliability has become so good that there will be relatively few failures of satellites prior to the scheduled replacement time.

In the INTELSAT System, a new generation of satellites is being introduced on the average of one every four years. Counting INTELSAT I and II as one series, starting in 1965 the system has progressed through INTELSAT III, IV and IV-A to INTELSAT V in 1980. The capacity has increased from 240 circuits to about 12,000, a ratio of 50. The mass in orbit increased with each subsequent launch from 38 kg for Early Bird to 967 kg for INTELSAT V. A summary of the INTELSAT spacecraft characteristics is shown in Table 11-1.

We believe that in the future some satellites will be designed for longer life, such as 10 years, and others will have a shorter design life with more complexity. For the purpose of this study we have assumed an average replacement cycle for all satellites of 6 years. In addition, we have assumed that satellites of subsequent series will generally be heavier. Both these assumptions are justified by the operating experience with the INTELSAT System (see also Annex D, Satellite Reliability History) and with the relatively mature domestic systems of Telesat and Western Union.

In developing a satellite launch requirements model we have therefore assumed satellites will be replaced 6 years after launch and that the replacement at times will be in the next larger launch weight category.

Table 11-1

INTELSAT Spacecraft Characteristics*

	INTELSAT I TD**	INTELSAT II TD	INTELSAT III TD	INTELSAT IV AC***	INTELSAT IV-A AC	INTELSAT V AC
Year of First Launch	1965	1967	1968	1971	1975	1979
Height (Centimeters)	59.6	67.3	104	528	590	1,570
Mass In Orbit (Kilograms)	38	86	152	700	790	967
Primary Electric Power (Watts)	40	75	120	400	500	1,200
Effective Bandwidth (Megahertz)	50	130	500	500	800	2,300
Capacity (Telephone Circuits)	240	240	1,200	4,000	6,000	12,000
Design Lifetime (Years)	1.5	3	5	7	7	7
Investment Cost Per Circuit-Year	$32,500	$11,400	$2,000	$1,200	$1,100	$ 800

*Burton I. Edelson, "Global Satellite Communications," Scientific American, February, 1977, p.58

**TD = Thor Delta

***AC = Atlas Centaur

When a new system is introduced, we have assumed that the second satellite will be launched in the second year of operation, and that the third satellite will be launched in the fourth year of operation. For satellites already in orbit, we have assumed that they will be replaced 6 years after initial launch.

An average percentage was developed for the launch of satellites by the Space Shuttle as opposed to launch by Ariane and other expendable launch vehicles. The derivation of this percentage is shown in Table 11-2. Satellites for the USSR and Eastern Europe have been excluded from this average, since we assumed zero percent probability of Shuttle launch for these programs. Based on this evaluation it was concluded that the Space Shuttle will carry about 92 percent of the communications satellite launches, excluding those of the USSR and Eastern Europe.

The 92 percent factor means that calculated spacecraft launch requirements have to be reduced by 8 percent to account for non-Shuttle launches.

Going back to Section 7 we find that the INTELSAT series experienced two apogee motor failures in 21 successful injections into transfer orbit. This is a failure ratio of 9.5 percent. We consider it reasonable to allocate a similar ratio for possible failures of the SSUS or the IUS.

Within the accuracy of our assumptions the two ratios cancel: by first reducing the Shuttle launches by 8 percent to account for expendable launch vehicles and then increasing them by 9.5 percent we obtain roughly the same figure with which we started. Of course, the match of these two figures is purely coincidental.

Table 11-2

Percentage of Shuttle Launches of Total Launches

Satellite System	Satellites by Year 2002	Percentage of Shuttle Launches	Satellites by Year 2002 Launched On The Shuttle
Communications Satellites			
Japan	4	50	2
Western Europe	8	80	6
China	4	50	2
Others	73	100	73
Video Conferencing Satellites			
Western Europe	5	80	4
Japan	2	50	1
China	2	50	1
Others	14	100	14
Direct TV Broadcast Satellites			
Western Europe	4	80	3
Japan	1	50	0
China	2	50	1
Others	15	100	15
INTELSAT	15	100	15
Aeronautical and Maritime	9	100	9
Total	158	92%	146

SECTION 12

SATELLITE LAUNCH AND SHUTTLE FLIGHT REQUIREMENTS

This section develops the number of satellite launches in each year by satellite class and the consequent number of Space Shuttle flights.

Table 12-1 shows the results. The first four columns are the total number of communications satellites in orbit and the break-down of satellites by weight class. The next three columns are the number of satellites launched in each year, again segregated by satellite size. The last column is the resulting number of Space Shuttle flights (full and fractional) based on 100 percent fill factor.

Space Shuttle flights were calculated as follows:

$\frac{1}{4}$ times satellites size A

plus

$\frac{1}{2}$ times satellites size B

plus

1 times satellites size C

Total Shuttle flights in support of the launch of commercial communications satelites rise from five per year in the early 1980's to 10 per year in the mid 80's and level off at about 17 in the mid 90's.

Table 12-1

Satellite Launch and Shuttle Flight Requirements

Year		Satellites in Orbit Size*			Satellites Launched Size*			Number of Shuttle Flights
	Total	A	B	C	A	B	C	
1982	38	23	14	1	8	4	1	5.00
83	47	28	18	1	10	7	0	6.00
84	57	32	22	3	9	8	2	8.25
85	66	37	25	4	11	7	1	7.25
86	75	40	29	6	10	9	3	10.00
87	85	44	32	9	11	8	5	11.75
88	92	47	35	10	11	9	3	10.25
89	101	50	38	13	11	9	5	12.25
1990	108	51	41	16	10	10	6	13.50
91	116	53	44	19	11	10	6	13.75
92	123	54	47	22	10	11	7	15.00
93	127	55	48	24	10	9	6	13.00
94	134	55	51	28	9	11	9	16.75
95	139	54	53	32	8	11	9	16.50
96	144	54	55	35	9	11	9	16.75
97	146	53	55	38	8	9	9	15.50
98	149	50	57	42	5	10	11	17.25
99	151	50	57	44	8	8	9	15.00
2000	153	48	58	47	6	9	11	17.00
2001	156	48	58	50	8	8	11	17.00
2002	158	47	58	53	7	8	12	17.75
Total					190	186	135	275.50
Average Per Year					9.05	8.86	6.43	13.12

*A = Delta equivalent, B = Atlas Centaur equivalent, C = IUS equivalent

ACKNOWLEDGEMENTS

This study was prepared by Future Systems Incorporated between August 9 and September 7, 1977. Valuable guidance was given during the course of the study by Mr. William Armstrong of NASA Headquarters. The study was prepared by Mr. Reinhard Stamminger with assistance from Mr. John Stein. Ms. Nancy Cooper typed the report, and the artwork was done by Ms. Jeanie Eisenberg.

ANNEX A

FORECASTING LITERATURE AND INFORMATION SOURCES

This Annex lists reference literature which has been used in constructing the traffic forecast for domestic satellite communications through the year 2002 for the preparation of the spacecraft technology forecast and for general information in areas where judgement was required.

FSI Library of Future-Oriented Books

Bell, Daniel, ed. Toward The Year 2000: Work In Progress. Boston, 1967.

Spekke, Andrew, ed. The Next 25 Years: Crisis & Opportunity. Washington, 1975.

The Future: A Guide To Information Sources. Compiled and edited by the World Future Society. Washington, 1977.

An Introduction To The Study Of The Future. Prepared by the World Future Society. Washington, 1977.

McHale, John. World Facts And Trends. New York, 1972.

Energy: Today's Choices, Tomorrow's Opportunities. Prepared by the World Future Society. Washington, 1974.

Toffler, Alvin. Future Shock. New York, 1970.

Kahn, Herman and Anthony Wiener. The Year 2000: A Framework For Speculation On The Next Thirty-Three Years. New York, 1967.

O'Neill, Gerard. The High Frontier: Human Colonies In Space. New York, 1977.

Meadows, Donella, Dennis Meadows, Jorgen Randers and William W. Behrens. The Limits To Growth. New York, 1974.

Clark, John, Sam Cole, Ray Curnow and Mike Hopkins. Global Simulation Models. New York, 1975.

Theobald, Robert. An Alternative Future For America II. Chicago, 1968.

Mesarovic, Mihajlo and Eduard Pestel. Mankind At The Turning Point. New York, 1974.

Moffitt, Donald, ed. The Wall Street Journal Views America Tomorrow. New York, 1977.

Kahn, Herman and B. Bruce-Briggs. Things To Come. New York, 1972.

Ruedisili, Lon and Morris Firebaugh, editors. Perspectives On Energy. New York, 1975.

An Analysis Of Domestic And Foreign Small Earth Station Markets. U.S. Department of Commerce, Office of Telecommunications. May, 1976.

Forrester, Jay. World Dynamics. Cambridge, 1973.

Economic Growth In The Future. Edison Electric Institute. New York, 1976.

Aviation Futures To The Year 2000. Federal Aviation Administration. February, 1977.

A Study Of Technical And Economic Aspects Of Combining Maritime And Aeronautical Communication Satellite Services - 1985-2000. Satellite Systems Engineering, Inc. Washington, 1977.

Dolotta, T.A., M.I. Bernstein, et. al. Data Processing in 1980-1985. New York, 1976.

Kahn, Herman, William Brown and Leon Martel. The Next 200 Years. New York, 1976.

Beckwith, Burnham Putnam. The Next 500 Years. New York, 1967.

The Futurist Magazine. Published by the World Future Society, Washington.

Rappoport, P.N. "Some Alternative Time Series Approaches to Forecasting International Message Telephone Service," Presented to the Public Utilities Forecasting Conference, Bowness-on-the-Windermere, United Kingdom, 1977.

Bech, N.K.I. "Price Influences on the Demand for Telephone Services," Teleteknik Journal, 1969, pgs. 45-49.

Bech, N.K.I. "Some Telecommunications Econometrics With Respect to the Telephone Service," Teleteknik Journal, 1970, pgs. 27-31.

"AT&T Forecasting Methodology," FCC Docket 18875, Question B, December 30, 1975.

Carreon, C.S. "The Requirement of Developing Countries," Presented at the World Telecommunication Forum, Geneva, 1975.

Elias, D. "Future World Telecommunication Networks," Presented at the Technical Symposium of the World Telecommunication Forum, Geneva, 1975.

Wheelon, A.D. "The Future Outlook for Communication Satellite Applications," Presented at the World Telecommunication Forum, Geneva, 1975.

Martin de Bustamante, J.L. "Telecommunications 2000," Telecommunications Journal, Vol. 43, pgs. 361-365.

Bebee, E.L. and E.J.W. Gilling. "Telecommunications and Economic Development: A Model for Planning and Policy Making," Telecommunications Journal, Vol. 43, pgs. 537-543.

Gimpelson, L.A. "Communications Planning for Developing Countries," Telecommunications Journal, Vol. 43, pgs. 486-491.

"World Bank Atlas: Population, Per Capita Product and Growth Rates." Published by the World Bank, 1976.

"International Financial Statistics," International Monetary Fund, Washington, D.C. 1977.

"The World's Telephones as of January, 1976." AT&T Long Lines, December, 1976.

Packet Data Communications, Volume I. Future Systems Incorporated, Gaithersburg, Maryland, 1977.

ANNEX B

HISTORICAL TRAFFIC DATA

Figures B-1 through B-5 show the correlation factor GNP per telephone for 17 representative countries for which adequate statistics were available. The telephone statistics were derived from the ITU handbook on telephone statistics and from the AT&T publications of "The World's Telephones".

For the number of telephones the total phones were used; that is, business and private phones with extensions. GNP represents 1977 figures derived from the International Monetary Fund's "International Financial Statistics". The latter lists GNP in constant 1970 monetary units. From these we derived the GNP in 1977 monetary units for each country and translated them into dollars using the 1977 exchange rate. The translation from constant 1970 to constant 1977 monetary units was made by using the GNP inflater. This method gives somewhat higher inflation than when the consumer price index is used to calculate inflation.

Figures B-6, B-7 and B-8 show the number of long distance calls per telephone. Long distance calls are the total long distance calls including international calls. The latter, however, is only a small percentage of the total long distance calls.

Figures B-9, B-10 and B-11 show the number of long distance calls per $1,000 GNP. For developing countries this figure is in the range of one to two long distance calls per $1,000 GNP. For developed countries it is in the range of three to 10 long distance calls per $1,000 GNP.

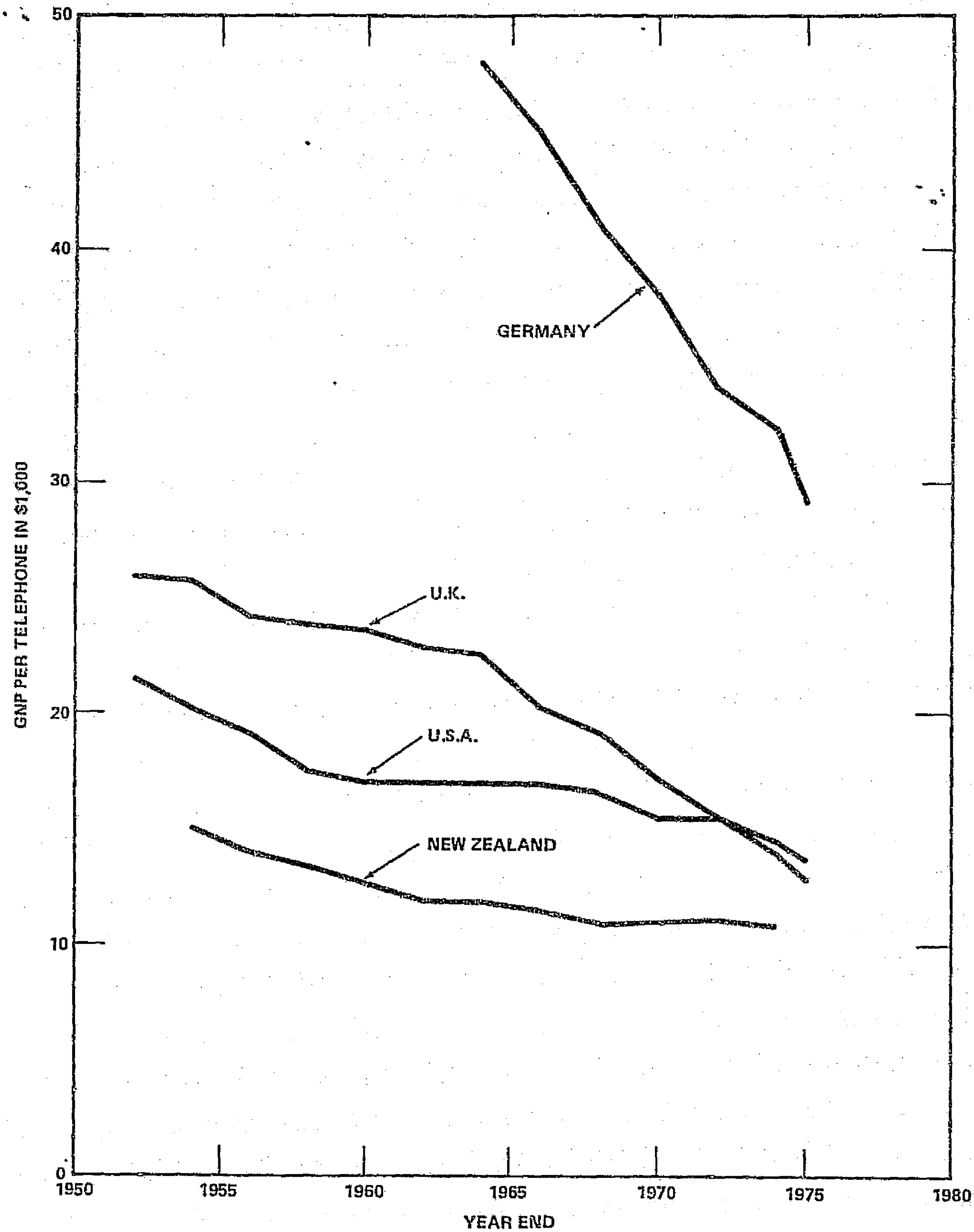


FIGURE B–1
GNP PER TELEPHONE

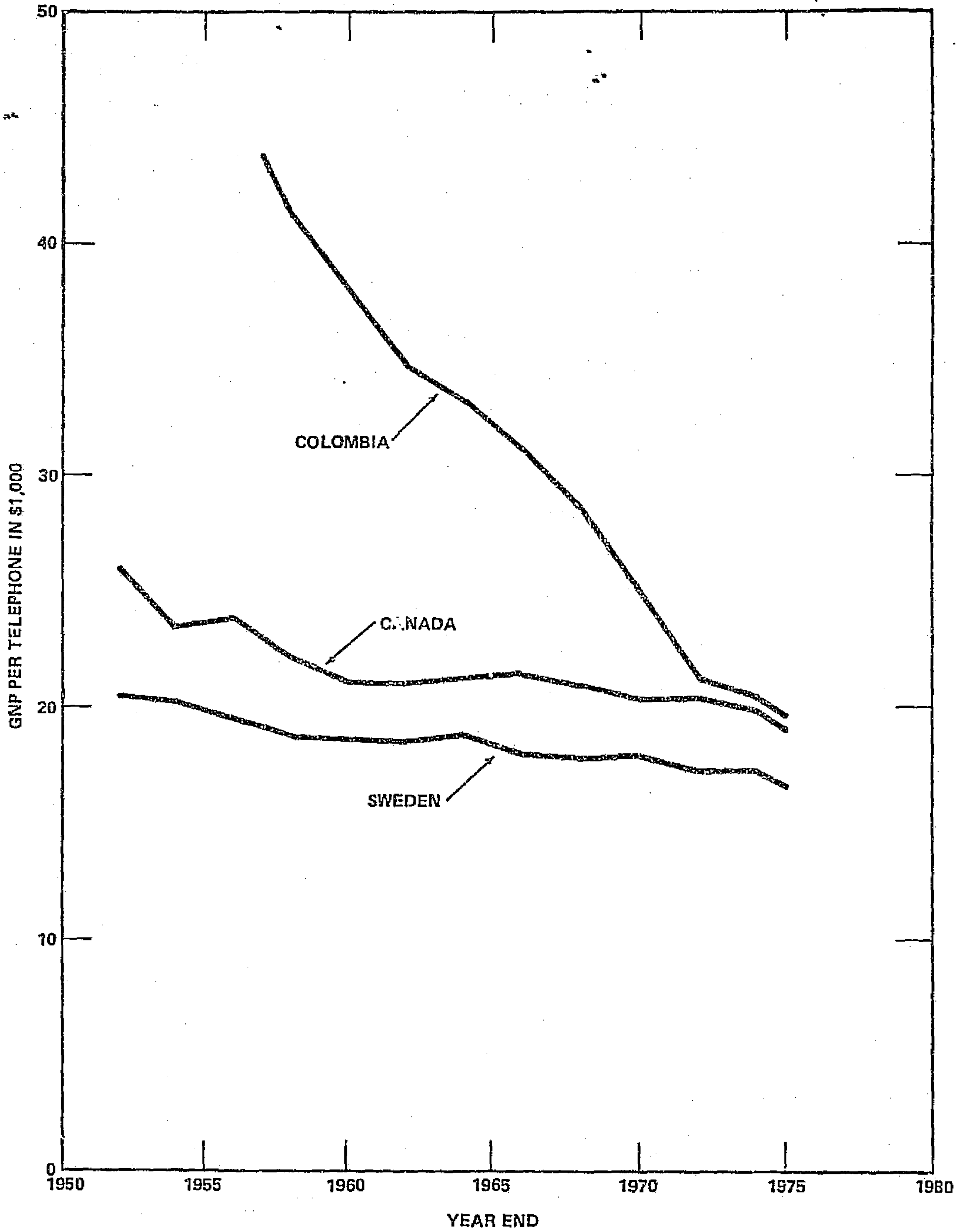


FIGURE B–2
GNP PER TELEPHONE

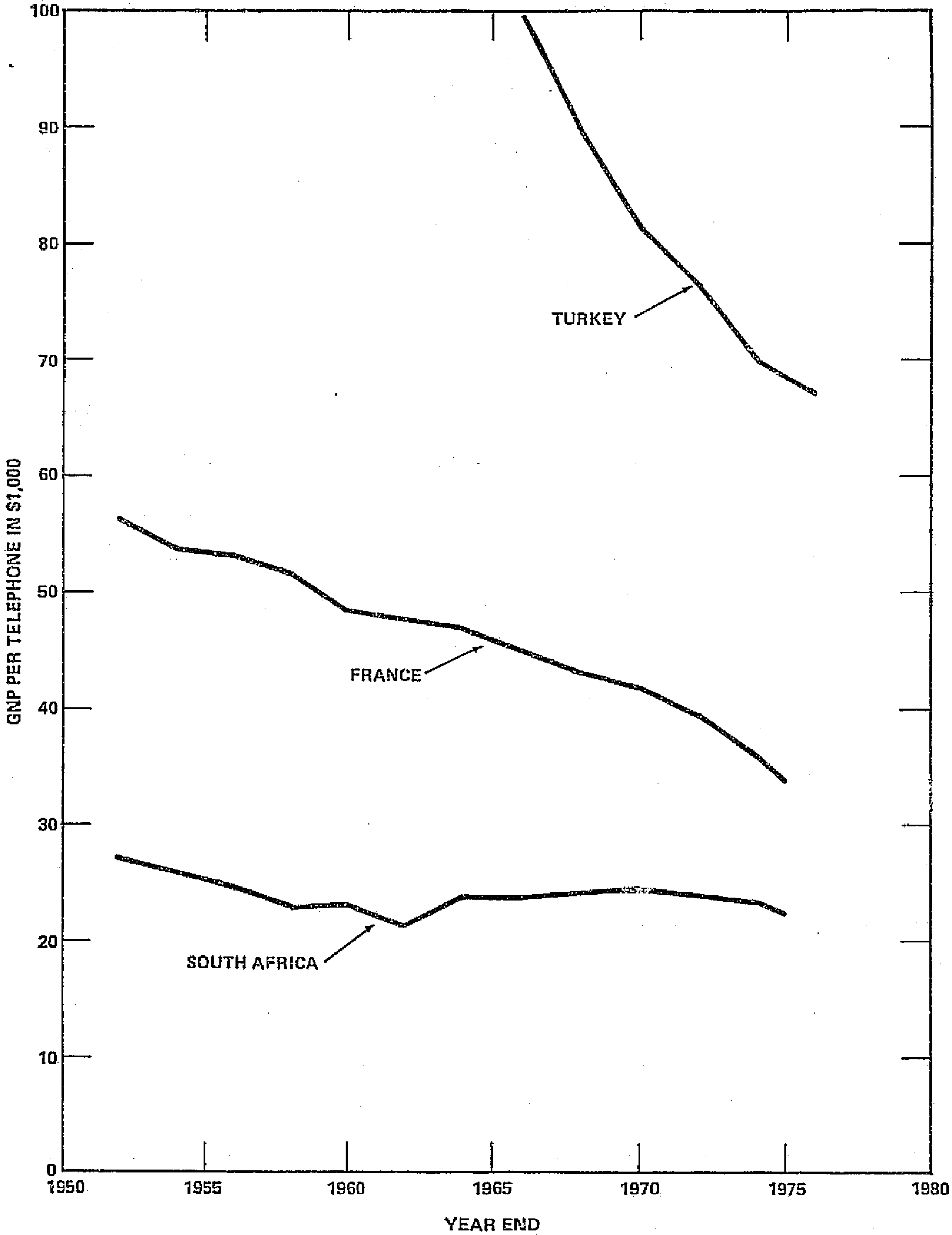


FIGURE B–3
GNP PER TELEPHONE

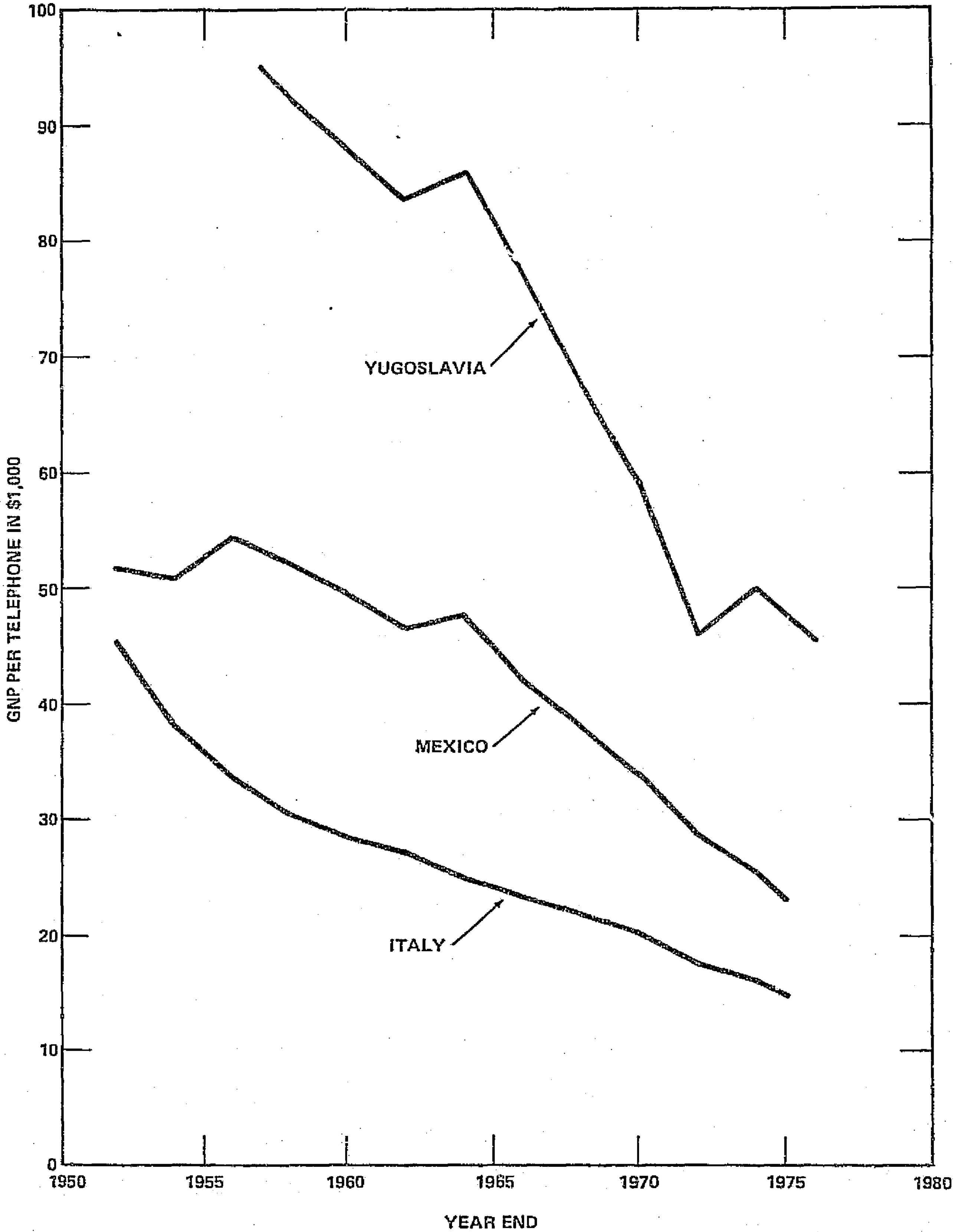


FIGURE B–4
GNP PER TELEPHONE

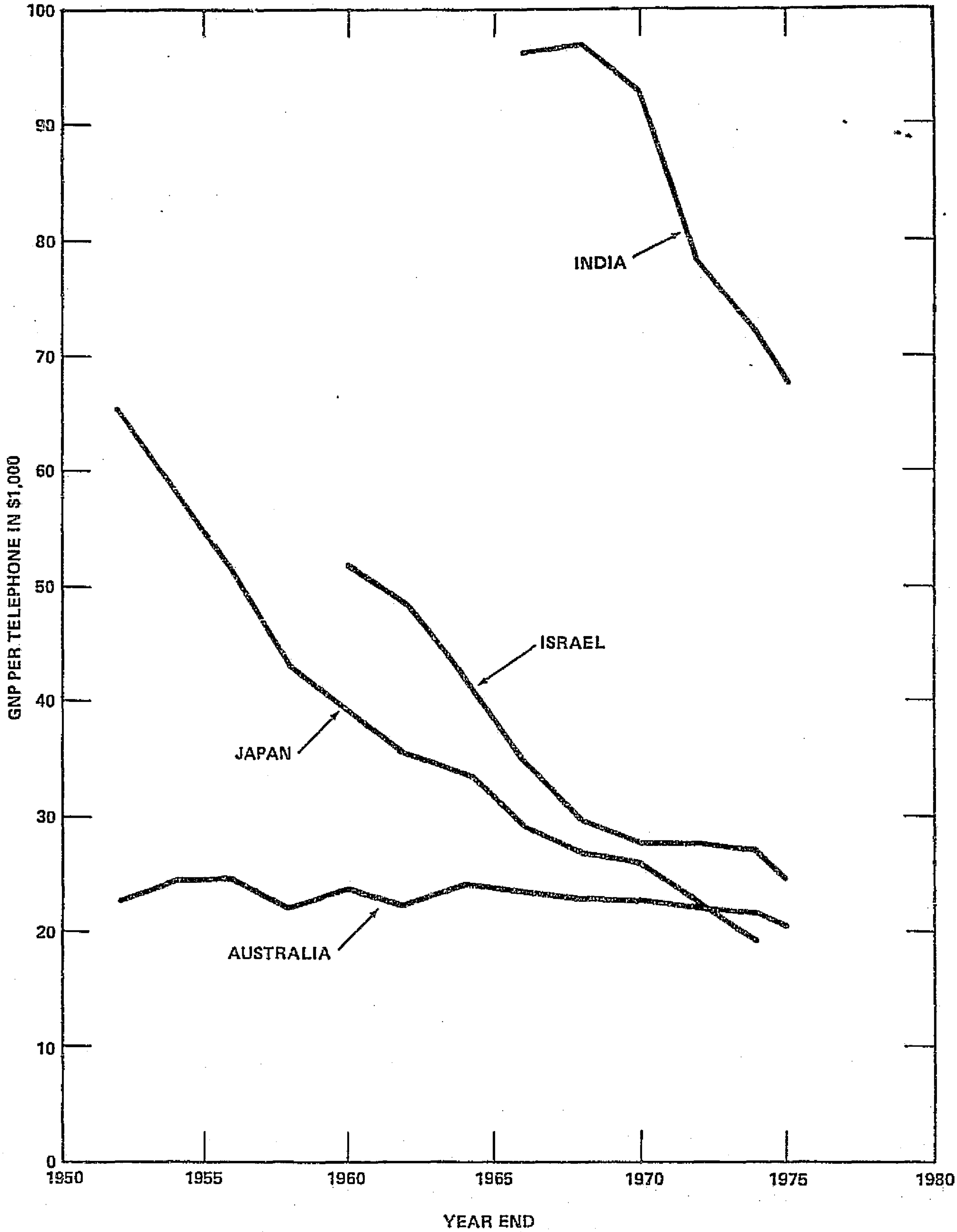


FIGURE B–5
GNP PER TELEPHONE

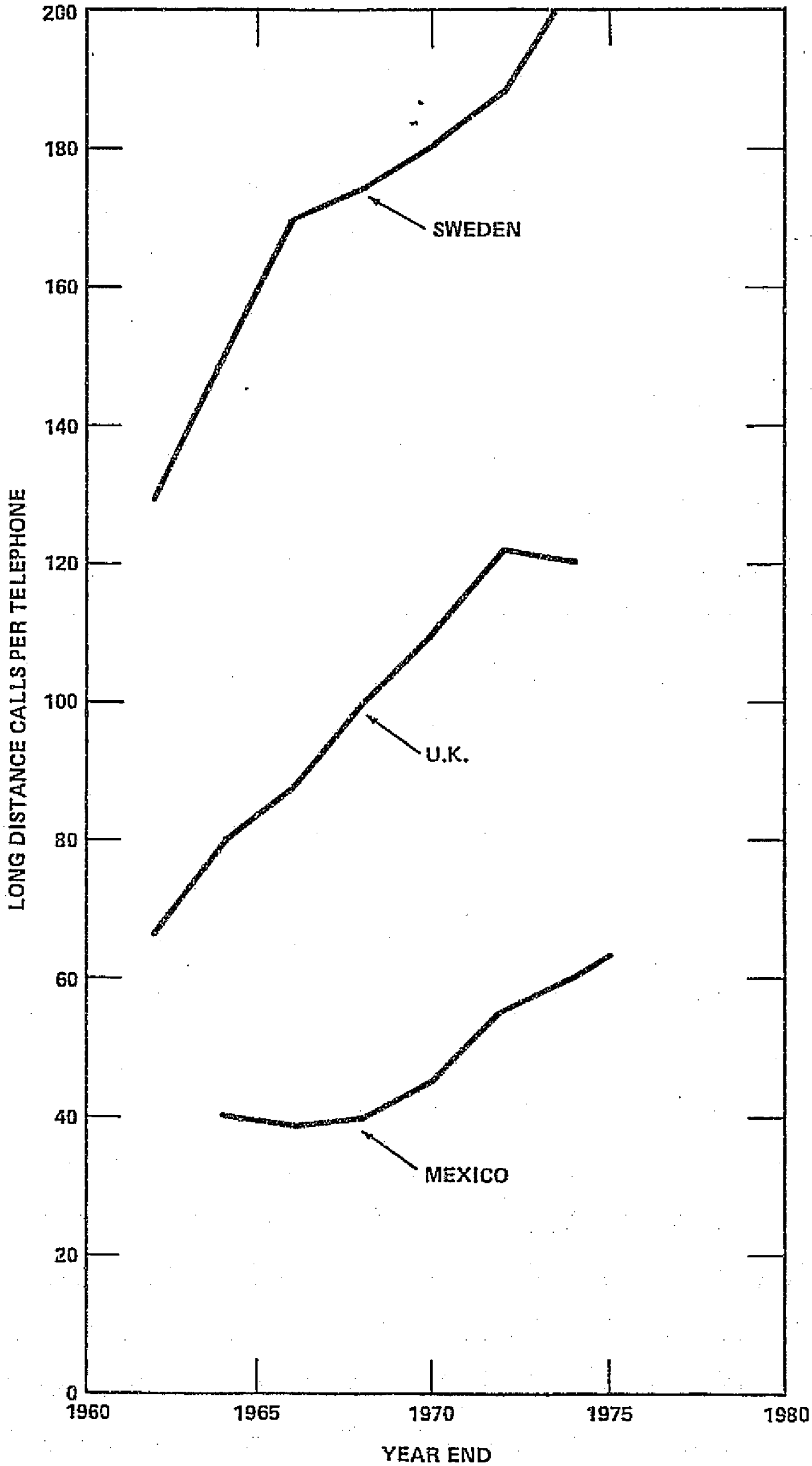


FIGURE B–6
LONG DISTANCE CALLS PER TELEPHONE

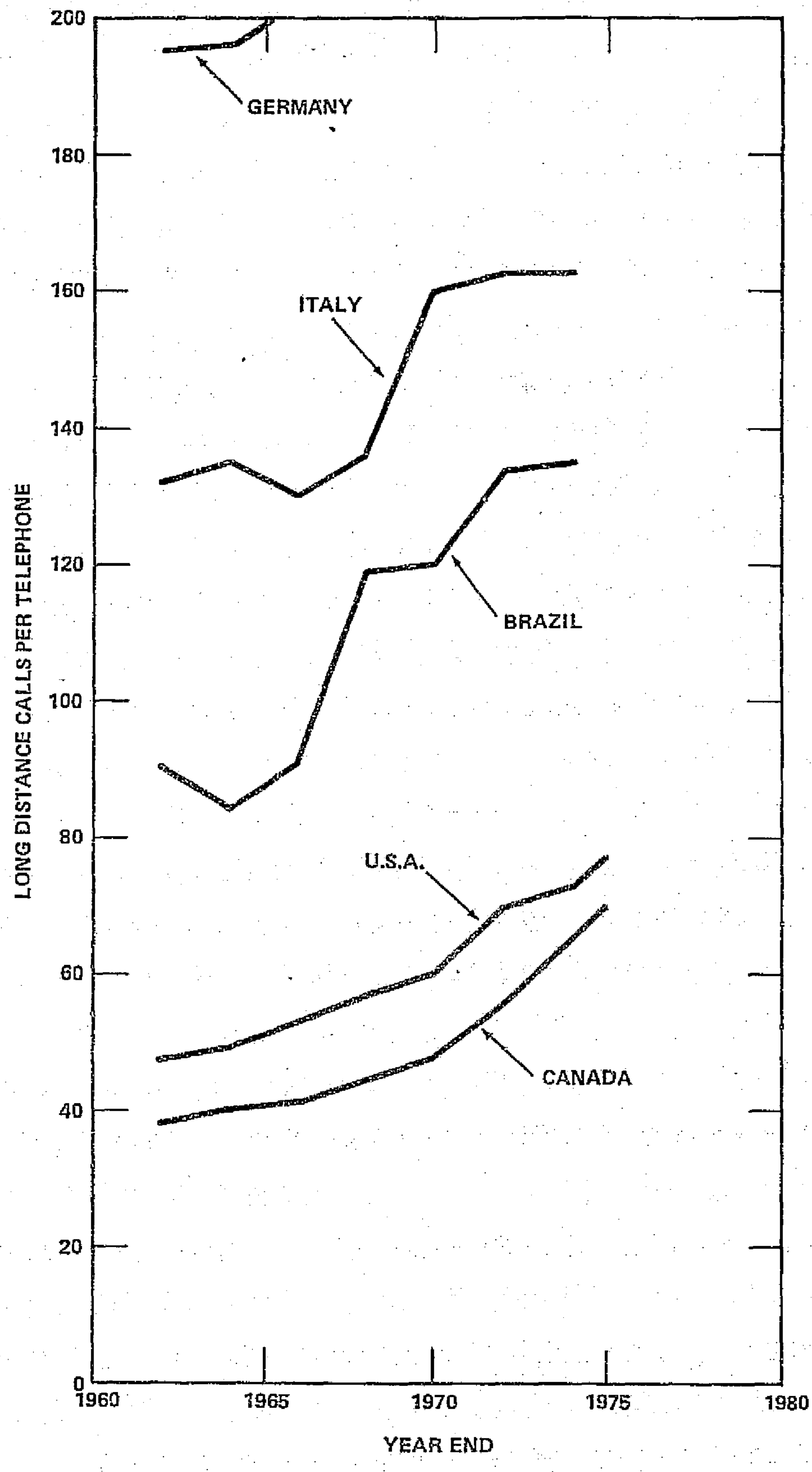


FIGURE B–7
LONG DISTANCE CALLS PER TELEPHONE

C-2

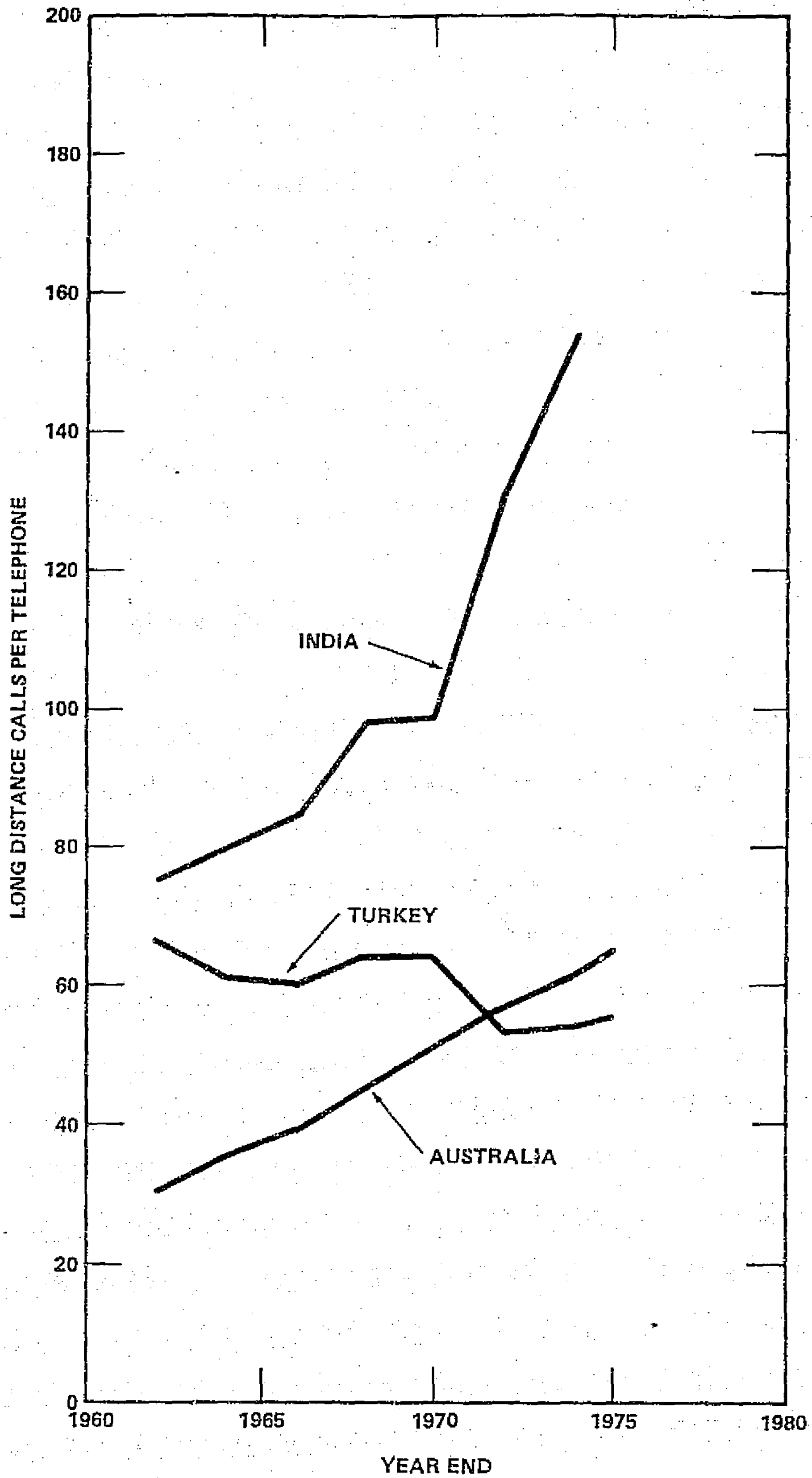


FIGURE B–8
LONG DISTANCE CALLS PER TELEPHONE

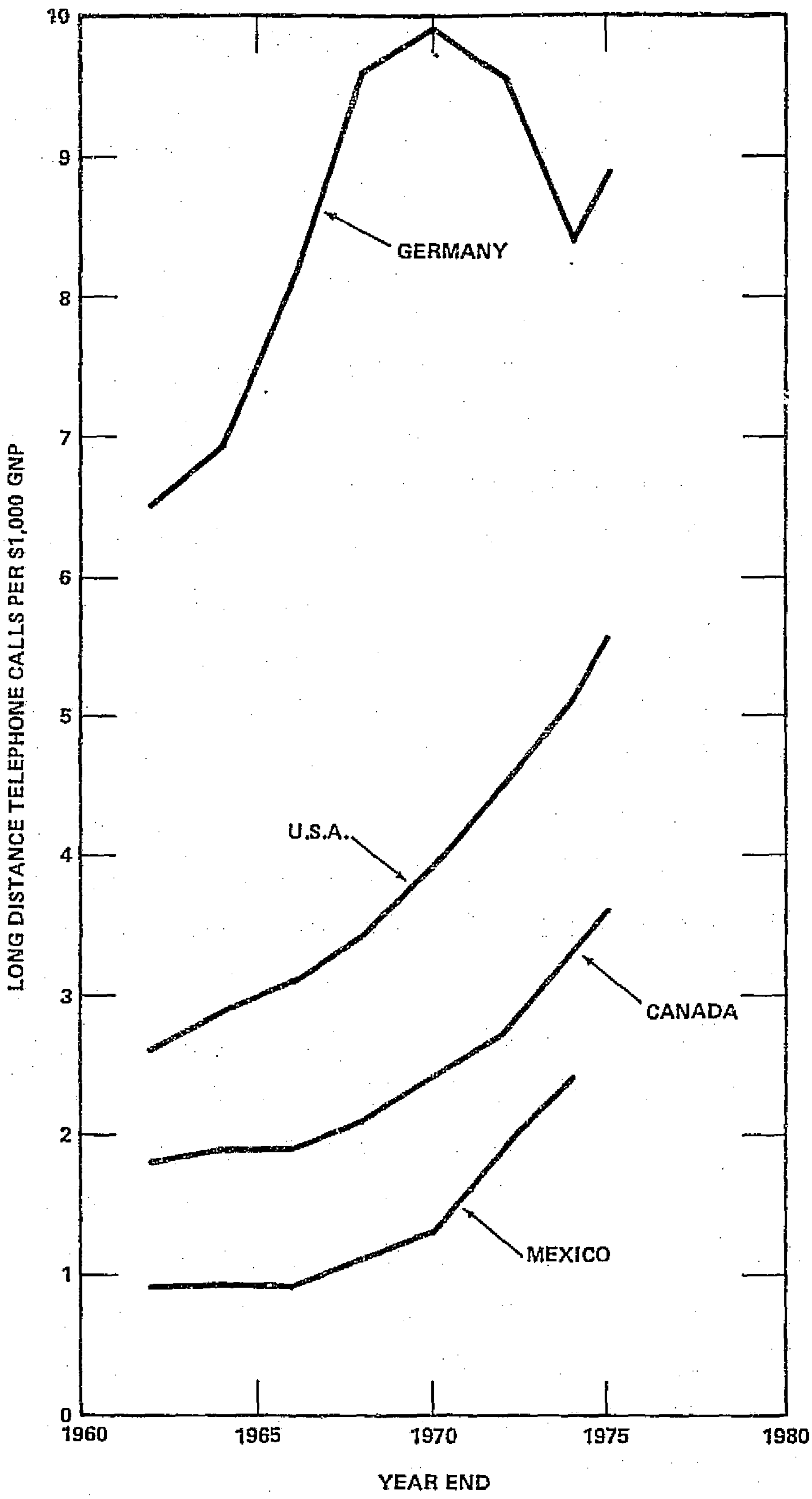


FIGURE B–9
LONG DISTANCE TELEPHONE CALLS PER $1,000 GNP

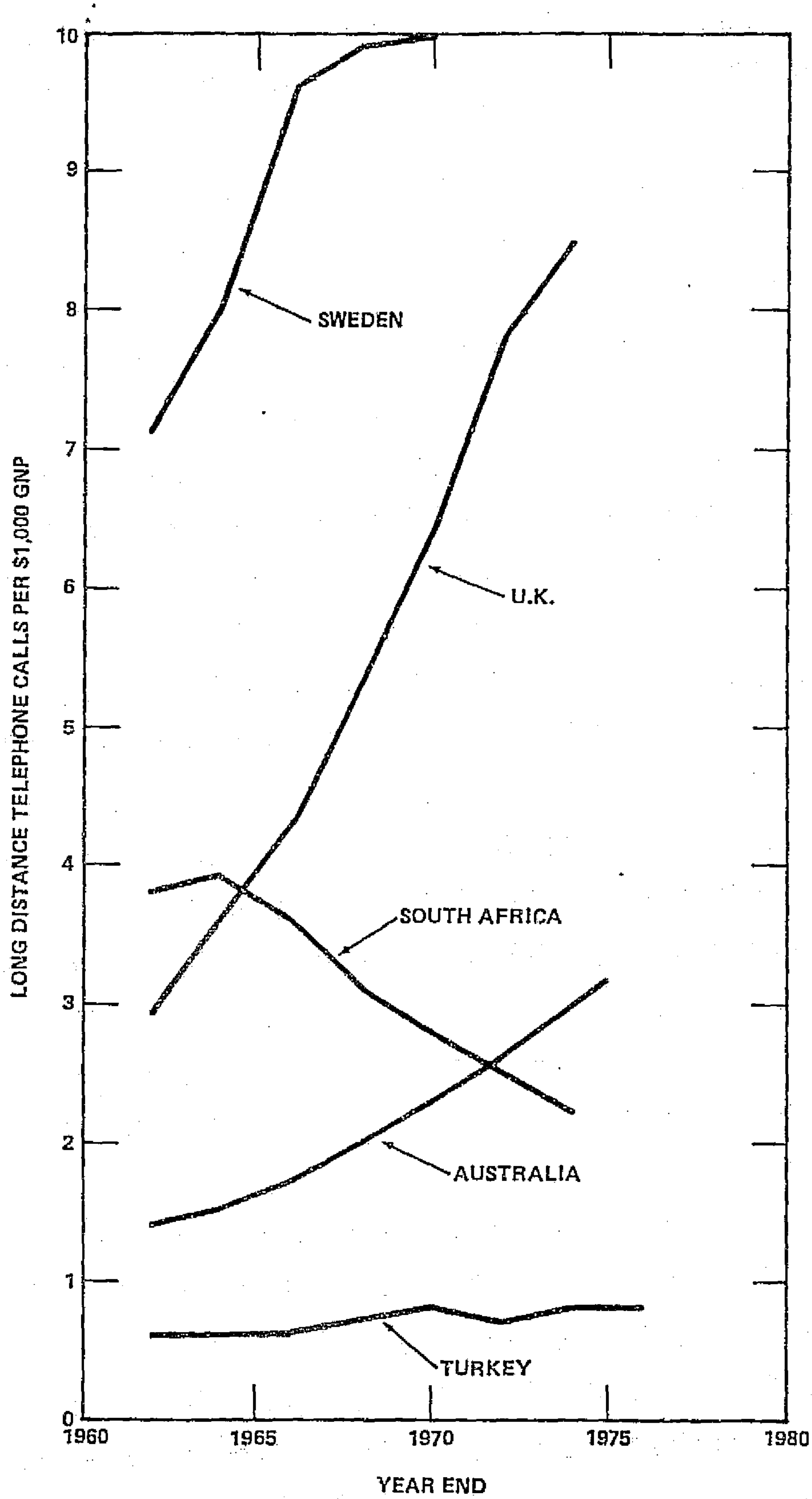


FIGURE B–10
LONG DISTANCE TELEPHONE CALLS PER $1,000 GNP

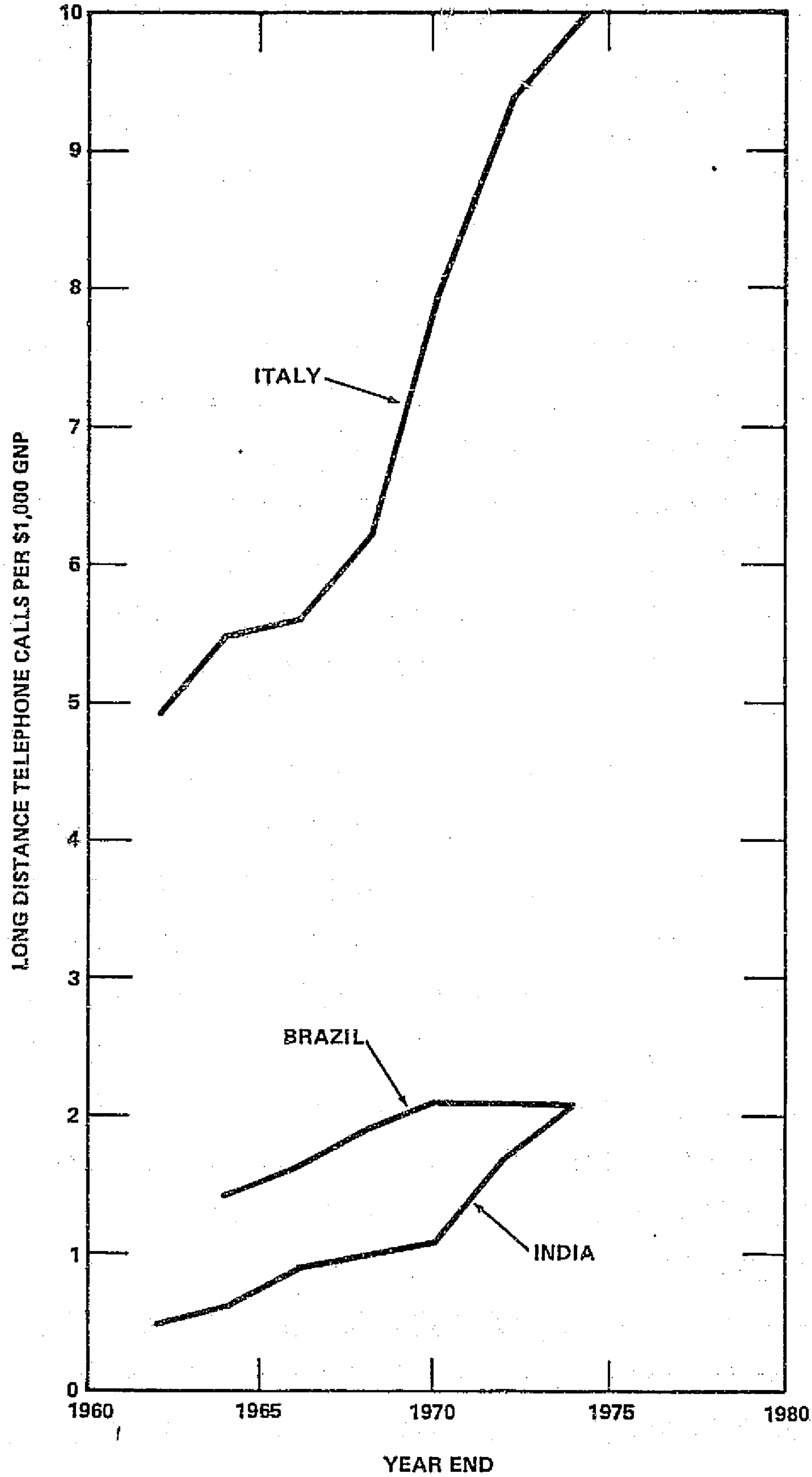


FIGURE B–11
LONG DISTANCE TELEPHONE CALLS PER $1,000 GNP

ANNEX C

VIDEO CONFERENCING

This Annex contains an excerpt of an unsolicited proposal by FSI to NASA Goddard. It is included in this report because it gives a description of the video conferencing satellite system referred to in Section 5.4 of this main report.

EXCERPT FROM AN

Unsolicited Proposal for the Conceptual Design of a

VIDEO CONFERENCING SATELLITE SYSTEM

August 18, 1977

Prepared for

NASA Goddard Space Flight Center

by

Future Systems Incorporated
4 Professional Drive, Suite 141
Gaithersburg, Maryland 20760

(301) 840-0320
TWX 710-828-9617

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

Future Systems Incorporated (FSI) is pleased to present this unsolicited proposal to NASA GSFC for a study of the conceptual design of a video conferencing satellite system.

As we are approaching the depletion of the world's oil reserves, travel costs will further increase, and it will become essential to substitute communications for travel, where practical. Teleconferencing will play an important role in this substitution.

It was found for some teleconferencing applications that sound augmented by facsimile transmission is adequate. Such conferencing is practical and economical with present transmission media. For other conferencing applications, however, high quality video is essential. The cost of present transmission media is too high and the capacity too low to permit the widespread use of video conferencing. It is suggested that NASA consider the development of the technology required to implement a high capacity video conferencing satellite system.

Presently existing and planned satellite systems have a capacity of 20 to 50 two-way video circuits per satellite, at a bit rate of 20 MBps for each one-way video channel. It is suggested that a special purpose video conferencing satellite system can be designed, with a capacity of 8,000 two-way video circuits per satellite.

Such a system will be based on multiple frequency re-use and special video processing techniques. It promises travel cost savings of about $10 billion per year for the USA and air travel substitution of about 20 percent of the 1974 air travel level. The system would pay for itself quickly and be of major benefit in the nation's oil conservation program. It is fully compatible with NASA's long-range objective for improvement in space electronics for Global Services Systems.

The proposed system requires challenging development efforts in the following areas:

Multibeam spacecraft antennas with high beam pointing stability and low sidelobe levels.

On-board signal processing and switching

Video processing for high quality transmission at low bit rates specially designed for conferencing applications.

We believe that without NASA support the industry will not be able to develop such a system in this century.

FSI proposes to conduct a study and to prepare a report on the conceptual design of such a system, including economics calculations, and to deliver the final report 2 months ARO. Because of the background of FSI personnel and extensive prior in-house work, we can prepare this report covering the complete transmission system, studio to studio, at an effort of only $1\frac{1}{2}$ men-months.

The report will provide NASA GSFC with all required information to permit evaluation of the desirability to proceed with further work on the program.

2. INTRODUCTION

As shown in the literature listed in Attachment C, it is expected that the world's oil reserves would be depleted in 30 to 50 years, if oil consumption were to increase at present rates. As a result we expect further sharp increases in oil prices, at least until oil demand is reduced by the shift to alternate energy sources. Air travel will be greatly affected by this process, since, according to the FAA, it is not expected that aircraft operating on non-petroleum sources will be in use during this century.

For this reason it will become increasingly more desirable to substitute communications for travel, where practical. The availability of high quality two-way video links in addition to regular telephony transmission will facilitate this substitution.

Regardless of whether analog or digital transmission techniques are employed, the bandwidth and power requirements for high quality video transmission are about 300 times larger than those for voice transmission. Existing telecommunications systems have generally been sized for telephony transmission and are therefore not adequate for high volume video transmission. Furthermore, the video transmission costs with conventional systems are too high to permit widespread use. On the other hand, a satellite system designed specifically for high capacity video transmission will result in substantial transmission cost reductions.

We believe that NASA should develop the necessary technology and conduct the required experiments to bring such a system into being. A high quality low cost video conferencing system will benefit the nation by reducing travel and thus oil consumption. It will improve efficiencies in conducting business and improve services, and eventually it will permit more decentralized living and work locations which will bring about a general improvement in the quality of life.

The development of such a video conferencing system is fully compatible with NASA's long-range objectives for Global Services Systems, which call for a 1000-fold increase in capability at reduced cost.[1]

[1] Peter R. Kurzhals, New Directions in Space Electronics

3. COMPARISON WITH PSCS

The proposed Public Services Communications Satellite provides CONUS coverage with four area coverage beams, steerable spot beams and special spot beams for Alaska, Hawaii and Puerto Rico at K-band as well as UHF coverage for CONUS. The antenna coverage at K-band is improved relative to TDRSS and Advanced Westar presently under construction by TRW, and the proposed levels are increased by a factor of 5 relative to TDRSS.

PSCS will therefore have a better capability to provide video conferencing than currently existing or planned commercial systems, but it will not achieve the transmission cost savings that are possible with a satellite optimized for video conferencing.

4. STATUS ON VIDEO CONFERENCING

Attachment D provides a partial listing of some of the papers and study reports on the subject of teleconferencing. The following conclusions are drawn from these studies:

a. Many experimental systems are in operation in the USA and elsewhere.

b. The majority of the users like the systems and continue to use them.

c. Some experimenters question the value of video in addition to sound, in view of the high cost of the video circuits and the small display size which does not give a life-like impression.

d. The extensive use of video conferencing will need changed behavior patterns which will require time to establish.

e. There is some reluctance to justify video conferencing systems on the basis of travel cost reduction due to the concern that this might lead to a cut in the travel budget.

f. There is general agreement that a high quality TV video conferencing with life-like video and sound presentation at low cost would be desirable and would lead to substantial substitution of communications for travel.

In our opinion, the controversy about whether video should be provided in addition to sound can be easily eliminated. We believe that there will be a need for both systems. Some conferences can well be conducted with sound only, while others will require video. Both types of systems will be developed and will be a factor in travel substitution. Sound conferencing, however, can be provided adequately with present transmission media. Only the video conferencing system provides a technical challenge and a new high capacity satellite system.

5. USE OF EXISTING OR PLANNED SATELLITE SYSTEMS

Existing or planned commercial satellite systems result in transmission costs per voice channel of about $6,000 per voice circuit year, equivalent to the terrestrial circuit lease costs for 500-route miles distance. The space segment alone for a high quality video circuit costs about $1.5 million per year. The video circuit capacity of existing and planned commercial systems is as follows:

Satellite	Number of Two-Way Video Circuits*
Westar, 12 transponders, 60 MBps per transponder	18
Satcom (RCA), 24 transponders, 60 MBps per transponder	36
Comstar, 24 transponders, 60 MBps per transponder	36
TDRSS type, assumed 1500 MBps at k-band and 750 MBps at C-band	56
SBS satellite, 10 transponders of 43 MHz	18
PSCS, assumed 3 times frequency re-use, 2,250 MBps	56

It can be seen that a single satellite can support approximately 20 to 50 two-way video circuits. In comparison, the same satellites have a capacity of 5,000 to 17,000 voice circuits. The small video capacity inevitably keeps the cost per video circuit high.

Even worse is the fact that the low video capacity per satellite will prevent widespread use. Even if people were willing to pay the price for more circuits, the limitations in orbital arc availability would prevent the placement of sufficient conventional satellites. To have real impact, a special purpose, high capacity video satellite is needed.

*Based on 20 MBps per one-way video channel

6. MULTIPLE SPOT BEAM CONCEPT

The use of multiple spot beams to achieve area coverage is the most effective way to increase channel capacity of a satellite. Multiple spot beams have the following advantages:

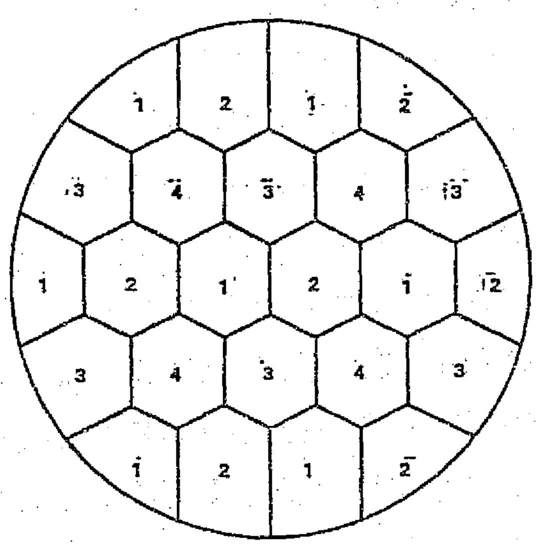
a. Capacity increase due to frequency re-use.

b. Satellite receive and transmit antenna gain reduces satellite and earth station power requirements and earth station antenna antenna size requirements.

c. Directive spacecraft antenna beams reduce the interference from and into other systems (on a per channel basis).

The basic concept of area coverage with multiple spot beams is illustrated below.

Development work is required to provide multibeam antennas with good coverage without gaps and low sidelobe levels to limit self interference.



NUMBERS 1 – 4 INDICATE FREQUENCY ASSIGNMENT

7. SCPC VERSUS TDMA

TDMA is a good technique to provide multiple access to a transponder while operating near transponder saturation. It also permits flexible cross connection of antenna beams by means of time division switching. Each earth station, however, must transmit at peak power levels corresponding to the whole transponder bit rate.

SCPC permits simple demand-assigned transmission and reception on the ground and results in less complexity for earth stations using only one or a small number of circuits. Flexible interconnection of satellite beams, however, is more demanding on spacecraft design, and may well require demodulation and switching within the satellite.

Both alternatives will have to be considered in detail before a decision can be made as to which one is preferable. At this time we consider the SCPC solution to be the more promising one. Either solution presents a challenging development effort.

8. SATELLITE CAPACITY

Satellites may operate at 12/14 GHz or 18/30 GHz or at both bands. The available bandwidths are 500 and 2500 MHz, respectively. The achievable satellite capacities depend on the number of frequency re-uses.

Satellite Capacity With Current Coding Techniques

Frequency Band	12/14 GHz	18/30 GHz	Both Bands
Bandwidth per frequency use in MHz	500	2500	3000
Megabits per second per frequency use	800	4000	4800
Two-way video circuits per frequency use	20	100	120
Video Circuits Per Satellite With Frequency Re-use as Shown:			
2 times frequency use	40	200	240
4 times frequency use	80	400	960
10 times frequency use	200	1000	1200
20 times frequency use	400	2000	2400

The premise of these calculations is that high quality, two-way video is desirable. A bit rate of 20 MBps has been chosen for a one-way channel, since at least one currently available system* may have adequate quality at this bit rate. Further advances in digital coding will permit improvements in quality at 20 MBps or the same quality at lower bit rates.

*NETEC by NEC

Unlike network TV which requires good quality sports transmissions with occasional high rate of change of picture content, video conferencing need not employ zooming and panning techniques. The background is relatively static and the overall rate of change of picture content is small. This feature permits the design of special video coding circuitry for high quality transmission at low bit rates.

The approach that was taken by NEC may be further developed for this specific application as follows:

a. Store at least one complete frame and transmit only frame to frame changes.

b. Increase the quantizing steps for those portions of the picture which are in rapid motion. The eye is not sensitive to quantizing noise on moving pictures.

We consider it likely that special coding will permit the reduction of bit rates by factors of 2 to 4, with an equivalent increase in channel capacity.

With 20 times frequency use and 4 times improvements in coding, the total achievable capacity is 8,000 to 10,000 two-way video circuits per satellite.

9. IMPACT ON TRAVEL

To obtain a general impression of the impact on travel that one could expect from a fully loaded video conferencing system with 8,000 video circuits per satellite, the following order of magnitude calculations are performed:

Average conference duration, in hours	3
Average number of conferences per circuit day	3
Average number of people traveling to a conference in the absence of video conferencing	2
Number of person-trips avoided:	
per circuit day	6
per satellite day	50,000
per day for a 2-satellite system	100,000
Average cost per person-trip	$ 500
Travel cost savings, per day, in millions	$ 50
Travel cost savings, per year, with 200 days per year, in billions	$ 10
Average passengers per flight	100
Flights avoided, per day	1000
Person-trips avoided, per year, in millions	20
Total emplaned passengers in 1974, in millions	207
Total reduction in air-travel, 1974 level	20%

As mentioned above, this is an order of magnitude calculation. All figures are estimates, except for the total passengers emplaned, which was taken from an FAA study.

In practice, the satellite system will be used for improved service as well as for travel substitution. Thus, not the total capacity would be available for travel substitution. On the other hand, travel substitution will favor the longer distances, and therefore the 20 percent figure may be realistic.

A similar system could be used by INTELSAT on a global basis to help reduce international travel.

These results show that a very high capacity satellite is necessary both to reduce circuit costs and to have a measurable impact on total travel.

ANNEX D

SATELLITE RELIABILITY HISTORY

This Annex provides summary information on the reliability history of the INTELSAT satellites. This information has been used for the prediction of future satellite lifetimes, which is required for the generation of a satellite replacement schedule.

Tables D-1 through D-4 show the launch dates and success history of all INTELSAT satellites launched to date. Table D-5 shows the evaluation of satellite lifetime data based on the satellites which have failed so far, and on successful in-orbit experience with the nine satellites currently in orbit and still operating satisfactorily.

Table D-6 is the listing of launch attempts, failures and successes.

Table D-1

Satellite type	Intelsat I			Intelsat II	
Satellite mfg.	HAC			HAC	
Estimated number of parts	3,500			5,000	
Number of transponders	1			1	
Design life, years	1.5			3	
Flight No.	F1	F1	F2	F3	F4
Launch date	4/65	AF*	1/67	3/67	9/67
Date of failure	5/70		8/70	10/70	8/71
Lifetime, years	5.1	--	3.6	3.6	3.9

*AF = Apogee Motor Failure

Table D-2

Satellite type	Intelsat III
Satellite mgf.	TRW
Estimated number of parts	7,000
Number of transponders	2
Design life, years	5

Flight No.	F1	F2	F3	F4	F5	F6	F7	F8
Launch date	LF*	12/68	3/69	5/69	LF*	1/70	5/70	AF**
Date of failure		5/70	5/69 6/77	11/72		1/75	5/71 1/72	
Lifetime, years	--	1.4	0.2 7.3 (3.7)	3.5	--	5	1 1.6 (1.3)	

*Launch Failure

**Apogee Motor Failure

Table D-3

Satellite type	Intelsat IV
Satellite mfg.	HAC
Estimated number of parts	17,000
Number of transponders	12
Design life, years	7

Flight No.	F2	F3	F4	F5	F6	F7	F8	F1
Launch date	1/71	12/71	1/71	6/72	LF*	8/73	11/74	5/75
Date of failure	6/77	--	--	--		--	--	--
Life time, years	6.4	>5.7	>5.6	>5.2		>4.0	>2.8	>2.3

*Launch Failure

Table D-4

Satellite type		Intelsat IV-A	
Satellite mfg.		HAC	
Estimated number of parts		19,000	
Number of transponders		20	
Design life, years		7	
Flight No.	F1	F2	F4
Launch date	9/75	1/76	5/77
Date of failure	--	--	--
Life time, years	>1.9	>1.7	>0.3

Table D-5

Evaluation of Lifetime Data

Satellite Series	Intelsat I/II	Intelsat III	Intelsat IV/IV-A
Actual Failures, Years after launch	5.1	1.4	6.4
	3.6	3.8	
	3.6	3.5	
	3.9	5.0	
		1.3	
Mean Life	4.1	3.0	7
Standard Deviation	0.62	1.43	1

Table D-6

Launch Failures and Apogee Motor Failures

Satellite Series	Launch Attempts	Launch Failures	Apogee Motor Failures	Successful Orbit Injection
Intelsat I	1	--	--	1
Intelsat II	4	--	1	3
Intelsat III	8	2	1	5
Intelsat IV	8	1	--	7
Intelsat IV-A	3	--	--	3
Total	24	3	2	19
Percent	100	13	8	79