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GEOSYNCHRONOUS PLATFORM DEFINITION STUDY

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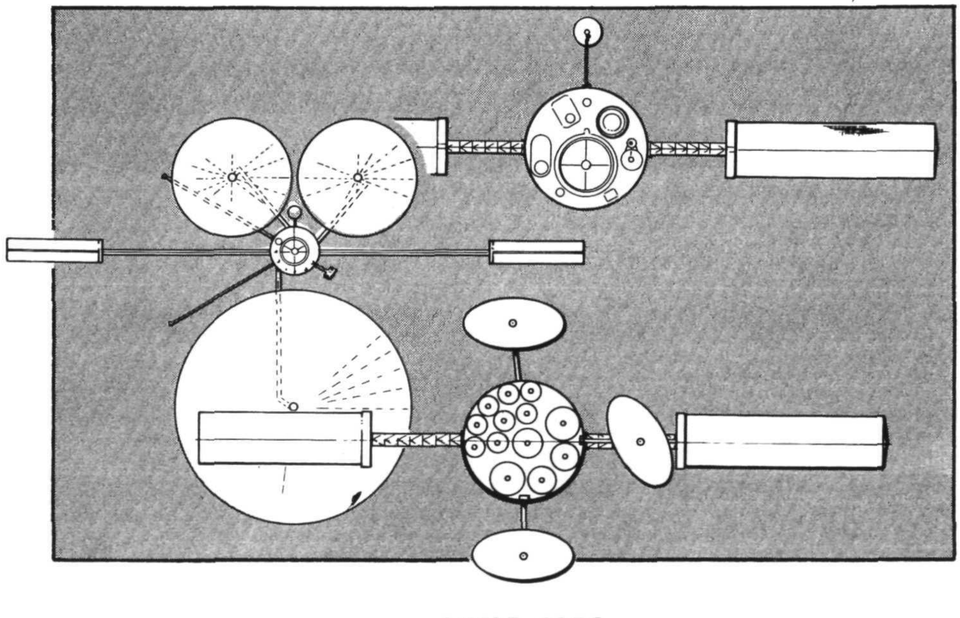
Volume IV - Part 2

TRAFFIC ANALYSIS AND SYSTEM REQUIREMENTS FOR THE NEW TRAFFIC MODEL



JUNE 1973

Space Division
Rockwell International

12214 Lakewood Boulevard
Downey, California 90241

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Volume IV - Part 2
TRAFFIC ANALYSIS AND SYSTEM REQUIREMENTS FOR THE NEW TRAFFIC MODEL

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FOREWORD

The Geosynchronous Platform Definition Study was a pre-Phase A analysis conducted by the Space Division of Rockwell International Corporation (Rockwell) under Contract NAS9-12909 for the Lyndon B. Johnson Space Center of the National Aeronautics and Space Administration. The study explores the scope of geosynchronous traffic, the needs and benefits of multifunction space platforms, transportation system interfaces, and the definition of representative platform conceptual designs. The work was administered under the technical direction of Mr. David Brown (Telephone 713-483-6321) of the Program Planning Office/Future Programs Division of the Lyndon B. Johnson Space Center.

This report consists of the following seven volumes:

Volume I - Executive Summary	SD 73-SA-0036-1
Volume II - Overall Study Summary	SD 73-SA-0036-2
Volume III - Geosynchronous Mission Characteristics	SD 73-SA-0036-3
Volume IV, Part 1 - Traffic Analysis and System Requirements for the Baseline Traffic Model	SD 73-SA-0036-4 Part 1
Volume IV, Part 2 - Traffic Analysis and System Requirements for the New Traffic Model	SD 73-SA-0036-4 Part 2
Volume V - Geosynchronous Platform Synthesis	SD 73-SA-0036-5
Volume VI - Geosynchronous Program Evaluation and Recommendations	SD 73-SA-0036-6
Volume VII - Geosynchronous Transportation Requirements	SD 73-SA-0036-7

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ABBREVIATIONS

ASCS	Attitude stabilization and control system
ATS	Applications Technology Satellite
CCD	Charge coupled device
CCIR	Consultative Committee for International Radio
CM	Crew module
C/N	Carrier-to-noise ratio
COMM	Communications
Comsat	Communications Satellite
CSM	Common support module
DMS	Data management subsystem
Domsat	Domestic Communications Satellite
ECS	Environmental control subsystem
EIRP	Effective isotropic radiated power
EPS	Electrical power subsystem
FDMA	Frequency division multiplexing
FM	Frequency modulation
GEOPAUSE	Geodetic satellite in polar geosynchronous orbit
Geoseps	Geosynchronous solar electric propulsion stage
Intelsat	International Communication Satellite
IPACS	Integrated power and attitude control system
Mersat	Metrology and Earth Observations Satellite
Navsat	Navigation and Traffic Control Satellite

OTS	Orbital transportation system
PCM	Pulse code modulation
PSK	Phase shift keying
RCS	Reaction control subsystem
RSU	Remote service unit
SATA	Small Application Technology Satellite
SEP	Solar electric propulsion
SGLS	Space-ground link subsystem (part of U.S. Air Force Satellite Control Facility)
SNR	Signal-to-noise ratio
SSM	Spares storage module
STDN	Spaceflight tracking and data network
STS	Space transportation system
TDMA	Time division multiple access
TDRS	Tracking and Data Relay Satellite
TPS	Thermal protection subsystem
TT&C	Tracking, telemetry and command
UHF	Ultra high frequency
VHF	Very high frequency
WARC	World Administrative Radio Conference
XMTR	Transmitter

1.0 INTRODUCTION

This volume presents the traffic analyses and system requirements data generated during the Geosynchronous Platform Definition Study. It is divided into two parts: the baseline traffic model and the new traffic model.

The new traffic model discussed in this part was derived principally from forecasts of user demands and was intended to reveal the true potential for geosynchronous traffic. Study results presented in this part include:

1. Selection of candidate functions employing geosynchronous operations, development of forecast models projecting user demand levels and growth profiles for each function, and the synthesis of traffic elements and delivery schedules based on satellite characteristics similar to those contained in the baseline traffic model.

2. Satellite location criteria and the resulting distribution of the satellite population.

3. Geosynchronous orbit saturation analyses, including the effects of satellite physical proximity and potential electromagnetic interference.

4. Platform requirements, which differ from those generated by the baseline traffic model because of the additional amount and types of traffic.

As with the baseline model, the development of the new traffic model is described and its missions analyzed to determine the potential grouping of satellites for geosynchronous platforms. Satellite crowding also was investigated based on the traffic indicated in the new model. These efforts were combined with those resulting from the baseline traffic model study to provide the system-level requirements and guidelines for the candidate platform designs presented in Volume V. They also served as the key source for key mission and schedule data used in the program evaluation presented in Volume VI.

2.0 SUMMARY

This section provides a condensed summary of the traffic analyses and systems requirements for the new traffic model. The results of each study activity are explained, key analyses are described, and important results are highlighted.

NEW TRAFFIC MODEL

The new traffic model was structured on the basis of the utilitarian benefits it provides to mankind. This represents a different approach than applied to the baseline traffic model described in Part 1. The baseline model was based principally on historical trends and provided a traceable base of mission planning data which relates to other industry studies. The new traffic model reflects the dynamic growth in satellite communications and other space applications which is just beginning to emerge. It was intended to represent the true potential for geosynchronous traffic through 1990. These traffic models form the basis for defining the nature, number, and schedule of geosynchronous mission activities which are utilized as key input data to many important tasks.

The approach to construction of the new traffic model is outlined in Figure 2.0-1. Twenty-two major functions were identified which require the unique features provided by geosynchronous operations. Forecast models of user demands and their projected growth profiles were constructed for each function. Commercial functions were based on estimates of the user population for the United States and then extrapolated to other world areas. Scientific and developmental functions were based on budget forecasts of U.S. and foreign national space programs. These provided the requirements for synthesizing geosynchronous programs. For convenient comparison with the baseline traffic model, the functional demand profiles were converted into the number of equivalent satellites required to satisfy the demands. The resulting traffic summary for the new model is shown in Table 2.0-1. As can be seen, 413 satellites are required compared to the 180 contained in the baseline model.

The same satellite location criteria used to determine satellite distribution for the baseline traffic model were applied to the satellite population in the new model. The resulting distribution by year for each of the six zones is shown in Table 2.0-2. Also included are the number of inactive satellites remaining on-orbit if all those whose active mission life expires after the reusable tug becomes available (1982) are retrieved. If no satellites are retrieved and allowances are made for the pre-1973 population and projected estimates of DoD traffic, the total 1990 on-orbit population will become 499 satellites.

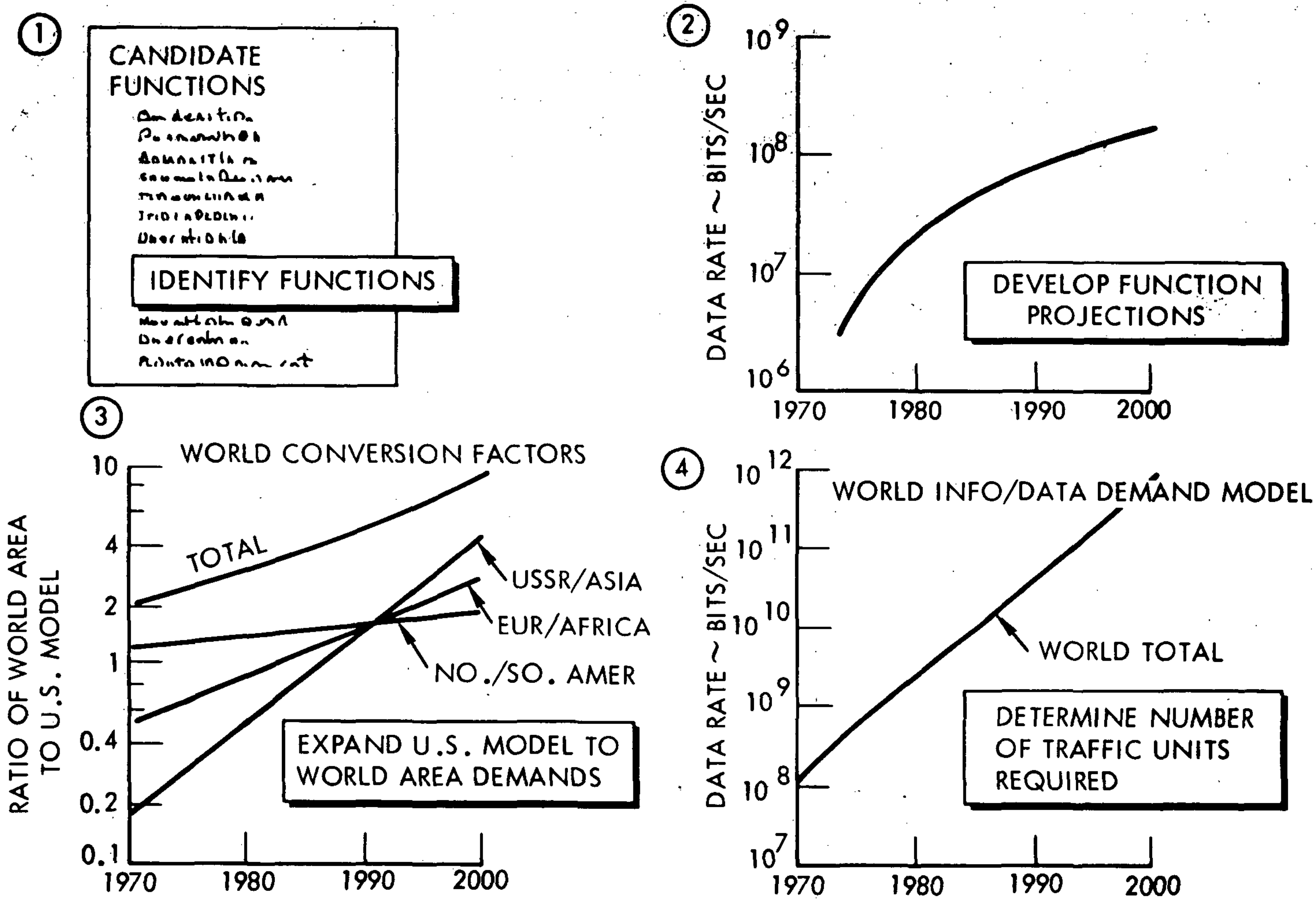


Figure 2.0-1. New Traffic Model Development Approach

Table 2.0-1. New Traffic Model Summary

SATELLITE TYPE	SCHEDULE (CALENDAR YEAR)																		TOTAL	SUB-TOTAL	CUM TOTAL
	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90			
INTELSAT																					
ATLANTIC OCEAN	1			1	1		1		1		2	1	1	2	1	2	1	3	18		
PACIFIC OCEAN	1			1		1		1		1	2	1	2	1	2	2	3	4	22		
INDIAN OCEAN		1			1		1	1		1	1	2	1	3	3	2	3	4	24		
SUBTOTAL	2	1	-	2	2	1	2	2	1	2	5	4	4	6	6	6	7	11		64	64
DOMSAT																					
NORTH AND SOUTH AMERICA	1		2	2	2	2	1	1		2	3	3	3	3	3	6	7	9	50		
EUROPE/AFRICA/USSR (W)			1		1		1		1	2	2	2	2	4	6	6	10	12	50		
USSR (E)/ASIA/AUSTRALIA					2	2	2			2	2	2	4	6	8	10	18	22	80		
SUBTOTAL	1	-	3	2	5	4	4	1	1	6	7	7	9	13	17	22	35	43		180	244
MERSAT	2	2	1	2	3	-	2	2	-	2	2	-	2	2	-	-	-	-	22	22	268
NACSAT	1	-	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	-	61	61	327
ATS																					
UNITED STATES		1	1	1		1	1		1	1		1	1		1	1		1	12		
FOREIGN		2	1	2		1	2	2	1	1		2	2		1	1	3	1	22		
SUBTOTAL	-	3	2	3	-	2	3	2	2	2	-	3	3	-	2	2	3	2		34	361
ASTRONOMY																					
UNITED STATES						1		1		1		1		1		1		1	7		
FOREIGN								2		1		2		1		2		2	10		
SUBTOTAL	-	-	-	-	-	1	-	3	-	2	-	3	-	2	-	3	-	3		17	378
TDRS																					
UNITED STATES						2	1				2	2				2	2		11		
FOREIGN						2	1	1	1	1	4	3	1	1	1	4	3	1	24		
SUBTOTAL	-	-	-	-	-	4	2	1	1	1	6	5	1	1	1	6	5	1		35	413
ANNUAL TOTAL	6	6	10	13	14	16	17	15	9	19	24	26	23	28	30	43	54	60			

Table 2.0-2. Satellite Distribution for the New Traffic Model

ZONE	MODE	SCHEDULE (CALENDAR YEAR) 73		75					80					85					90
1 (0-45°E)	ACTIVE	4	5	6	6	8	6	6	7	8	9	11	13	15	18	24	29	37	47
	INACTIVE		1	2	3	4	7	9	10	11	13	13	13	13	13	13	13	13	13
	TOTAL ON-ORBIT	4	6	8	9	12	13	15	17	19	22	24	26	28	31	37	42	50	60
2 (45°E-165°E)	ACTIVE	1	3	4	5	7	11	17	19	19	23	27	30	33	39	49	61	80	103
	INACTIVE	1	1	1	1	3	3	5	8	8	8	8	8	9	9	9	9	9	9
	TOTAL ON-ORBIT	2	4	5	6	10	14	22	27	27	31	35	38	42	48	58	70	89	112
3 (165°E-165°W)	ACTIVE					2	5	5	5	5	5	5	6	6	6	6	6	6	6
	INACTIVE																		
	TOTAL ON-ORBIT					2	5	5	5	5	5	5	6	6	6	6	6	6	6
4 (140°W-165°W)	ACTIVE	3	3	3	3	3	4	4	5	5	6	8	9	10	11	12	14	16	18
	INACTIVE	2	2	2	4	4	5	6	6	6	6	6	6	6	6	6	6	6	6
	TOTAL ON-ORBIT	5	5	5	7	7	9	10	11	11	12	14	15	16	17	18	20	22	24
5 (45°W-140°W)	ACTIVE	5	5	7	13	17	20	20	21	21	20	22	24	25	27	29	35	40	46
	INACTIVE	1	2	3	4	4	5	9	10	15	18	18	17	17	17	17	17	17	17
	TOTAL ON-ORBIT	6	7	10	17	31	25	29	31	36	38	40	41	42	44	46	52	57	63
6 (0-45°W)	ACTIVE	3	4	8	9	9	9	11	12	13	13	12	12	13	14	15	15	17	19
	INACTIVE	6	6	6	7	8	10	10	14	15	15	16	16	16	16	16	16	16	16
	TOTAL ON ORBIT	9	10	14	16	17	19	21	26	28	28	28	28	29	30	31	31	33	35
1-6	ACTIVE	16	20	28	36	46	55	63	69	71	76	85	94	102	115	135	160	196	239
	INACTIVE	10	12	14	19	23	30	39	48	55	60	61	60	61	61	61	61	61	61
	TOTAL ON-ORBIT	26	32	42	55	69	85	102	117	126	136	146	154	163	176	196	221	257	300
		73		75					80					85					90

GEOSYNCHRONOUS ORBIT SATURATION

The orbit saturation analysis for the new traffic model was the same as for the baseline model: to determine the nature and degree of satellite congestion in geosynchronous orbit if the current process of launching individual satellites is continued through 1990.

As with the baseline model, satellite physical proximity and potential electromagnetic interference (EMI) were investigated for the active satellite population. The larger number of satellites in the new model forced a closer look at the simplified one-dimensional spacing model developed for the baseline traffic analyses. In this case, the effects of luni-solar perturbations were applied to the orbits of the active satellites. Even though the normal east-west stationkeeping operations are employed, the luni-solar perturbations cause long-period (53 years) cyclic changes in the inertial orientation of geosynchronous orbits.

These changes and their effects on the satellite ground traces are depicted in Figure 2.0-2. Geostationary satellites S_1 and S_2, launched in different years, acquire different orbit inclinations (i_1 and i_2), and their orbit nodes are separated by an angle dependent upon the interval between their launches. Their resultant ground trace patterns reflect these differences through the size of their figure eight patterns and the relative phase relationships within their figure eight patterns. The maximum phase mismatch which can occur within the seven-year active satellite lifetimes contained in the traffic model is slightly greater than one-tenth of a day. The effect of this mismatch is negligible on their separation distance at the point of closest approach. Thus, the minimum spacing limit between adjacent satellites is governed principally by their east-west stationkeeping capability. For this analysis, a 50 percent margin was applied to a typical stationkeeping band of ± 0.125 degree to produce an allowable spacing limit of 0.40 degree.

This compares favorably with the actual spacing projected for the active satellite populations in the new traffic model which range from 0.4 to 1.2 degrees. It was concluded that satellite physical proximity was not a critical problem with the 239 active satellites in the new mode-. Even extending this number to include inactive and estimated DoD satellites (499 satellites assuming no retrieval), the problem is not expected to be critical. As noted in Part 1, the combined effects of all orbit perturbations carry the inactive satellite populations through a total "swept" volume of space of nearly 3×10^{10} n mi^3. The average volume for a total satellite population of 499 becomes approximately 60 million n mi^3 per satellite. This enormous volume precludes any real collision hazards and supports the conclusion that physical crowding will not pose a critical problem.

Although there is no likely collision hazard, if all the communications relay satellites are configured similar to the currently planned Intelsat/Domsat satellites (24-transponder, C-band units), as assumed for purposes of constructing the satellite populations in the new traffic model, it is virtually certain that severe EMI problems will result. Even removing the conservatism in the EMI spacing model constructed for the baseline traffic analyses would not eliminate the problem. Utilizing 97-foot instead of 60-foot ground

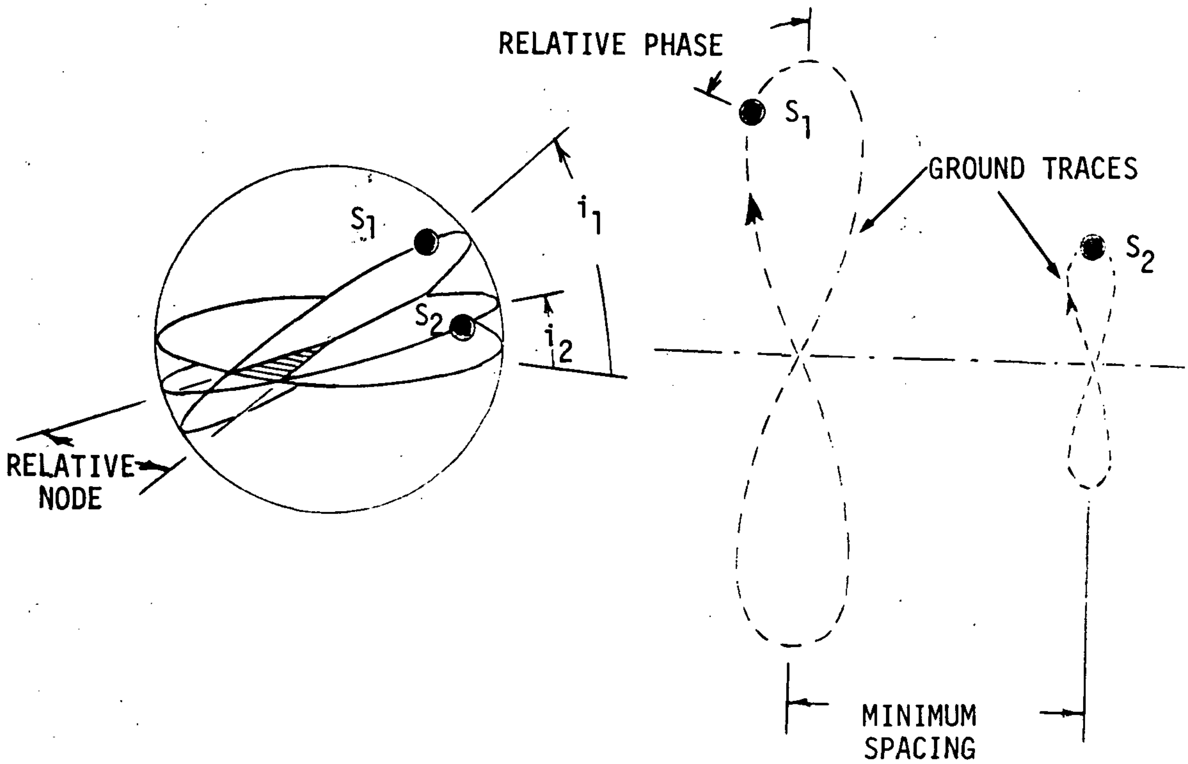


Figure 2.0-2. Satellite Spacing Geometry

antennas and allowing for separation distance effects in the ground station locations could perhaps reduce the spacing requirement from 4.6 degrees between adjacent C-band satellites to a value approaching 3.0 degrees. This spacing criterion is violated in all six zones, with a peak density approaching 0.8 degree per satellite, as shown in Figure 2.0-3 for Zone 2. Hence, it is concluded that some form of multi-function platform utilizing additional frequency bands (K-band) will be required.

GEOSYNCHRONOUS REQUIREMENTS ASSESSMENT

Geosynchronous requirements assessment involves translating the traffic analysis, satellite/payload definitions, and mission characteristics data into system-level requirements for geosynchronous platforms. It includes the groupability of payloads through physical and functional considerations and the influences of various modes of on-orbit servicing and their related criteria factors. These requirements form the basis for the subsystem sizing, mission and subsystem equipment packaging, configurational arrangement, and related design analyses leading to the platform conceptual designs presented in Volume V.

To determine the general features and size of geosynchronous platforms, the important satellite/payload characteristics and related mission functions were assessed for compatibility and commonality. Since the same categories of functions appear in both the baseline and the new traffic model and their general operational features are similar, the grouping analysis results for

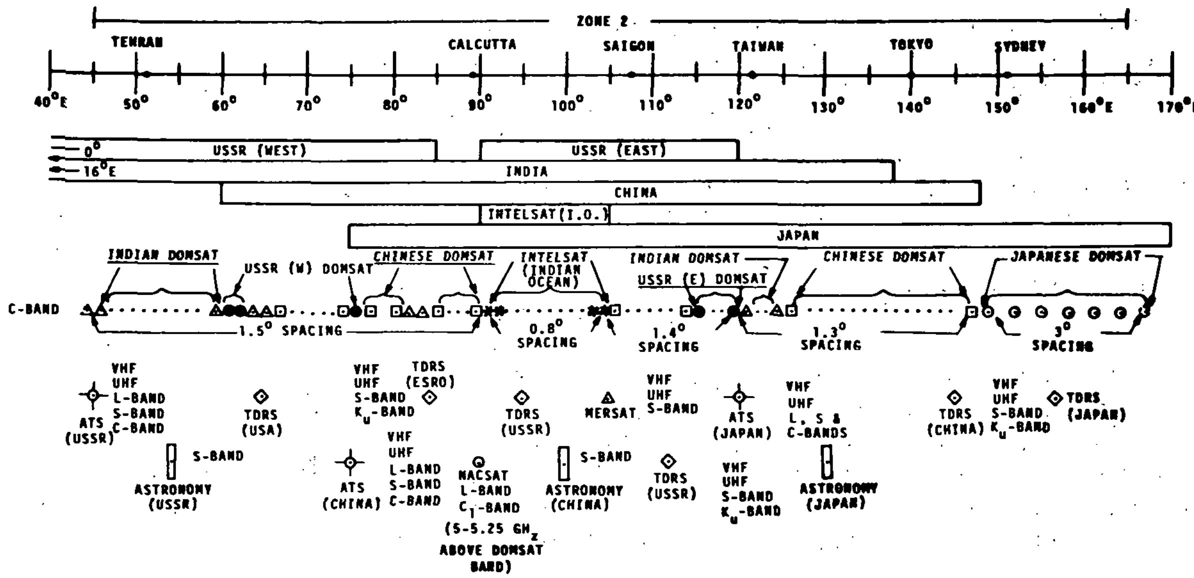


Figure 2.0-3. Zone 2 Satellite Distribution for The New Traffic Model (1990)

the baseline traffic are generally applicable to the new traffic model. The four global regions defined for the baseline traffic (Figure 2.0-5, Part 1) are applicable and the solar outage considerations require similar separation of communications payloads within each region. The other grouping constraints, such as unique placement, incompatible pointing envelopes, configuration/design complexities, and "uneven" mixes of payloads (oversize, standard, etc.) within each region, also apply and result in a similar inventory of platform types.

However, several important differences do appear. The amount of communications traffic, both domestic and international, is nearly quadrupled in the new traffic model. This means communications payloads in each region must be further separated because of technology limits. Sufficient bandwidth is not available within the usable spectrum to provide non-interfering communications at the traffic levels specified in the model. Frequency reuse utilizing multiple platforms is required. All platforms would operate with the same frequency bands but would be physically separated to preclude EMI. Thus, each communications relay platform satisfying the new traffic model would be a high-capacity device utilizing as much of the EM spectrum as technology permits.

In addition to differences in communications traffic, the navigation and traffic control function exhibits several new features in the new traffic model. Traffic coverage was extended to the polar regions, which requires inclined elliptical orbits, and the concept was extended to include position/navigation update signals in addition to the basic flow of traffic planning and control information. The orbit incompatibility coupled with the high power demands for transmitting traffic control information and navigation signals to the low-performance mobile receiver installations on the individual user vehicles

precluded their grouping with other geosynchronous payloads. Thus, the navigation and traffic control payloads were separated from the communications relay functions in the new traffic model.

Other functions remain relatively unchanged, although additional numbers of payloads may be present because of the introduction and buildup of foreign space programs. The complete inventory of platform types is summarized in Table 2.0-3 for the new traffic model. Again, as with the baseline traffic, the subsystem support requirements fall into the same general size range for all the platforms in this inventory. Also, the servicing requirements are similar. The same configurational arrangements for equipment access and provisions for servicing apply to platforms for both traffic models. Thus, the key differences between the baseline and new traffic models are centered in the communications relay traffic, its amount and distribution, and the navigation and traffic control functional and operational characteristics. These new requirements are the focal point for the platform configuration and design analyses for the new traffic model presented in Volume V.

Table 2.0-3. Platform Inventory for New Traffic Model
(Through 1990)

Platform Type	REGION			
	I	II	III	IV
Data relay	4	8	7	4
TDRS*	4	5	2	3
Earth observations	1	1	1	1
Astro-physics	2	4	2	4
Navigation and traffic control	1 + (4)**	1 + (4)	1 + (4)	1 + (4)

* Regional assignments are approximate because of unique placement requirements

** Platforms in parenthesis occupy inclined elliptical orbits

3.0 NEW TRAFFIC MODEL

The new geosynchronous traffic model was developed to accomplish a number of major objectives of the Geosynchronous Platform Definition Study. It was derived specifically from programs that maximize the benefits to mankind of geosynchronous space utilization.

The purpose of the new traffic model was to provide an independent basis (from current mission definitions) for subsequent analyses of geosynchronous mission characteristics, orbit saturation, requirements assessment, platform conceptual designs, and geosynchronous program analysis. Similar analyses were performed using the baseline traffic model. The relationship of the new traffic model to each of these analyses is shown in Figure 3.0-1.

The development approach for the new traffic model included: (1) the definition of beneficial geosynchronous mission objectives; (2) the projection of these objectives into mission requirements for the U.S. users and the extention of this to the world users; (3) the identification of the number of program elements (functional satellite types) needed to satisfy the defined requirements; (4) the definition of the program element characteristics; and (5) finally, the determination of the traffic schedule for each functional satellite type including geographic location.

The analyses performed in completing the definition of the new geosynchronous traffic model were based on preliminary Rockwell studies of information transfer traffic and utilitarian applications functions. The analyses performed in this study extended the earlier work to provide better definitions of functional and world user requirements in addition to the development of the new traffic model.

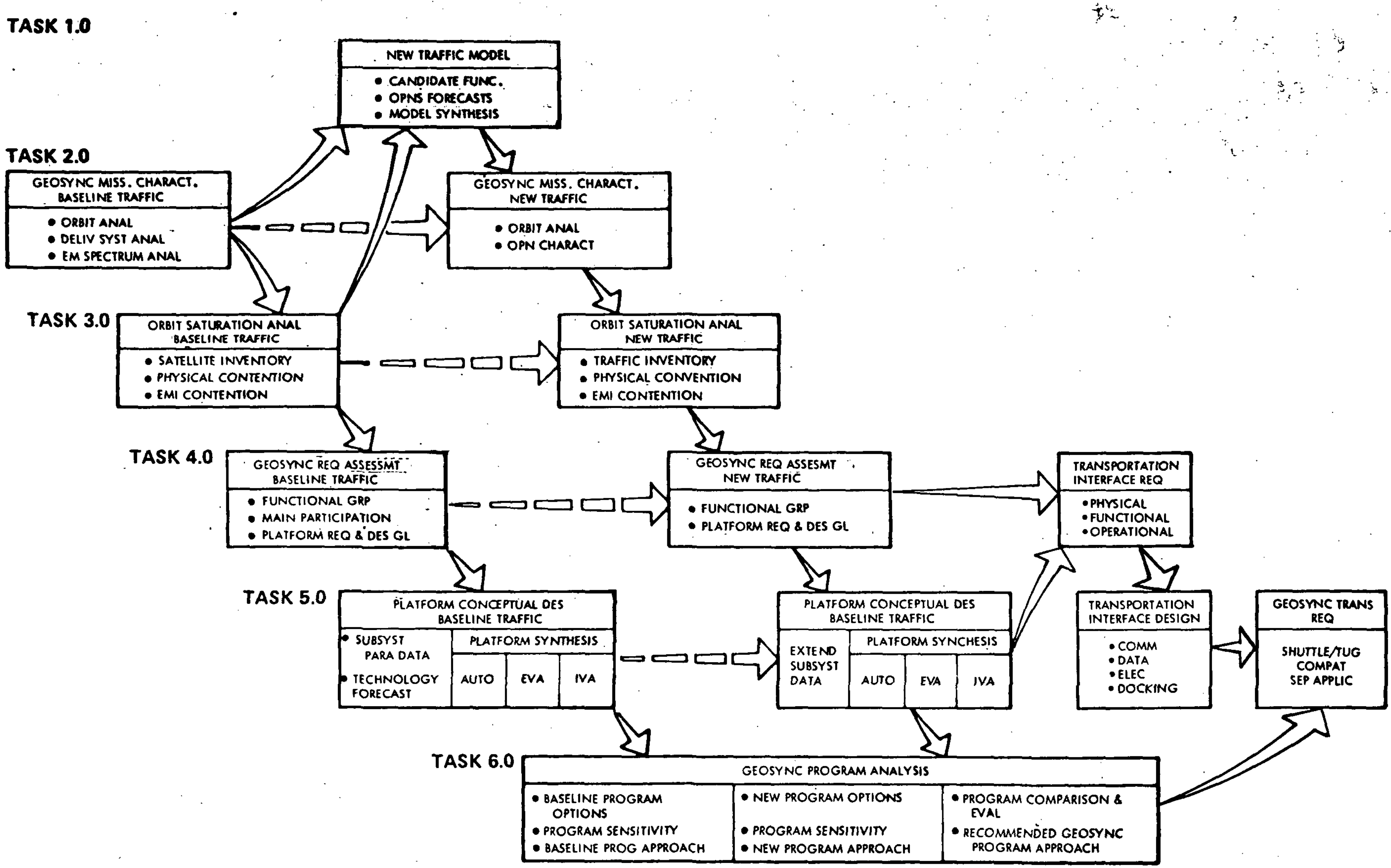


Figure 3.0-1. Geosynchronous Platform Definition Study Logic

3.1 CANDIDATE USER ORIENTED FUNCTIONAL APPLICATIONS

Candidate functions applicable to geosynchronous satellite systems are listed in Table 3.1-1 under three major categories. Communications and data functions are those which are applicable to international and domestic communications satellites. Science and applications functions are those special services that: (1) utilize sensors or equipments (onboard or remote) for global earth and environmental observations or for ship and air vehicular traffic control; (2) include space observations, the development and test of geosynchronous satellite systems of all kinds, and communications and data relay of low altitude science and applications satellite information; (3) relay light and power for terrestrial uses. National Defense includes those global communications and sensor functions necessary for national security. A detailed identification of these functions as well as communications and sensor function data traffic is classified information and is not included in the subsequent analyses and traffic model development.

Table 3.1-1. Candidate Functional Applications

Communications and Data	Science and Applications
1. Education	1. Meteorology
2. Commercial broadcast	2. Earth resources
3. Teleconference	3. Navigation
4. Telegraph	4. Aircraft control
5. Post office	5. Communications and systems test
6. Medical data bank	6. Astronomy
7. Banking/business/credit trans.	7. Tracking and data relay
8. Newspaper	8. Solar illumination
9. Electronic publishing	9. Space power relay
10. Civil defense	
11. Welfare data banks	
12. Library data banks	
13. Private record banks	
14. Telecomputations	
National Defense - communications and sensor data	

COMMUNICATIONS AND DATA

The subfunctions or scope of the 14 general functions listed in Table 3.1-1 are presented in Table 3.1-2. A general identification of source and user is also included. The function scope is identified to provide the basis for quantifying the amount of communications and data traffic that is projected for satellite relay. Most of the communications and data functions involve

Table 3.1-2. Candidate Communications and Data Functional Applications

Specific Function	Function Scope	Source	User
1. Education	Preschool, grade school, high school, college/universities, invalid, criminal, rural community	Educational broadcast stations	Schools, homes, hospitals, prisons
2. Commercial Broadcast	News, movies, theater, religious programs, entertainment programs, sports events, national and international special events	Commercial broadcast stations	Homes, hospitals, prisons, theaters, schools
3. Teleconferencing	Telephone, videophone, teleconference (conventions, business committees)	Person, union, legislature, U.N., embassies, business, etc.	Person, union, legislature, U.N., embassies, business, etc.
4. Telegraph	Personal greetings, emergency messages, urgent business correspondence	Individuals, businesses	Individuals, businesses
5. Post Office	Facsimile or video transmissions of letters/data	110 regional postal centers	110 regional postal centers
6. Medical Data Bank	Blood, eye, organ banks, hospital records, personal medical records, medical diagnostic data and consultation, medical library	Doctor, hospital, medical center, data center	Doctor, hospital, medical center, data center
7. Banking and Business Credit Transactions	Bank and credit card transactions, credit verification	Banks, savings and loan associations, credit centers, specific card center	Banks, savings and loan associations, credit centers, specific card center
8. Newspaper	Syndicated news dissemination and daily papers	Syndicate news center	Syndicate news printers
9. Electronic Publishing	Books and weekly to monthly periodicals	Publishing center	Remote publishing sites
10. Civil Defense	Law enforcement and emergency communications in disasters	City, State, Federal law and disaster centers	City and rural law centers, homes (emergency communication)
11. Welfare Data Bank	Social security records, housing and urban development records, unemployment records, disability and Medicare records	Service center, data center	Service center, data center
12. Library Data Bank	Microfiche transmittal and retrieval of books and technical reports from Library of Congress and other national libraries, patent data	Library, data center	Libraries, homes, business, data center
13. Private Record Banks	Large corporate and international company and government private record data bank access	Company/Corporate/Government record bank	Companies, corporations, governments
14. Telecomputations	Scientific and small business time-shared computer use, services (business and personal income tax computation, technical computations and computer-aided design), automated computer translation of languages	Type computer center	CPA's, businesses, consultants, schools, universities

two-way transmissions; i.e., send and receive at both ends of the transmission link. Exceptions would include commercial broadcast, most education, newspaper, and electronic publishing. Although some functions may be performed in several specific centralized locations, the functional users are located in all geographical land areas and more sparsely distributed in some ocean areas. Therefore, communications in this category may be point to point (telephone call), point to points (commercial broadcast), and points to point to points (data bank, etc.).

SCIENCE AND APPLICATIONS

The scope of science and applications functions is shown on Table 3.1-3. Most of the science and applications functions, with the exception of astronomy, solar illumination, and space power relay receive information from almost all of the global surface and/or low altitude space. Satellite relay or transmission of science and applications data will be directed to one or several specific functional centers for processing and distribution to users. In several cases data distribution or response to the users will be accomplished by satellite as is the case for navigation, air traffic control, tracking and satellite data control. The science and applications functions will, therefore, require points to point (meteorology, etc.), points to point to points (navigation and traffic control, etc.), and point to point (power relay, astronomy, and illumination).

Table 3.1-3. Candidate Science and Applications Functions

Specific Function	Function Scope	Source	User
1. Meteorology	Temperature, humidity, wind direction, cloud cover and altitudes, precipitation, obstructions to visibility, sea state	Balloon, buoy, ship, land sites, satellites	City and airport weather centers
2. Earth Resources	Mineral, agricultural, forestry, range, water, marine resources, topographic information	Earth's surface	State and Federal national resource centers, farm bureaus
3. Navigation	Range, range rate, to define position, course, speed data	Ships, aircraft, spacecraft	Ships, aircraft, spacecraft and control centers
4. Aircraft Control	Enroute air traffic control, and collision avoidance, air sea rescue	Aircraft	Control centers and aircraft
5. Communications and Systems Test	Communications development of direct broadcast, SHF, EHF, laser systems; test satellite support systems, on-orbit maintenance	NASA	NASA
6. Astronomy	Solar sphere monitor, XUV spectroheliograph, X-ray	Solar/stellar targets	Science organizations, universities
7. Tracking and Data Relay	Manned orbit support, satellite control, deep-space communications relay	Low-altitude spacecraft Planetary spacecraft	NASA
8. Solar Illumination	Night illumination of metropolitan and agricultural areas	Sun	Urban and agricultural area organizations
9. Space Power Relay	Energy transfer	Remote earth stations	Major metropolitan areas, general public

3.2 U.S. DATA TRAFFIC FORECASTS (COMMUNICATIONS, SCIENCE AND APPLICATIONS)

Communication and data traffic forecasts have been developed for each of the candidate functions listed in Tables 3.1-2 and 3.1-3 based on projected U.S. user demands. A primary reference source utilized for 12 of the 14 communications and data functions was "A Study of Trends in the Demand for Information Transfer", which was completed by the Stanford Research Institute (SRI) in February 1970 (Reference 3-1). Rockwell has developed the user demands for the remaining two communications and data functions (welfare data bank and telecomputations) and each of the science and applications functions. It is noted that the SRI data source presents the information traffic demands in terms of "total traffic" and "long distance traffic" only. Rockwell has extended these data further in that the percentage of the long distance traffic that would feasibly be carried by geosynchronous satellite relay has been forecasted.

This forecast analysis was accomplished by comparing measured U.S. 1970 Intelsat communications and data traffic rates with measured long distance communications and data traffic rates for the teleconference and commercial broadcast functions. (These two functions made up more than 95 percent of all Intelsat and long distance traffic.) The data comparison showed that 1.6 percent of the long distance communications traffic was being transferred by satellite. To determine the expected growth rate of satellite communications traffic, Comsat, Western Union, and several other domestic satellite contractor forecast estimates were obtained. These showed forecasted satellite usage growth rates of 30 to 40 percent per year for the next 5 to 10 years. These rates were based on previous historical growth trends. A projected growth rate of 25 percent per year was used from 1970 to the year 2000; the lower average rate being used because of the longer period (30 years) of the forecast. Using this projection, the long distance teleconferencing and commercial broadcast traffic carried by satellite will be about 30 percent of the total long distance traffic forecasted in the year 2000. Since ground versus satellite data links will probably remain highly cost competitive (at least in the U.S.) in the future, it is envisioned that an upper limit of 50 percent of long distance traffic will be carried by satellite in the year 2030. Figure 3.2-1 shows the present and projected ratio of satellite to long distance communications and data traffic based on the projected growth points.

Although Figure 3.2-1 is based on projections of the teleconference and commercial broadcast functions (which are expected to represent more than 90 percent of all communications and data traffic in the future), the ratio history projected should also be valid for the other communications and data transfer functions. Each of the functions in this category use the same communications frequencies, and the only factors that inhibit their present implementation using satellite relay are applicable user software programs, ground terminals and distribution networks. Therefore, the data shown in Figure 3.2-1 are used to forecast the satellite traffic based on total long distance traffic projections.

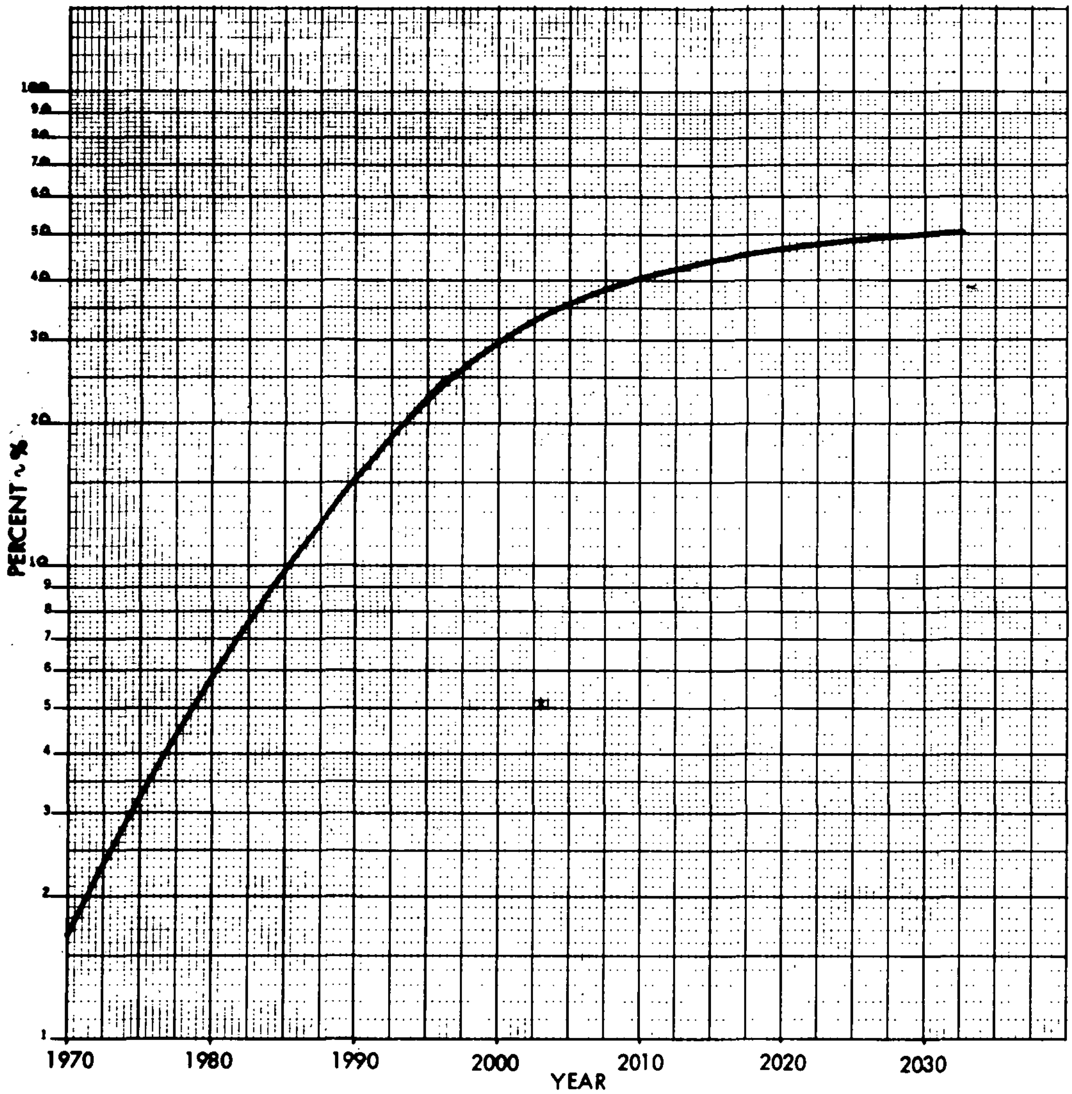


Figure 3.2-1. Ratio of Satellite to Long Distance Information Traffic

Frequent reference has been made to long distance information traffic. This raises the question, how far is "long distance"? SRI research of telephone, mail, and credit transaction functions produced several distance values for long distance traffic. Based on their values, a distance greater than 100 miles is used to distinguish long distance traffic from local traffic. Another approach to the definition of "long distance" resulted from recent Rockwell cost comparisons of satellite traffic to ground traffic. These market studies showed that satellite transmission costs are cheaper than terrestrial microwave links for distances greater than 300 miles and cheaper than telephone lines for distances greater than 150 miles. This reinforces the interpretation from SRI analyses, that any traffic greater than 100 miles can be categorized as long distance. The Rockwell cost comparisons also reinforce the concept that satellite information traffic may one day approach the 50 percent level of all long distance traffic.

The following paragraphs under each function contain reference data sources, approach, a sample computation used to determine the functional demand forecast, and the extrapolation basis or rationale.

EDUCATION

The functional information demand for education was extracted from the SRI function, television transmission (Reference 3-1). In 1970, there was one educational network and three commercial networks. SRI projects 20 networks (both education and commercial) in 1990 broadcasting 72,000 hours per year. Based on a 9-hour day and 5 day-week for educational TV and 15 hour-day and 7 day-week for commercial TV, this equates to 12 educational networks and 8 commercial networks in 1990. Twelve educational networks or, more probably, 12 educational channels in 1990 is not considered excessive when international or intranational low cost communications are a reality. Several of these channels may be foreign language oriented for outgoing and incoming educational programs.

For 1990, the average total long distance data rate projected is:

$$(12\ \text{channels}) \times (64 \times 10^6\ \text{bits/second}) = 7.68 \times 10^8\ \text{bits/second}$$

for a nine-hour day. The growth trend for the education function data rates shown in Figure 3.2-2 is based on: one channel, 8 hours per day in 1970; 8 channels, 8 hours per day in 1980; 12 channels, 9 hours per day in 1990; and 14 channels, 10 hours per day in 2000. The long distance and satellite traffic data rates are both illustrated in Figure 3.2-2.

COMMERCIAL BROADCAST

The information demand projection for commercial broadcast (by television) was obtained from Reference 3-1. As described previously, this functional data rate was computed with the education function. Based on the SRI 1990 projection and subtracting the education function, eight commercial channels, each broadcasting 5460 hours per year, are forecasted for 1990.

The average total long distance data rate projected for 1990 is:

$$(8\ \text{channels}) \times (64 \times 10^6\ \text{bits/second}) = 5.12 \times 10^8\ \text{bits/second}$$

for a 15-hour day. The growth trend for the commercial broadcast function data rates shown in Figure 3.2-3 is based on: 3 channels, 11 hours per day in 1970; 6 channels, 12 hours per day in 1980; 8 channels, 15 hours per day in 1990; and 9 channels, 16 hours per day in 2000. Both long distance and satellite data rates are illustrated for commercial broadcast in Figure 3.2-3.

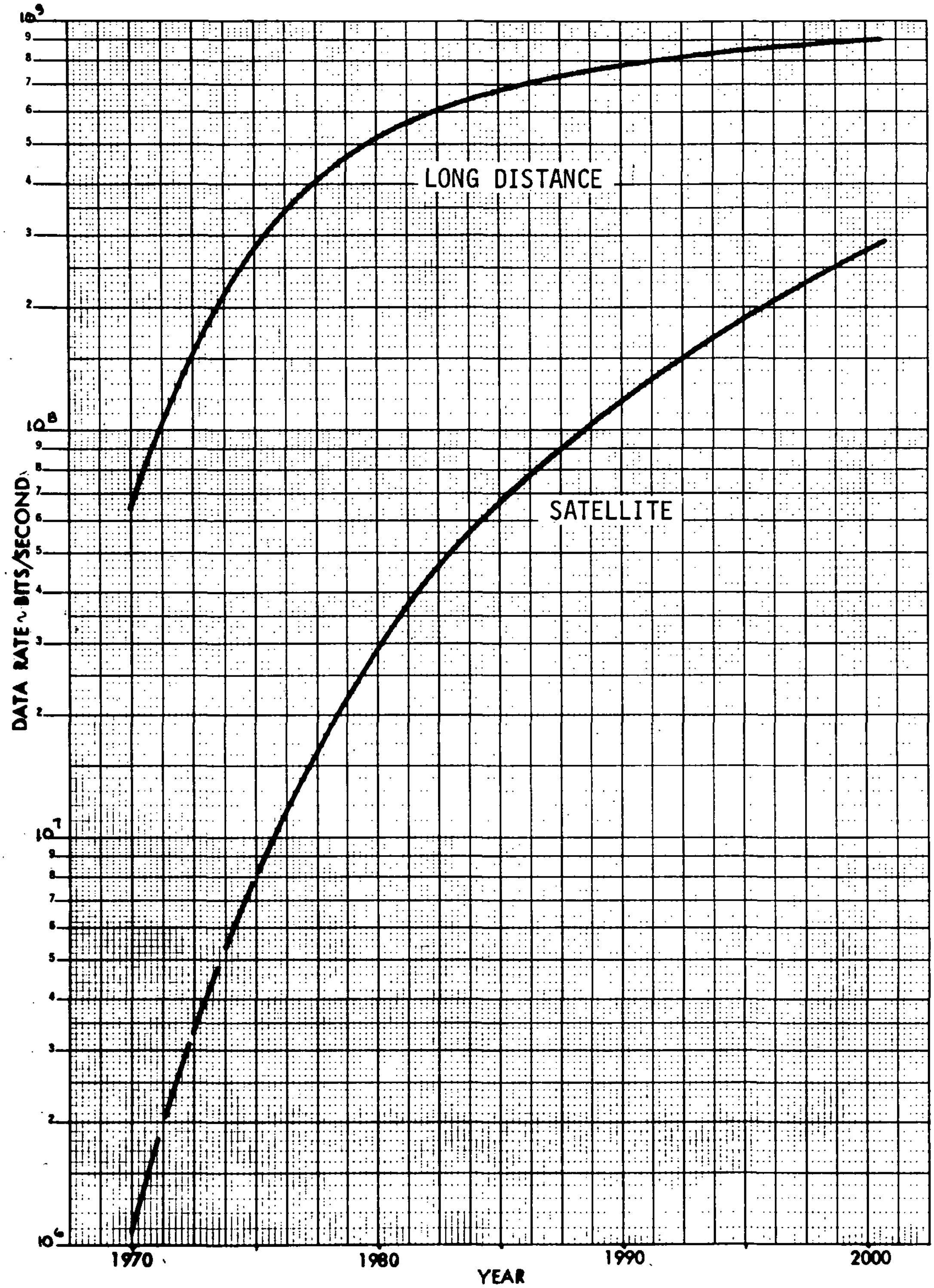


Figure 3.2-2. Education Function Demand Model for USA

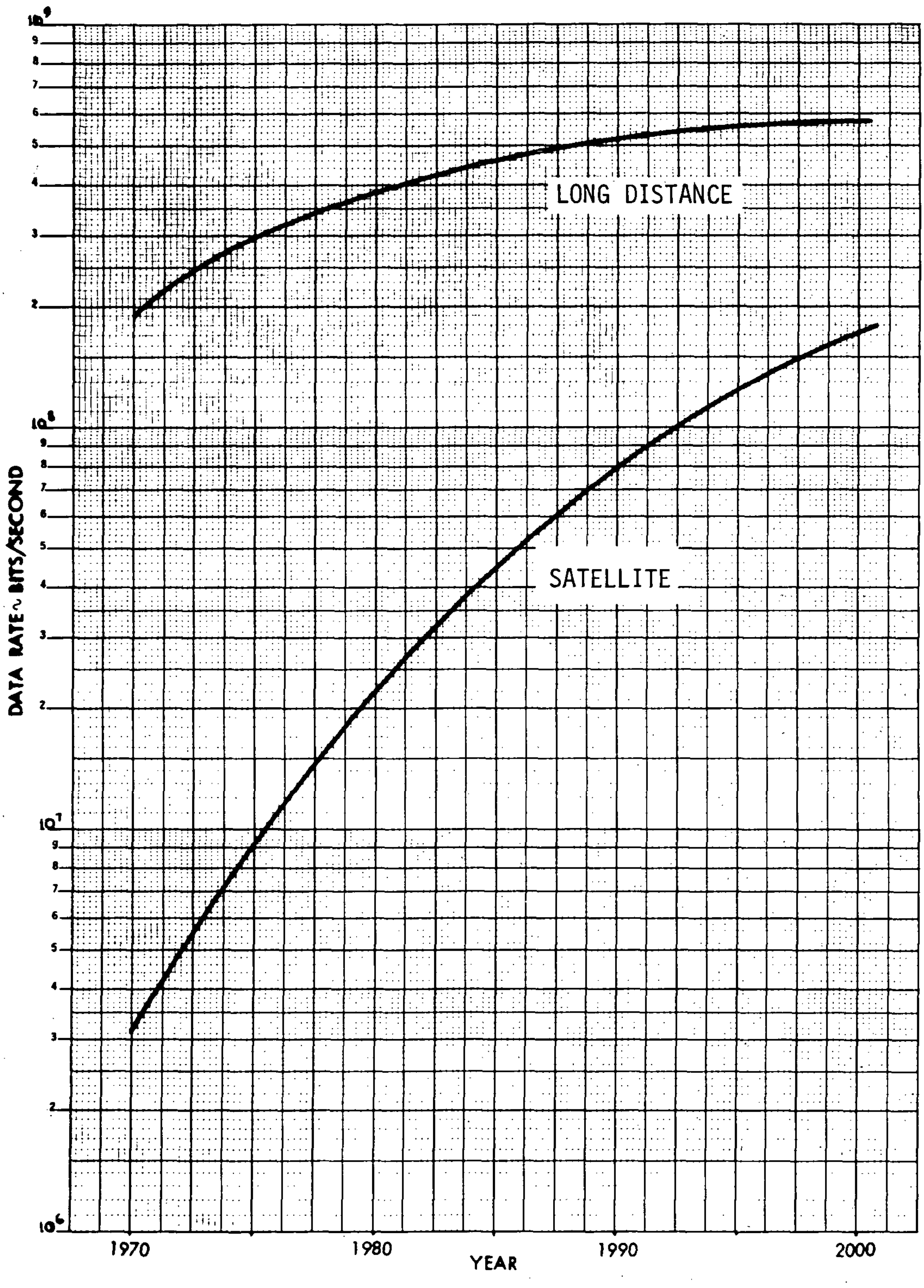


Figure 3.2-3. Commercial Broadcast Function Demand Model for USA

TELECONFERENCING

Teleconferencing includes both telephone and videophone. Long distance teleconferencing frequencies have increased more than eight percent per year in the last few years. As more and more videophones are added to homes in the next 10 to 15 years, teleconferencing data rates will increase at even greater rates. Reference 3-1 forecasts 48 billion long distance telephone calls and 100 million long distance videophone calls made in 1990. These values do not seem unreasonable in view of continual lowering of satellite communications channel lease costs. Current cost trends show that a voice channel price rate may be as low as \$200 to \$300 per year in the late 1970's using Intelsat V. Even if videophone requires up to 1000 voice channels, a 3-minute call by satellite may cost only two dollars.

The long distance data rate forecasted for 1990 based on the above number of calls is:

$(48 \times 10^9$ calls/year$) \times (6$ minutes/call$) \times (60$ seconds/minute$)$
$\times (64{,}000$ bits/second$) \div (3.15 \times 10^7$ seconds/year$) = 3.51 \times 10^{10}$
bits/second for telephone, and

$(100 \times 10^6$ calls/year$) \times (6$ minutes/call$) \times (60$ seconds/minute$)$
$\times (6.3 \times 10^6$ bits/second$) \div (3.15 \times 10^7$ seconds/year$) = 7.2 \times 10^9$
bits/second for videophone

Videophone data rates per year are expected to increase more than telephone data rates so that by the year 2000 the long distance videophone data rate will be 1.8×10^{11} bits/second compared to the long distance telephone data rate of 8.0×10^{10} bits/second. Figure 3.2-4 shows the data rates projected for long distance and satellite traffic. In 1970, teleconferencing made up about 95 percent of all satellite communications traffic. Likewise, in the year 2000 it is expected to remain at about 95 percent of all communications traffic.

TELEGRAPH

Long distance telegraph traffic has steadily declined since 1945. It is probable that personal greetings and business telegrams may continue to decline because of increased business data facsimile traffic (using telephone lines) and lowered telephone night rates which are increasing personal greetings by telephone.

The SRI forecast of telegraph traffic for 1990 (Reference 3-1) is based on the following:

$(35 \times 10^6$ messages/year$) \times (20$ words/message$) \times (50$ bits/word$)$
$\div (3.15 \times 10^7$ seconds/year$) = 1.11 \times 10^3$ bits/second

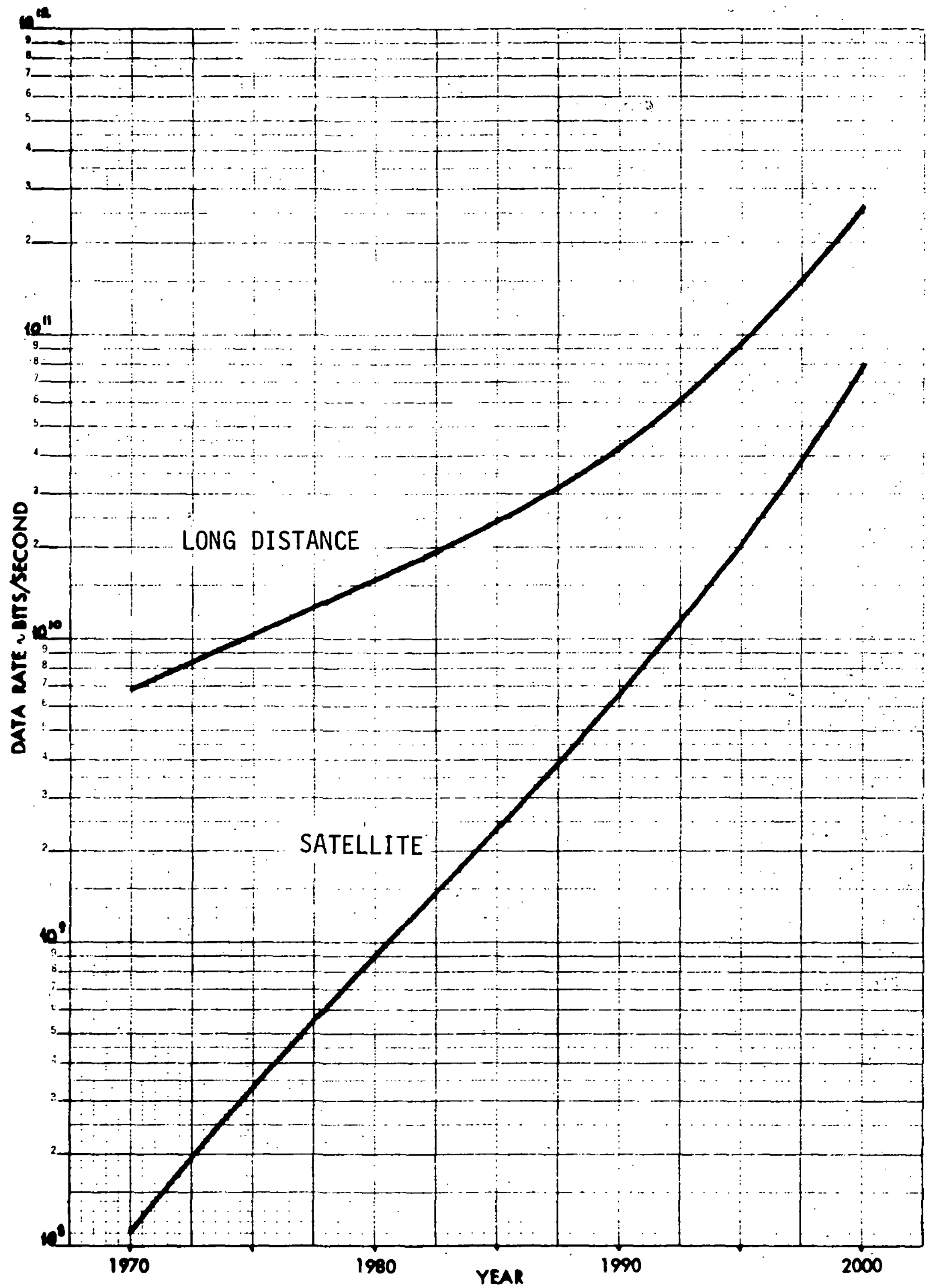


Figure 3.2-4. Teleconference Function Demand Model for USA

Since the forecasted continuous data rate shown is so small, this function is assumed to be included in the teleconferencing function.

POST OFFICE

The total of long distance first class and airmail letters has shown a consistent growth rate of 4.5 percent per year. These data are obtained from the "Annual Report of the Postmaster General" for GFY 1971. The SRI report (Reference 3-1) showed similar growth projections and estimated the number of first class letters that would be suitable for transmission by satellite. Present new postal services include mailgrams (sent by teleprinters - a Western Union function) and facsimile mail (to be extended soon to 100 major cites). Facsimile mail using ground communication links is the forerunner of the anticipated satellite mail system. These innovations may result in greater growth rates than forecasted.

The long distance postal data rate forecasted for 1990 is based on the following:

$(21.85 \times 10^9$ pieces mail/year$) \times (300{,}000$ bits/piece$)$

$\div (3.15 \times 10^7$ seconds/year$) = 2.08 \times 10^8$ bits/second

Figure 3.2-5 illustrates the postal function long distance and satellite forecasted data rates. It is not expected that satellite transmission of mail will occur until 1975 to 1980 since initiation of this function will be dependent on the U.S. Domsat system.

MEDICAL DATA BANK

Precursor experiments and tests of transmitting medical data such as electrocardiograms and medical diagnoses are being conducted using the Applications Technology Satellites. Reference 3-1 provides the basis for projecting present and future medical data bank data rates. Remote medical diagnosis, literature searches, and electrocardiogram and other diagnostic data analysis are included.

The long distance data rates forecasted in Figure 3.2-6 for 1990 are based on the following:

$(180 \times 10^6$ cases/year$) \times (30{,}000$ bits/case$) \div (3.15 \times 10^7$ seconds/year$) = 1.71 \times 10^5$ bits/second for remote diagnosis, plus

$(180 \times 10^6$ searches/year$) \times (30$ pages/search$) \times (3 \times 10^4$ bits/page$) \div (3.15 \times 10^7$ seconds/year$) = 5.14 \times 10^6$ bits/second for literature searches, plus

$(80 \times 10^6$ tests/year$) \times (30{,}000$ bits/test$) \div (3.15 \times 10^7$ seconds/year$) = 7.61 \times 10^4$ bits/second for diagnostic test analysis, for a total of 5.39×10^6 bits/second.

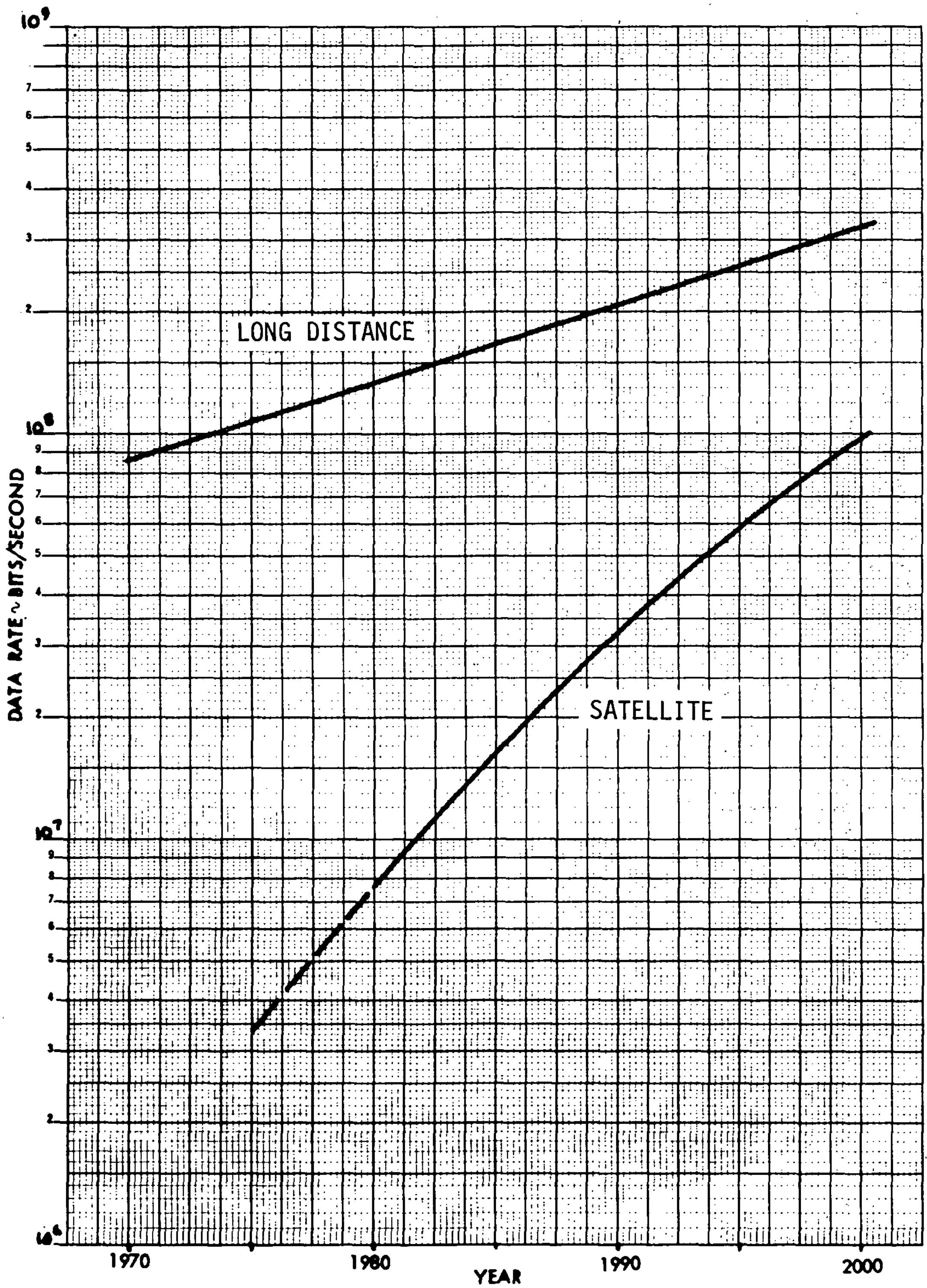


Figure 3.2-5. Postal Function Demand Model for USA

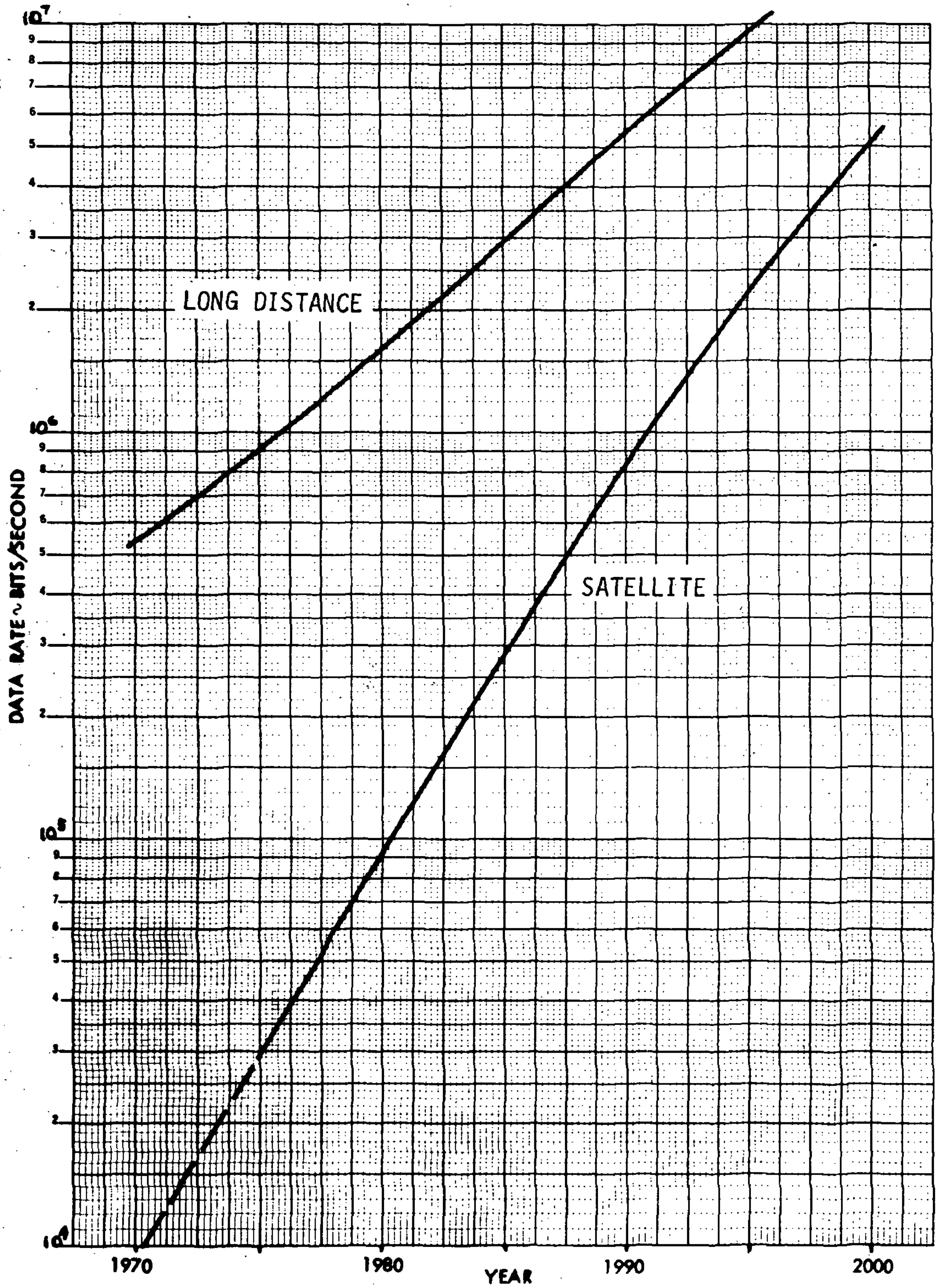


Figure 3.2-6. Medical Data Bank Function Demand Model for USA

The 12 percent per year long distance growth rate seems justified as communications costs are lowered and general practitioners do more long distance consulting with specialists (as well as specialist-to-specialist consultations).

BANKING, BUSINESS, AND CREDIT TRANSACTIONS

The following services are forecasted in Reference 3-1 which are representative of this function: patent searches; checks and credit transactions; stock exchange quotes; stock transfers; airline, auto, hotel, and entertainment reservations; and national legal information.

The 1990 long distance traffic model is based on the following:

(8.1×10^6 searches/year) x (6 pages/search) x (3×10^6 bits/page) $\div$ (3.15×10^7 seconds/year) = 4.63×10^6 bits/second for patent searches; plus

(136×10^9 transactions/year) x (50 characters/transaction) x (8 bits/character) $\div$ (3.15×10^7 seconds/year) = 1.73×10^6 bits/second for checks and credit transactions; plus

(4×10^9 transactions/year) x (100 bits/transaction) $\div$ (3.15×10^7 seconds/year) = 1.27×10^4 bits/second for stock exchange quotes; plus

(4.9×10^9 transactions/year) x (3000 bits/transaction) $\div$ (3.15×10^7 seconds/year) = 4.67×10^5 bits/second for stock transfers; plus

(1.4×10^9 passengers/year) x (3 transactions/passenger) x (200 characters/transaction) x (8 bits/character) $\div$ (3.15×10^7 seconds/year) = 2.13×10^5 bits/second for airline reservations; plus

(14×10^7 reservations/year) x (1000 bits/reservation) $\div$ (3.15×10^7 seconds/year) = 4.44×10^3 bits/second for auto and hotel reservations; plus

(2.0×10^8 reservations/year) x (200 bits/reservation) $\div$ (3.15×10^7 seconds/year) = 1.27×10^3 bits/second for entertainment reservations; plus

(3.0×10^7 searches/year) x (10 pages/search) x (3×10^4 bits/page) $\div$ (3.15×10^7 seconds/year) = 2.86×10^5 bits/second for national legal information,
for a total of 7.34×10^6 bits/second.

Figure 3.2-7 presents the total of all these services. The long distance traffic growth rate averages 3.8 percent per year from 1970 to 2000.

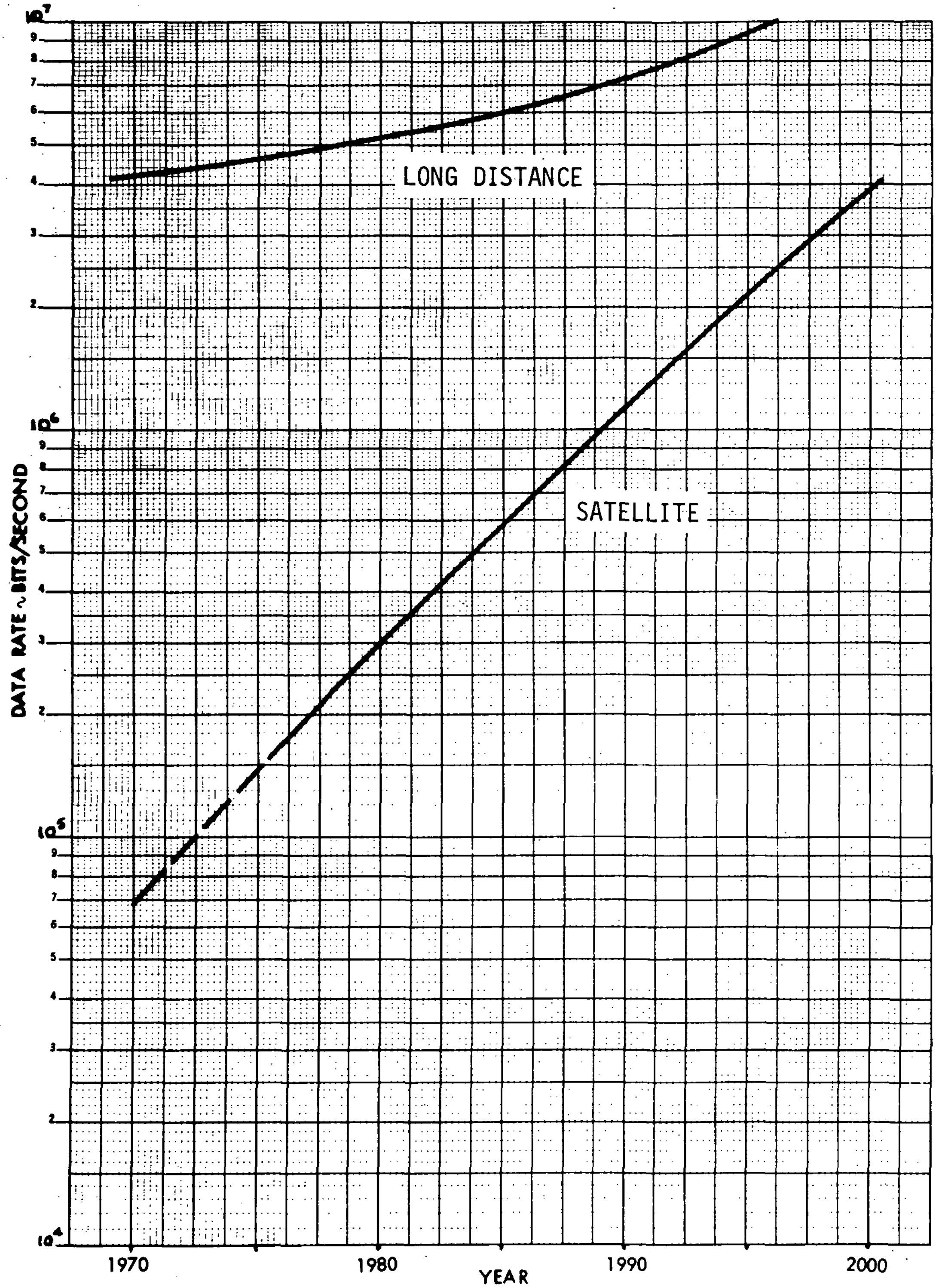


Figure 3.2-7. Banking, Business, and Credit Transaction Function Demand Model for USA

NEWSPAPER

Long distance facsimile transmittal of 20 different newspapers is forecasted for the year 1990 by SRI (Reference 3-1). This growth is projected from two newspapers currently using this service. Expansion should be rapid with the advent of low cost data transmission by Domsat.

The long distance data rate for 1990 is based on the following assumptions:

(20 newspapers using service) x (365 days/year) x (50 pages/day) x (180×10^6 bits/page) ÷ (3.15×10^7 seconds/year) = 2.09×10^6 bits/second

Figure 3.2-8 presents the long distance and satellite traffic trends for the newspaper function. The data rate shown is a continuous average rate. Actual data transmission by each paper might be at considerably higher data rates over shorter time intervals.

ELECTRONIC PUBLISHING

This function envisions the remote publication of popular books and best seller weekly and monthly magazines. The implementation of this function, as with many others, depends on the cost savings that can occur using this publication and distribution method. Reference 3-1 provides forecast values to 1990.

The long distance demand model for 1990 is based on the following computation:

(105,000 issues/year) x (10^7 bits/issue) ÷ (3.15×10^7 seconds/year) = 3.33×10^4 bits/second

Since the forecasted average data rate of this function is so small, it is assumed that this service is included with the newspaper function.

CIVIL DEFENSE

The major subfunctions of civil defense relate to police and public services in addition to periodic tests and regional area use of disaster warning communication networks. The specific services quantified are: national crime information; stolen property information; facsimile transmission of mug shots, fingerprints, all-points bulletins, court records, and, vehicle and personal license registration. Again, Reference 3-1 provides the basis for this forecast.

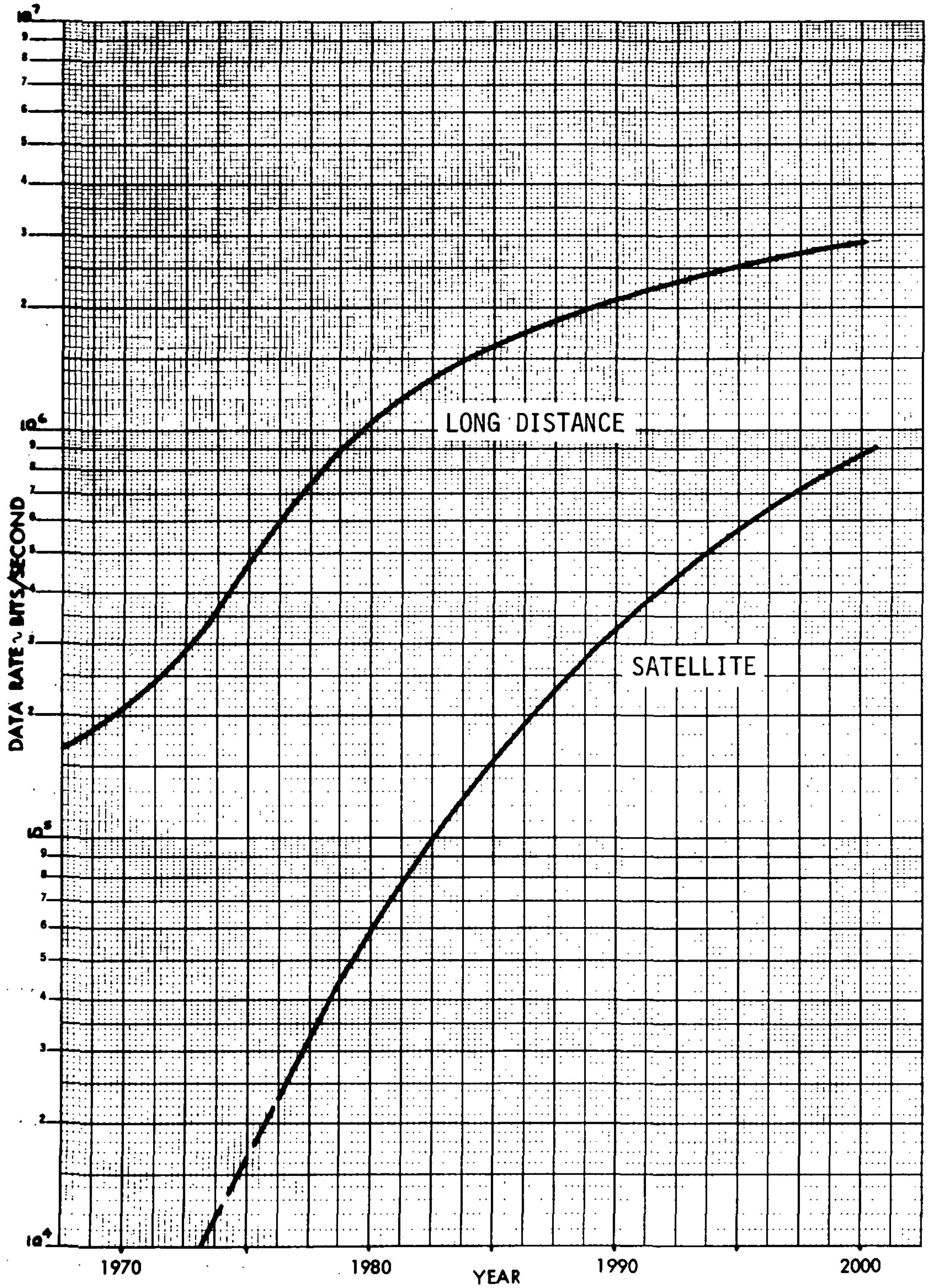


Figure 3.2-8. Newspaper Function Demand Model for USA

The 1990 long distance forecast is based on the following computations:

$(7 \times 10^7$ transactions/year) x $(3 \times 10^5$ bits/transaction) $\div (3.15 \times 10^7$ seconds/year) = 6.67×10^5 bits/second for national crime information; plus

$(1.16 \times 10^6$ cases/year) x (3000 bits/case) $\div (3.15 \times 10^7$ seconds/year) = 110 bits/second for stolen property information; plus

$(1.25 \times 10^7$ cases/year) x (10 pages/case) x $(3 \times 10^6$ bits/page) $\div$ (3.15) x 10^7 seconds/year) = 1.19×10^7 bits/second for mug shots, fingerprints, etc.; plus

$(3.02 \times 10^8$ registrations/year) x (6000 bits/registration) $\div (3.15 \times 10^7$ seconds/year) = 57,600 bits/second for vehicle registrations and drivers licenses.
for a total of 1.26×10^7 bits per second.

Figure 3.2-9 shows the long distance and satellite forecasted data rates for 1970 to 2000. The average long distance growth rate is about 7 percent per year based on the increased rates of crime during the 1950 to 1970 time period.

WELFARE DATA BANK

The principal services used to forecast welfare data bank data rates include bookkeeping, employment services and payment records for all persons receiving old age benefits, unemployment benefits, and medicare benefits. The forecasts are based on Rockwell analyses of data contained in the 1972 World Almanac (Reference 3-2). Due to the rapid changes, both up and down, in the number of benefit receivers in the past years (for which there are records), this model has been conservatively forecasted at a long term growth rate of about 1.5 percent/year which slightly exceeds the U.S. population growth history.

The 1971 long distance data rates for the above services are based on the following computations:

$(2.19 \times 10^7$ persons/year) x (13 transactions/person) x (200 characters/transaction) x (8 bits/character) $\div (3.15 \times 10^7$ seconds/year) = 1.45×10^4 bits/second for old age benefits; plus

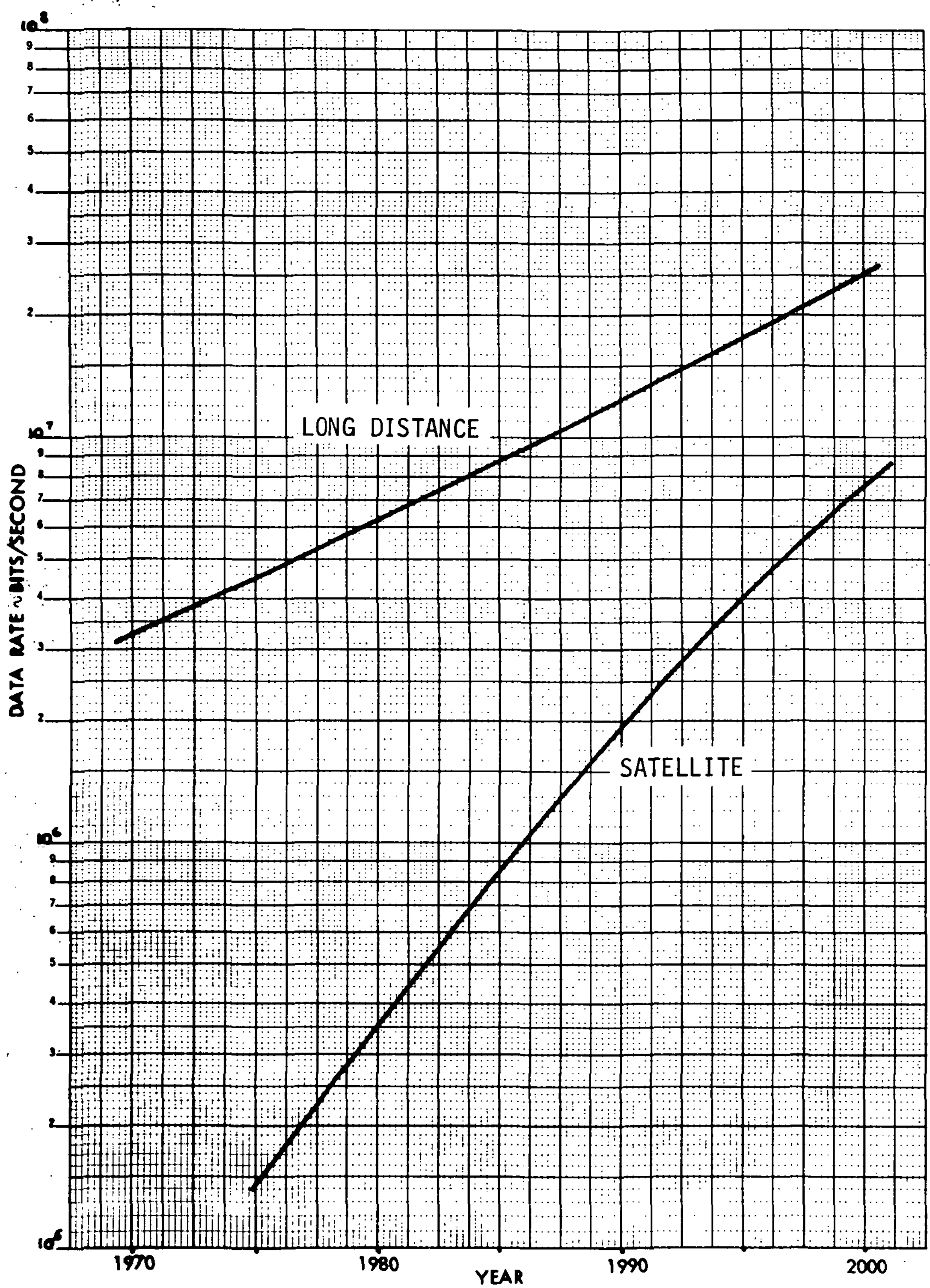


Figure 3.2-9. Civil Defense Function Demand Model for USA

$(6.1 \times 10^6$ persons/year) x (30,000 bits/person) $\div$ $(3.15 \times 10^7$ seconds/year) = 5810 bits/second for Medicare records; plus

$(8.34 \times 10^6$ persons/year) x (52 records/person) x (10,000 bits/record) + (160,000 bits/initial record) $\div$ $(3.15 \times 10^7$ seconds/year)

$= 1.38 \times 10^5$ bits/second for unemployment services and records,

for a total of 1.58×10^5 bits per second.

Figure 3.2-10 illustrates the data rate traffic forecasted for 1971 to 2000.

LIBRARY DATA BANK

The library data bank is envisioned as a Library of Congress function of the future. This center could provide to remote users such services as remote title and abstract searches, remote library browsing searches, and interlibrary transmittals of out-of-print books and documents (by facsimile or other means). Reference 3-1 provides the estimates of data rate traffic for this function.

The long distance data rate for 1990 is based on the following computations:

$(10^7$ searches/year) x (30 pages/search) x $(3 \times 10^4$ bits/page)

$\div$ $(3.15 \times 10^7$ seconds/year) $= 2.86 \times 10^5$ bits/second for title

and abstract searches; plus

$(1.8 \times 10^7$ accesses/year) x (200 pages/access) x $(3 \times 10^5$ bits/page)

$\div$ $(3.15 \times 10^7$ seconds/year $= 3.43 \times 10^7$ bits/second for remote

browsing; plus

$(10^7$ x books/year) x 10^7 bits/book) $\div$ $(3.15 \times 10^7$ seconds/year)

$= 3.17 \times 10^6$ bits/second for interlibrary transmittals,

for a total of 3.78×10^7 bits/second.

Figure 3.2-11 shows the data rate forecasts from 1975 to 2000. Because of the expected usefulness of this service, long distance growth rates are initially (1975 to 1978) predicted to be about 30 percent per year declining to about 12 percent per year in 2000.

PRIVATE RECORD BANKS

Large companies, corporations, and large government agencies have established corporate record data banks for their personal and business needs. This function assumes the eventual use of satellite transmittal for much of these data. The SRI report (Reference 3-1) provides the initial estimates for this function which is assumed to be representative for the year 1975.

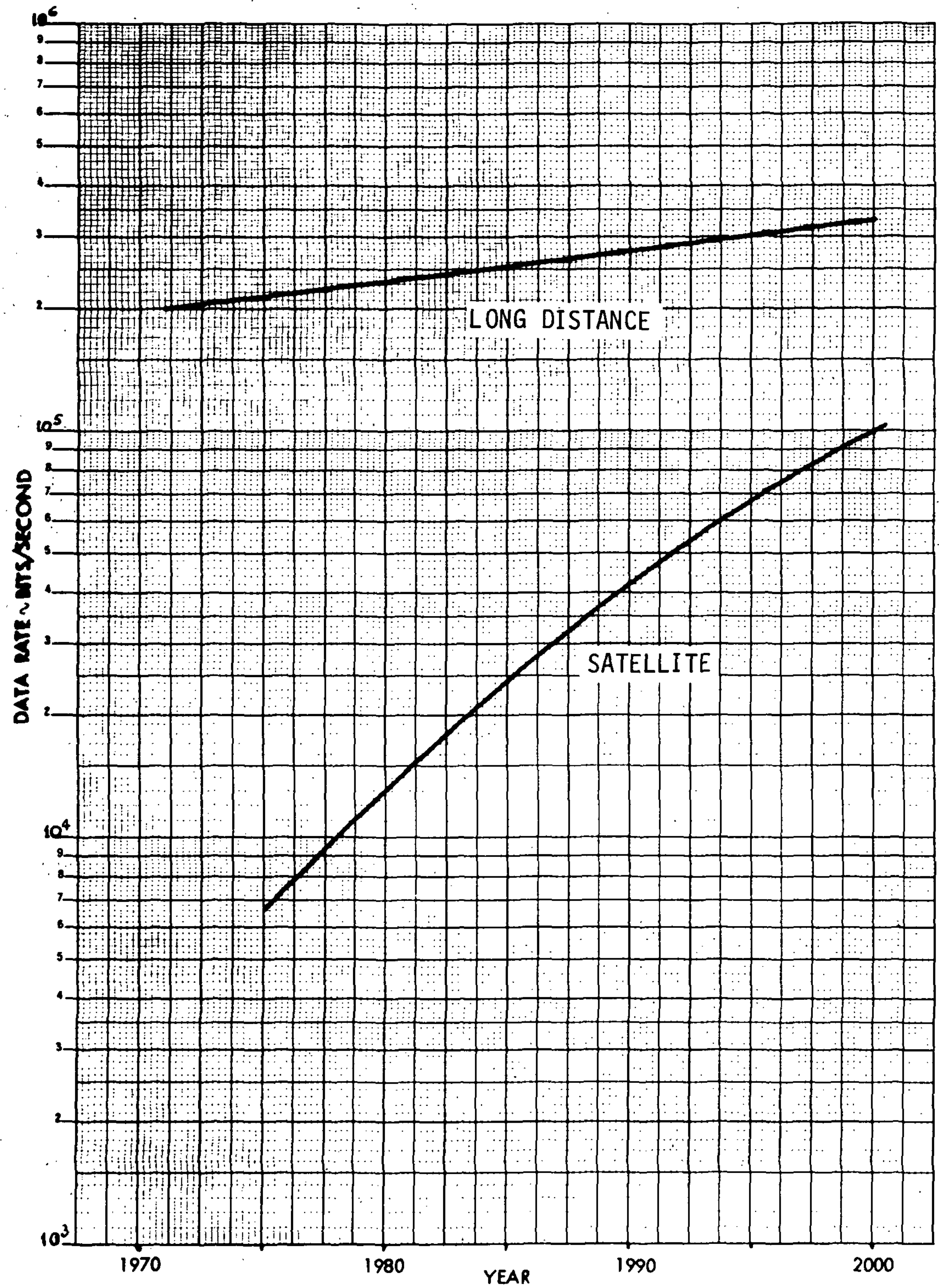


Figure 3.2-10. Welfare Data Bank Function Demand Model for USA

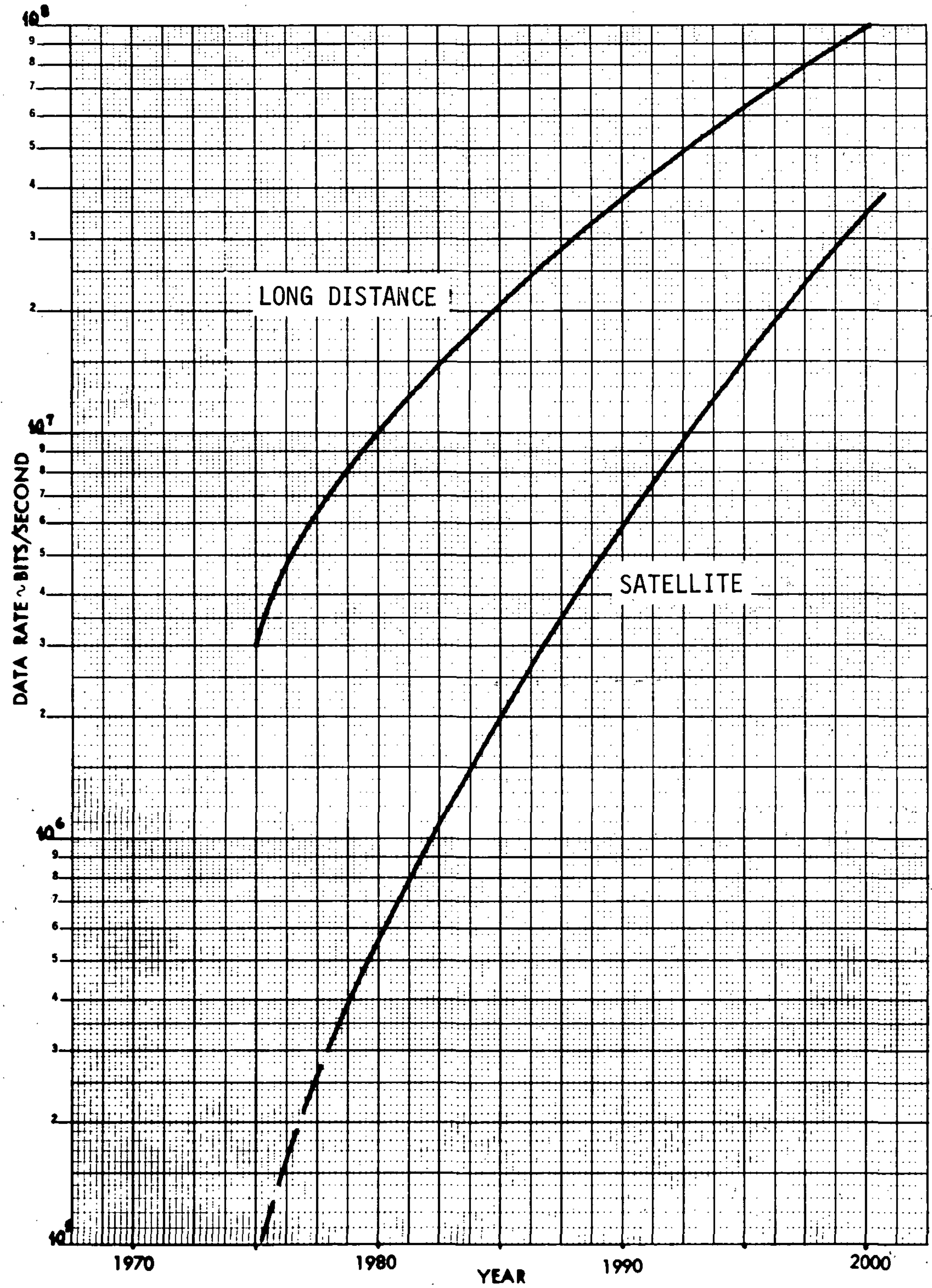


Figure 3.2-11. Library Data Bank Function Demand Model for USA

The long distance traffic data rate is based on the following values:

(400 large corporations or other) x (3 data transmission systems/corporations) x (25,000 messages/day) x (200 characters/message) x (10 bits/character) ÷ (86,400 seconds/day) = 6.95×10^5 bits/second

It is estimated that this function will expand at the rate of 30 percent per year between 1975 and 1980, 20 percent per year between 1980 and 1990, and 6 percent per year from 1990 to 2000. Such systems as these are anticipated to become economically feasible with the operational implementation of Domsat. The expected satellite and long distance traffic for this function is shown in Figure 3.2-12.

TELECOMPUTATIONS

Telecomputations is the functional classification that covers computer data transmission services for the small business organizations that cannot afford their own private computer. These businesses can effectively utilize a large centrally located computer(s) on a time sharing basis with access through remote terminals. This function is also envisioned to become cost effective to remote households with the use of the telephone or satellite for data transmittal from and to the remote terminal (in the home).

The following approach was used to develop the data rate forecasts for this function. A cursory survey of the Los Angeles and Orange County telephone yellow pages showed the existence of several hundred computer data centers of which approximately 35 can be addressed by remote services. The large number of these centers verified the service demand by small businesses. Data from Reference 3-2 showed receipts and profit totals for U.S. proprietorships, partnerships, and corporations. Other statistical references indicated that operating costs averaged 65 percent of receipts and that about 5 percent of the operating costs were related to data processing. The cost for data processing was assumed to be $400 per hour.

In time, every household may use a remote terminal (just as TV is now in 95 percent of all homes) for large computer access (for scientific computations or household records). It is estimated that these homes may average one hour machine time per year. Using these assumptions and the available statistics from Reference 3-2, the total data rate demand for 1968 was 5.09×10^9 bits/second. This value was given a constant annual growth rate of 6.5 percent per year (1.5 percent user growth + 5 percent for increased services). Long distance traffic was assumed to vary linearly from 6 percent in 1968 to 12.5 percent in 2000 of the total traffic rates computed. Potential satellite traffic was estimated using values from Figure 3.2-1.

Figure 3.2-13 shows the results of this cursory analysis. The practicality and wide use of this function via satellite transmission may be dependent upon nearby ground station terminals with access to Domsat-to-computer links as well as lower computer costs and low remote terminal rental costs.

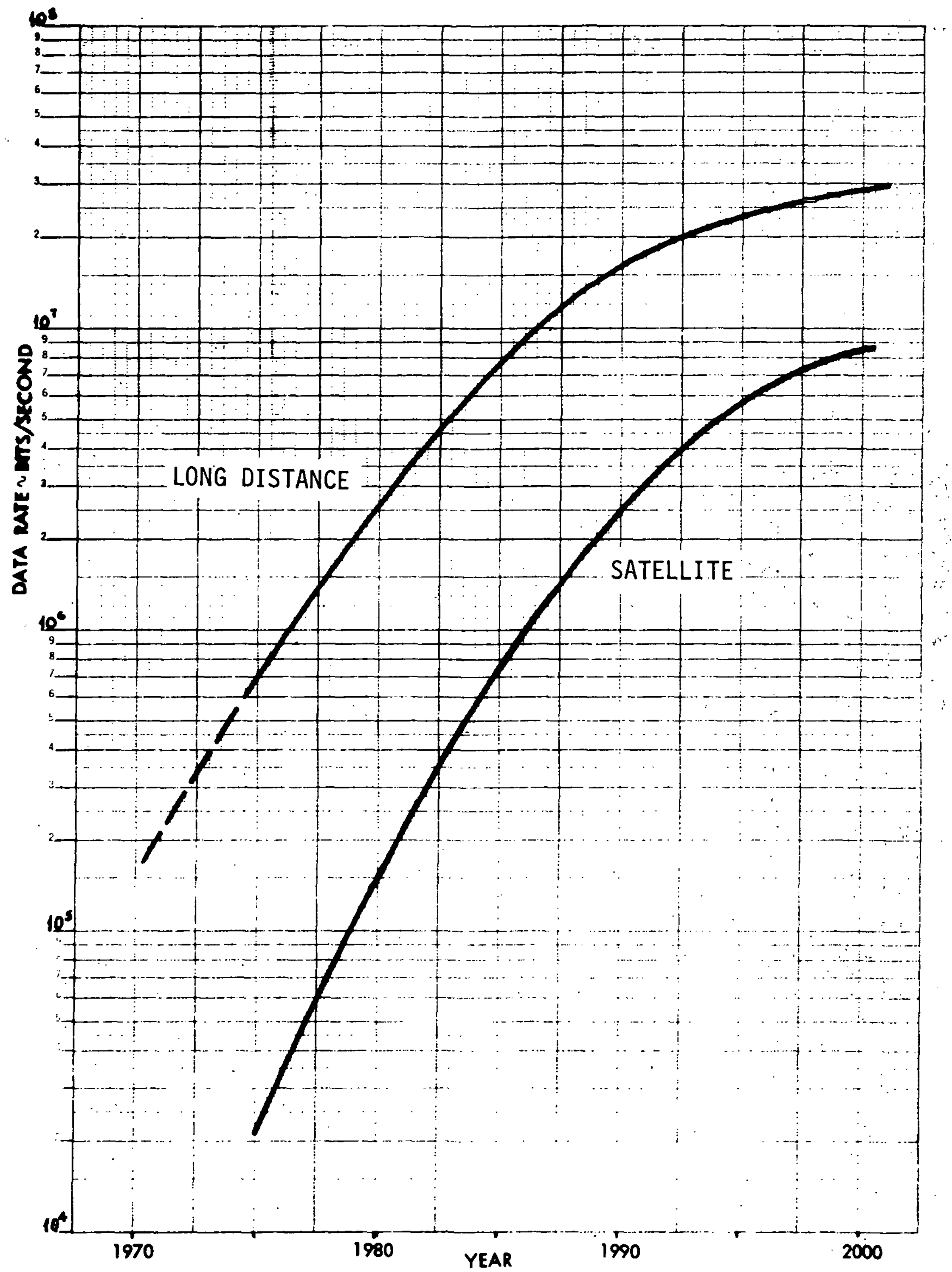


Figure 3.2-12. Private Record Bank Function Demand Model for USA

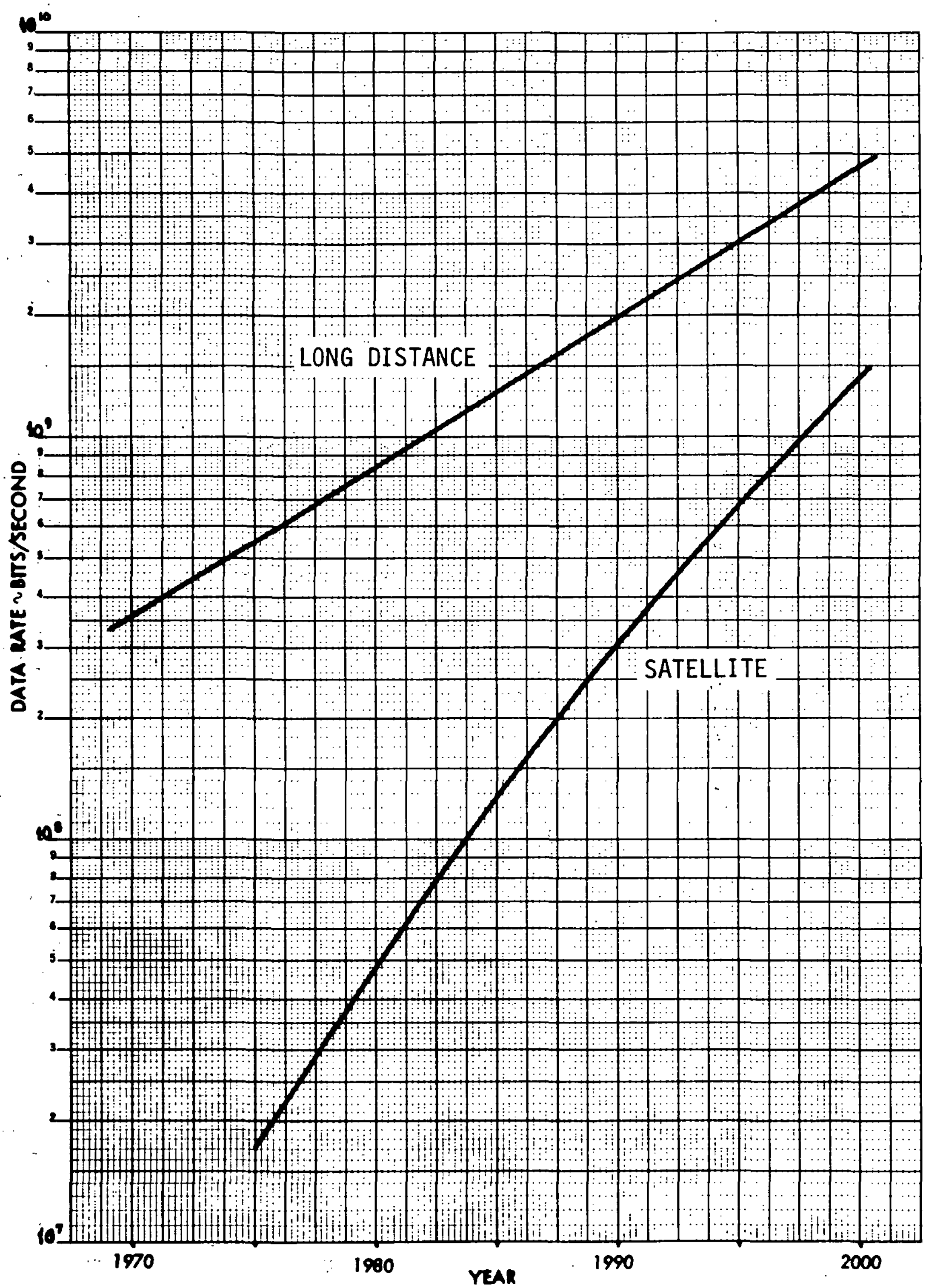


Figure 3.2-13. Telecomputation Function Demand Model for USA

METEOROLOGY

A typical mid-1970 meteorological satellite will sense a number of atmospheric conditions as well as relay data from numerous remote earth locations. These locations are strategically distributed in both hemispheres to provide weather data for all nations. The U.S. geographical area including some ocean areas to the east and west can be monitored by a single meteorological satellite providing a zone of coverage for a substantial portion of the western hemisphere. This zone would cover a minor circle on the earth ranging from 76 degrees north to 76 degrees south and $\pm$ 76 degrees of longitude from the satellite's location. This area is larger than required for local U.S. weather observations and forecast needs. However, to satisfy U.S. international air traffic and maritime forecast needs, other zonal data further to the east and west of the U.S. are also required. For the model shown, it is assumed that this other required zonal data compensates for the southern hemisphere zonal data at U.S. longitudes that is of little use to the U.S. Therefore, the U.S. user requirements will be equivalent to the data provided from a single zone.

Data from a single zone are initially expected to be equivalent to 10^7 bits per second. As greater and more detailed area coverage is desired, the single zone data are expected to double in eight years, triple in 16 years, and quadruple in 24 years. This is equivalent to a periodic average growth rate of 9 percent per year in the first eight years, 5 percent per year in the second eight years, and 3.65 percent per year in the third eight-year period. This projected forecast is illustrated in Figure 3.2-14.

EARTH RESOURCES

The mid-1970 geosynchronous earth resources satellite will also sense and continuously transmit data from scanned areas at an initial rate of approximately 10^7 bits per second. This system will be an outgrowth of the present Earth Resources Technology Satellite (ERTS) and will provide data for: mineral and land resource analysis; agriculture, forestry, and range resource analysis; water and marine resource analysis; soil differentiation and topographic information. As more sensitive sensors are developed for use at geosynchronous altitude and more detailed and greater land area coverage is desired, the data rate is expected to double in eight years, triple in 16 years, and quadruple in 24 years. This periodic growth rate is expected to be similar to that for the meteorology function. The forecast, shown in Figure 3.2-15, is the same as that illustrated for meteorology (Figure 3.2-14). These data rates also will more than cover the area requirements for the United States and are probably more representative of North and South America.

NAVIGATION

The navigation function is intended to meet the needs of maritime, aircraft, and low altitude spacecraft traffic. These needs are primarily global rather than restricted to a geographic area such as the U.S. and its surrounding land and water areas. Therefore, this functional forecast was developed for world user requirements rather than U.S. user requirements.

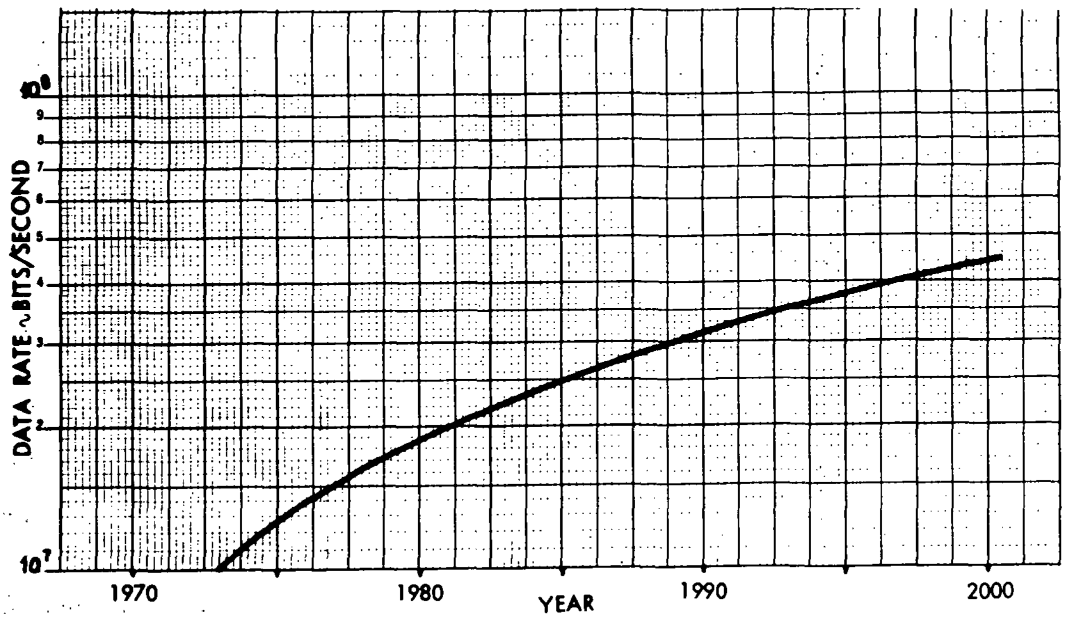


Figure 3.2-14. Meteorlogy Function Demand Model for USA

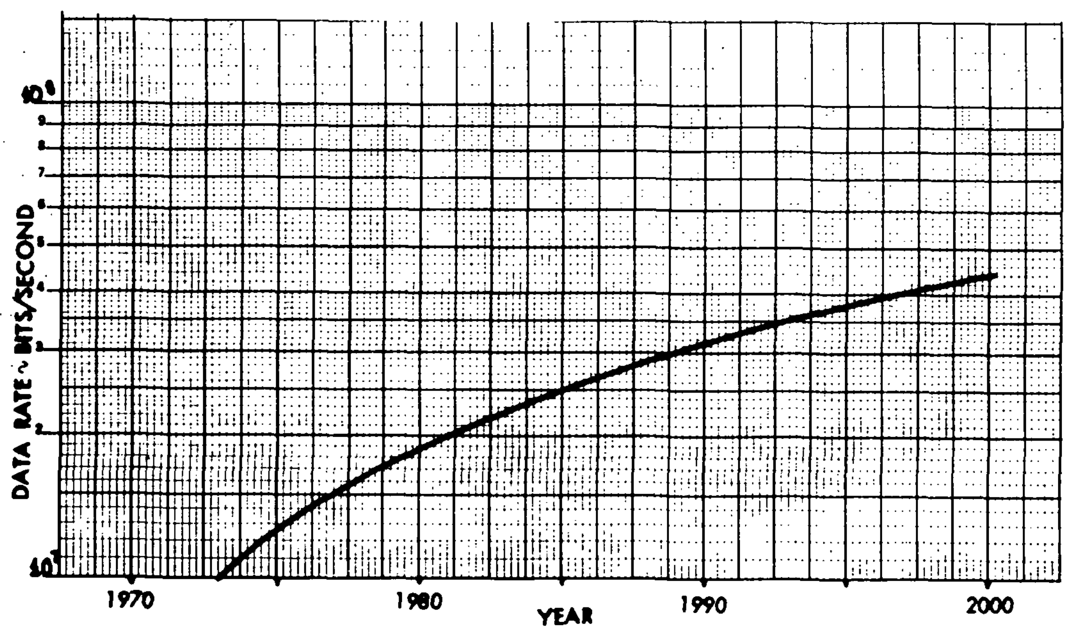


Figure 3.2-15. Earth Resources Function Demand Model for USA

Reference 3-3 provides information which defines the volume of maritime traffic and its expected growth rate of 5.2 percent per year. Reference 3-4 provides the basis for estimating the amount of world transocean air traffic in 1970. Other Aviation Week and Space Technology articles have indicated prospective traffic growth rates of about 5 percent per year. These references showed that maritime traffic outnumbers transocean traffic by a factor of 250 to one. It is expected that low altitude spacecraft will not contribute to the user demand until beyond the year 2000. The tracking and data relay function will provide this service in the interim period. Due to the majority of maritime traffic, the model has been segregated into principal ocean areas. This does not infer that aircraft navigation over desolate and expansive land areas would not be supported by the navigation function.

The navigation system assumed is based on an average intermittent operation by each ship about three times per hour and by each aircraft three times per minute. These operations assume the use of a minimum of three different navigation satellites for minimum system operational accuracy. The assumed navigation system is very similar to the concepts recently documented in Aviation Week and Space Technology (References 3-5 and 3-6). Data rates shown are based on the minimum navigation system but used by all the commercial vehicles forecasted. These compensating (or offsetting) assumptions should provide a reasonable demand model. Also in Reference 3-6, an article showed a current on-board navigation system cost of about $10,000 for transmitter, receiver, and computer. These costs are expected to reduce as communications system technology is further developed making it financially attractive to include precision navigation systems on all commercial maritime and aviation vehicles as well as many privately-owned ships and aircraft.

Figure 3.2-16 shows satellite demand traffic from 1970 to 2000. It is expected however, that U.S. systems tests may begin in about 1976 resulting in an operational global system in 1980 or 1981.

AIRCRAFT CONTROL

For the same reason given in the navigation function, the aircraft control function has been modeled for the world area. Data for the aircraft control function are based on transocean and long-range remote area aircraft traffic control. Aircraft control over relatively populated areas has not been included. Statistics on aircraft traffic were obtained from Reference 3-4 and other articles reflecting prospective traffic growth rates. Data rates are based on an average four messages per hour at 30 seconds per message (transmitted as digitized voice at a rate of 64,000 bits per second) per each airborne aircraft. Data rates for anticipated air-sea rescue operations have not been included because these are expected to be insignificant compared to the normal traffic levels.

Figure 3.2-17 shows the expected satellite demand traffic data rates for the three major ocean areas. Development of this system will occur at approximately the same projected time period as the navigation system.

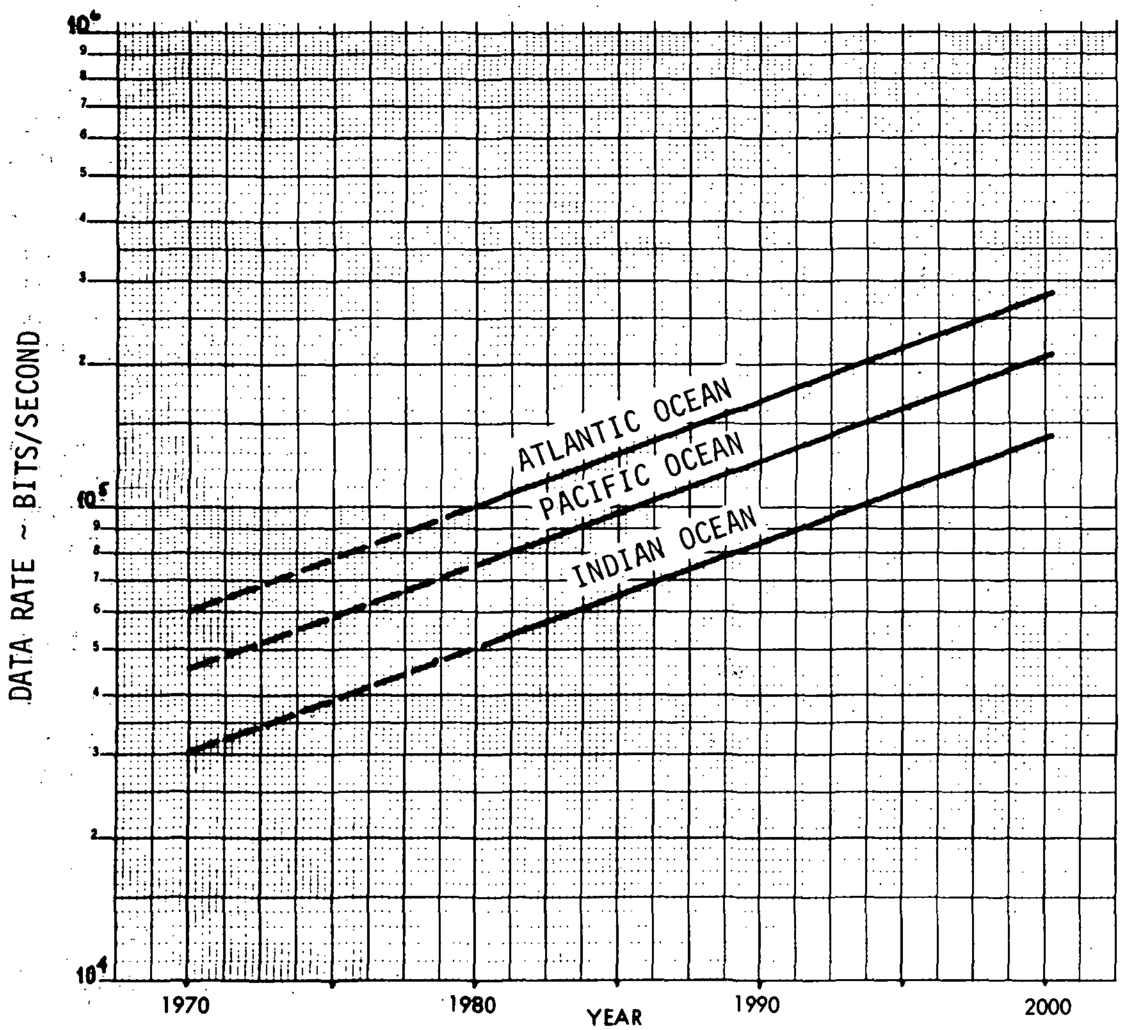


Figure 3.2-16. Navigation Function Demand Model
For World Users

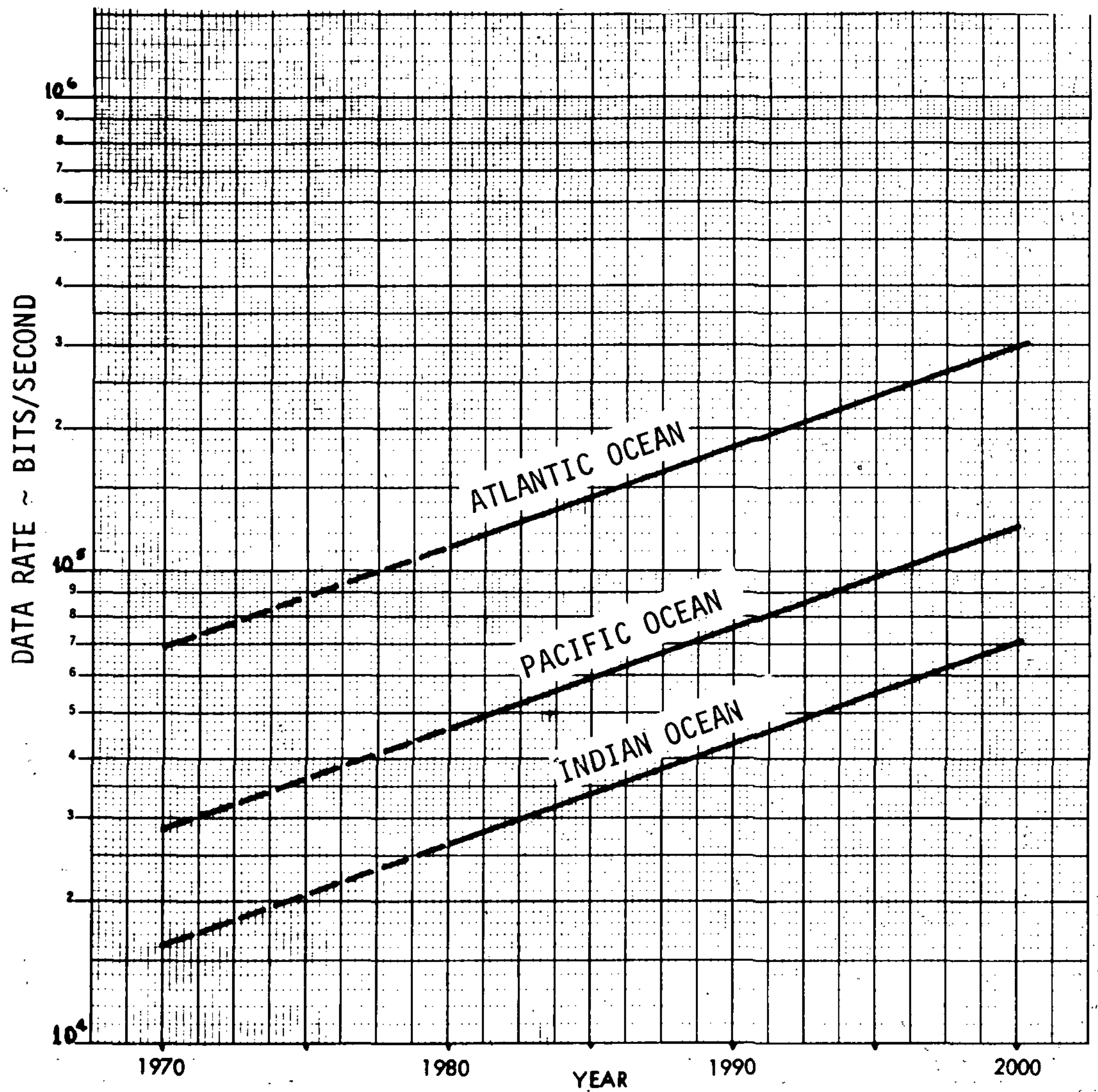


Figure 3.2-17. Aircraft Control Function Demand Model For World Users

COMMUNICATIONS AND SYSTEM TEST

This functional category was initiated in December 1966 with the launch of ATS-1, which is still in operational service. The applications technology satellite (ATS) series has performed development tests on the following functional systems: meteorology; voice communications at different band frequencies; range-rate experiments; self-contained navigation systems; teletype and facsimile transmissions; gravity gradient stabilization experiments; etc. Direct broadcast TV, control moment gyro stabilization systems development, laser beam optics experiments and further communications developments at higher frequencies are planned operational developments for future ATS satellites.

The data rate model presented for the U.S. in Figure 3.2-18 has been extrapolated from the planned ATS' capabilities at a 6 percent per year growth rate. This should reasonably be representative of further communications systems developments using super high frequency (SHF) and extremely high frequench (EHF) bands and laser systems. The data rate presented plus the indicated 12-hour transmission time per day is assumed to be equivalent to the total bits/day for high frequency wide band communication systems tests.

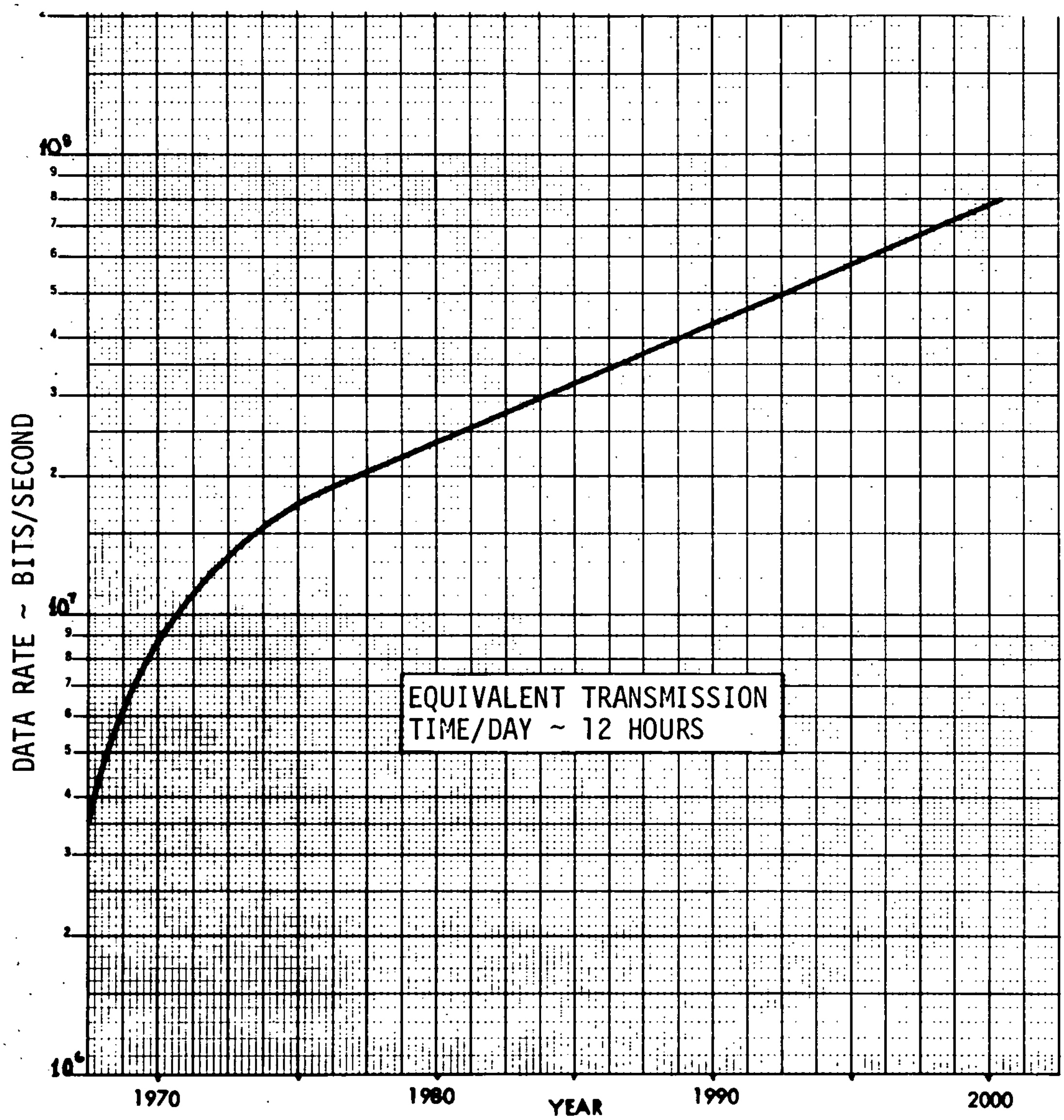


Figure 3.2-18. Communications and System Test Function Demand Model for USA

ASTRONOMY

The geosynchronous astronomy function is based on a review of planned U.S. applications using lower altitude spacecraft. High data rates are based on real time TV pointing and control of observations related to spectroheliograph and solar coronagraph experiments. Data rate growth is based on an increased demand for more observations and data as interest in this science expands. The data rate is expected to double in two years, triple in four years, quadruple in six years, and continue to monotonically increase in this way in each successive two-year period. These data rates are expected to be peak steady state values for four hours per day. The demand may be met by transmitting from several sources or at lower data rates for longer durations. Figure 3.2-19 shows the projected data rate model for this functional application.

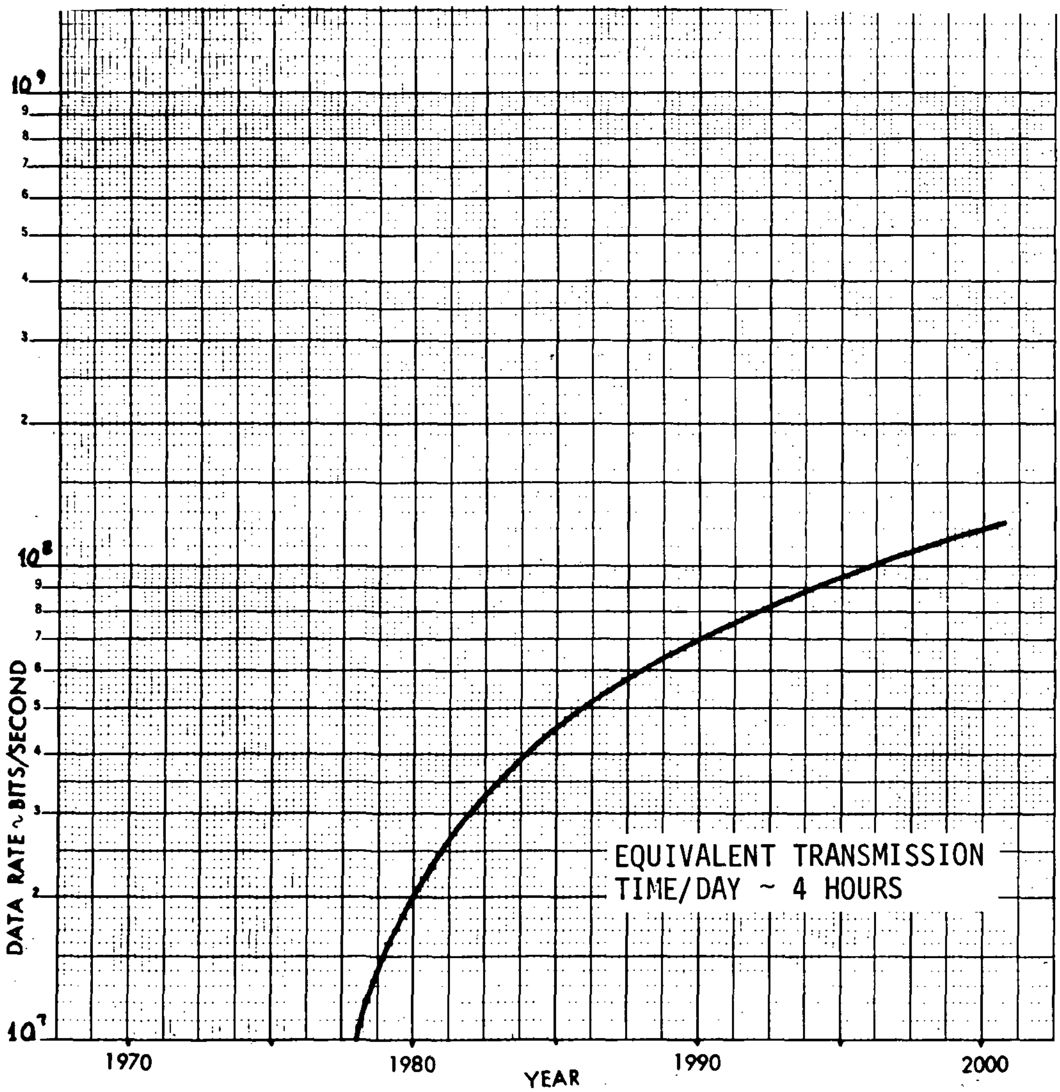


Figure 3.2-19. Astronomy Function Demand Model for USA

TRACKING AND DATA RELAY

The U.S. tracking and data relay satellite system (TDRSS) functions as a real time data relay link between low orbiting satellites like ERTS, Nimbus, Skylab, OSO, Code 467 and 1010 (Military), and the ground users. TDRSS will transmit and receive high data rate information primarily in the form of photographs of various types. R&D satellites are expected to handle data at 10^8 bits per second whereas future generation operational satellites may have the capability to handle data at greater rates than 10^8 bits per second.

As shown in Figure 3.2-20, the data rate growth forecast is based on a two-satellite (active) R&D system and a four-satellite operational system. The estimated operational dates are based on projected demands for data relay during the shuttle sortie, RAM and SOAR eras. Following this in the mid-1980's, the space station will require further growth in the TDRS system to relay detached RAM data to ground users. The average growth rate from 1980 to 2000 is seven percent per year. Although not shown, the data rate demand curve includes those smaller (10^7 bits/second) TDRS systems for real time continuous planetary systems data relay in the 1980's and 1990's. As with some of the other science and applications functions, the data rate demand can be satisfied at lower rates with corresponding increases in transmission time. The data shown in Figure 3.2-20 are based on 12 hours transmission per day.

SOLAR ILLUMINATION

The concept of solar illumination of earth from geosynchronous orbit is receiving serious study in the area of science and technology applications use of space (Reference 3-7). Solar illumination could provide useful night illumination with a mean brightness level of one to as much as 100 full moons by using large orbiting solar reflectors. A system concept, called Lunetta, could provide useful low-level illumination of major metropolitan areas for crime prevention and power conservation, agricultural areas for night crop attendance and harvesting, harbors and converging shipping lanes for collision avoidance, etc.

A forecast of light levels and locations to meet user demands cannot be established with the same confidence associated with each of the previous functions. However, it is envisioned that a 0.1 full moon demonstration platform will be placed in geosynchronous orbit in the 1985 to 1990 time period. This would be followed in the 1990 to 1995 period by a full scale demonstration platform providing illumination at the 10 full moon level. Figure 3.2-21 shows a system development schedule from concept formulation to operational use. Further definition of user requirements are difficult to assess at this time because they are strongly dependent on the eventual system feasibility. This advanced function is included in the study because it potentially imposes requirements for technology development missions (e.g., ATS) during the 1980's and may also influence the definition of space platform requirements in that era.

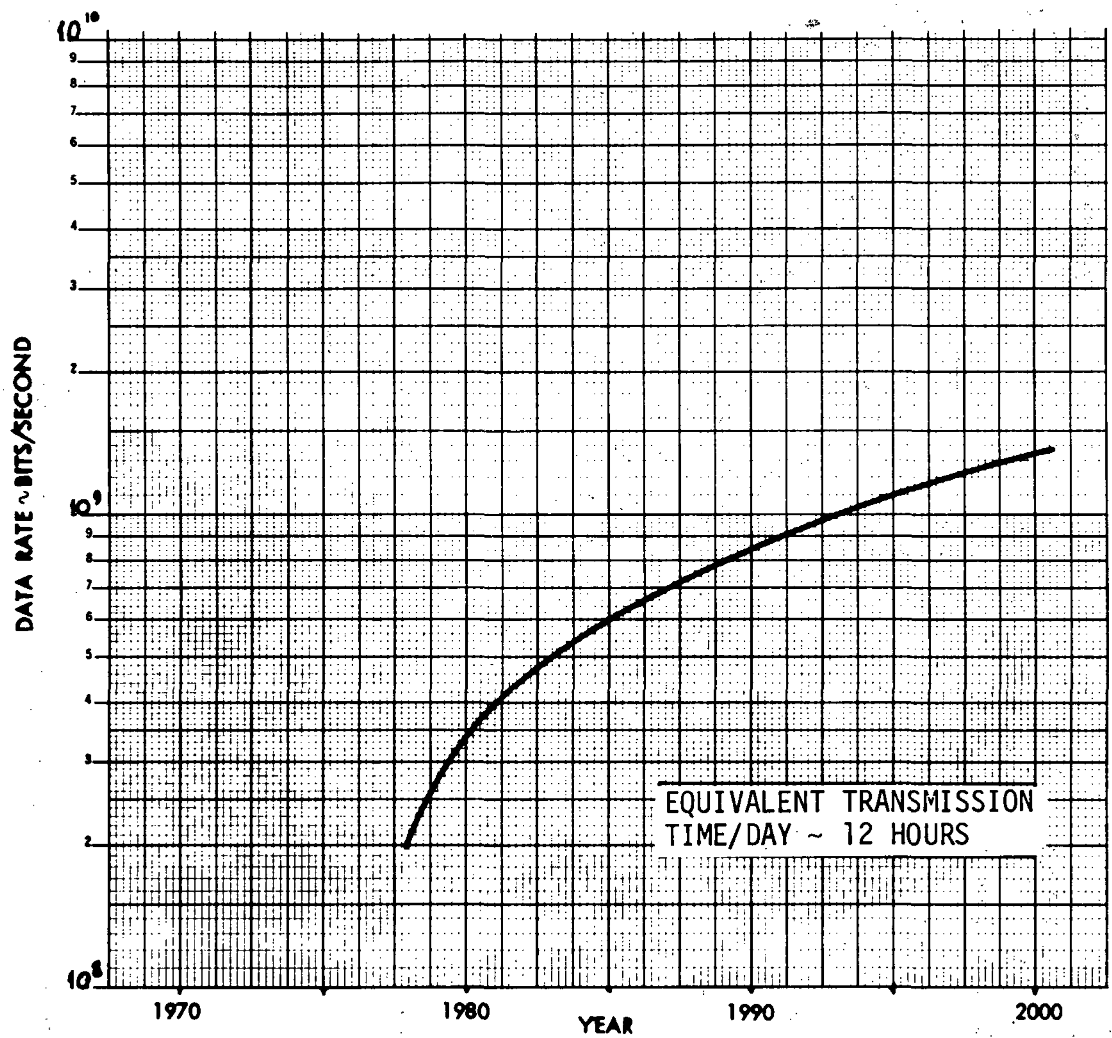


Figure 3.2-20. Tracking and Data Relay Function Demand Model for USA

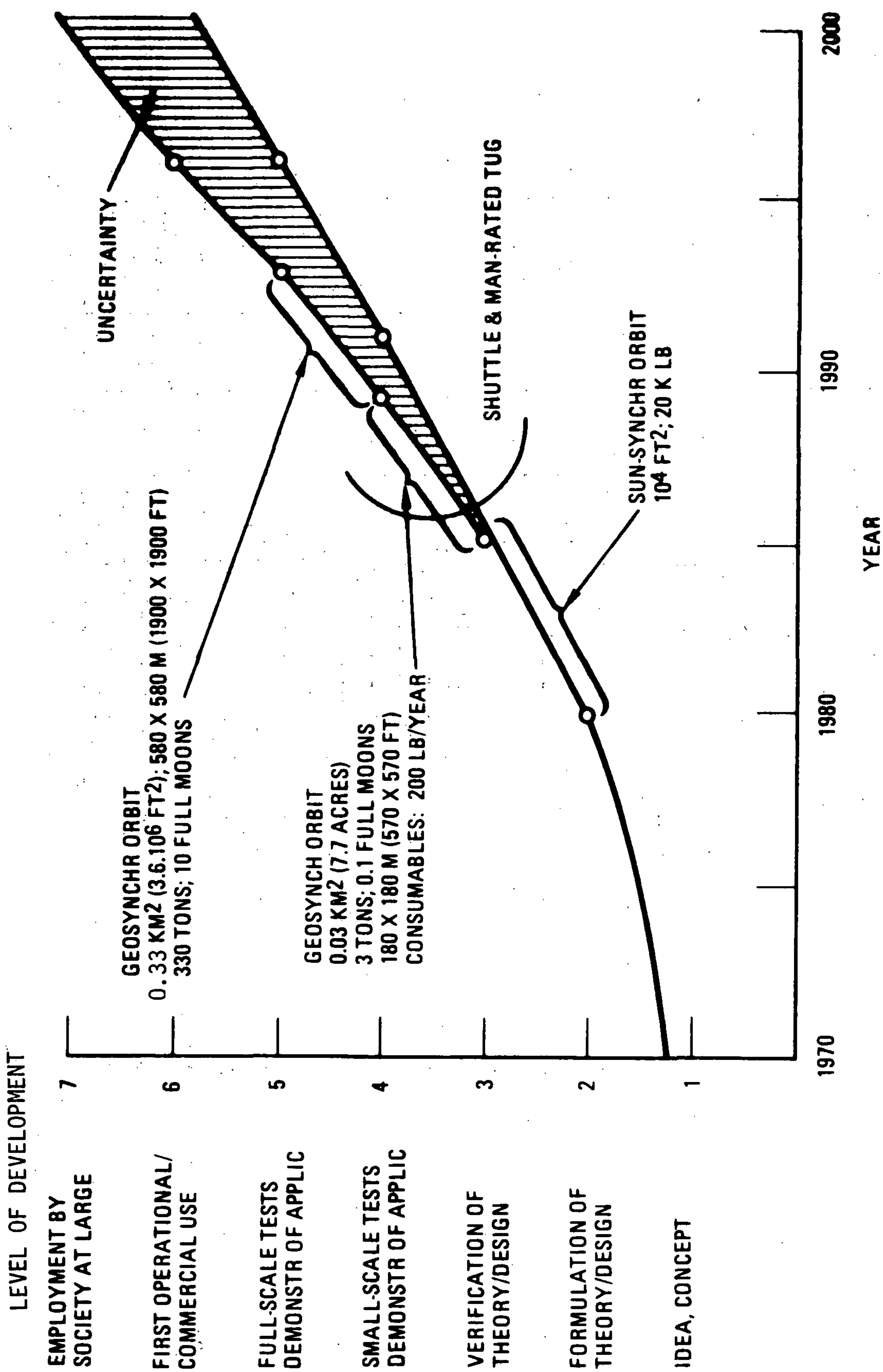


Figure 3.2-21 Solar Illumination Development Projection

SPACE POWER RELAY

Space power relay is also an advanced concept being studied (Reference 3-7) which opens a new dimension on the use of space to solve technical problems. The space power relay system uses geosynchronous satellites to transfer power from remotely located power generation complexes to the power users in major metropolitan areas. In this concept, nuclear power complexes are located in regions where there will be a minimum environmental impact. Also, solar power complexes may be located in remote solar energy intensive regions. The geosynchronous power relay satellites then becomes an integral part of the power distribution system to relay energy to the high energy consumption regions.

Like Lunetta, the forecast of power transfer requirements has not been determined in detail because system feasibility studies must first be accomplished. Figure 3.2-22 shows the development schedule for space power relay. The two advanced technology satellites to be flown in the 1980 to 1985 time period will demonstrate small scale microwave generation, power relay, and reconversion systems. In the 1985 to 1990 era a full scale 100 megawatt power relay demonstration prototype will be placed in geosynchronous orbit. This could be followed in the mid-1990's with 10 gigawatt power relay systems for commercial applications. As indicated, the continued development of this space applications function will influence several of the ATS' requirements and may also influence the definition of space platform requirements in the 1980 to 1990 time period.

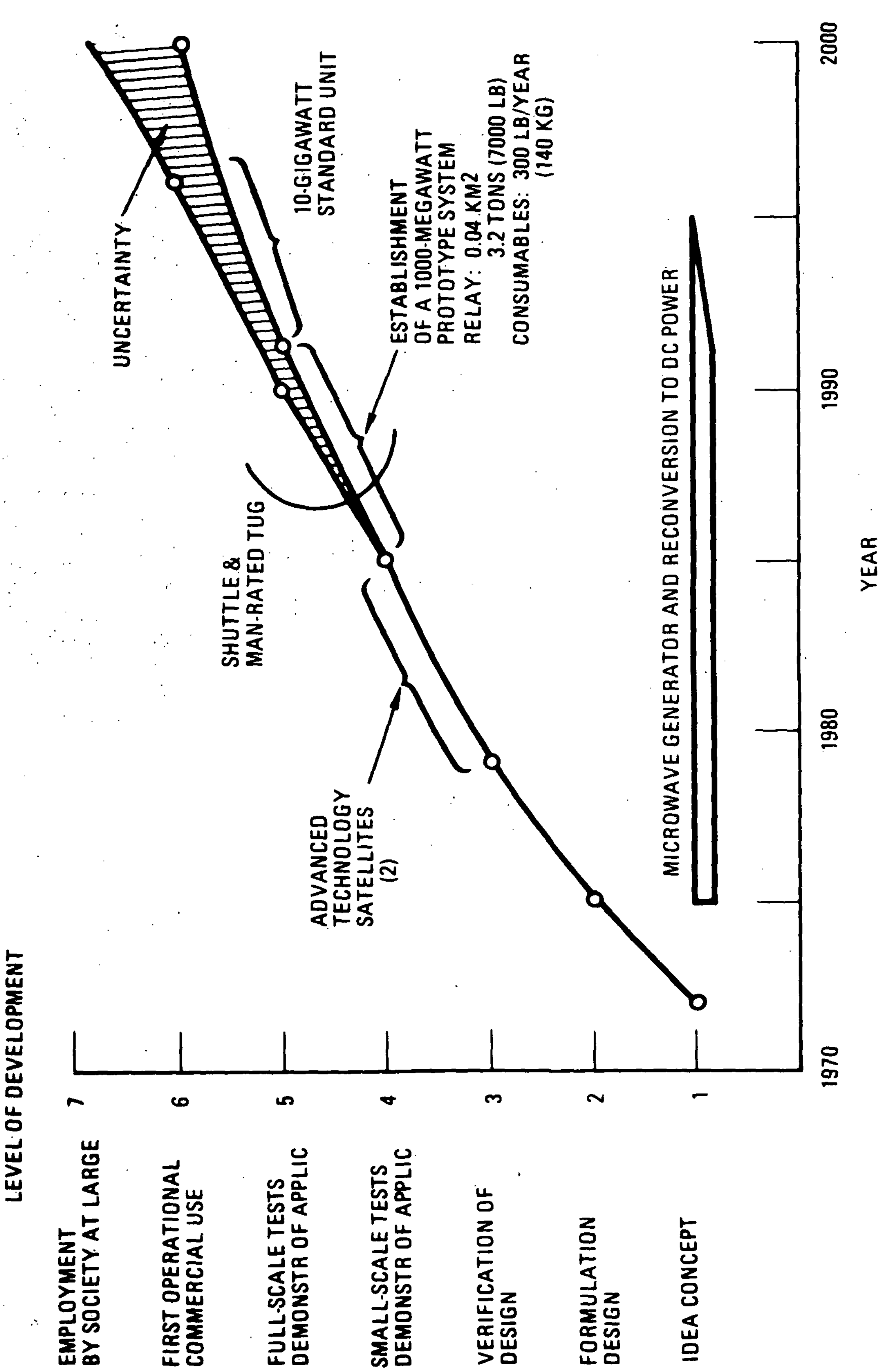


Figure 3.2-22. Space Power Relay Development Projection

3.3 WORLD AREA USER REQUIREMENTS DEVELOPMENT

Each of the preceding figures of functional data rate requirements are related to U.S. communications and science data forecasts only. An exception to this are the functional requirements for navigation and aircraft control which are presented on a world area user basis. Each of the other functional models also needs to be extended to a world area user basis from which a geosynchronous satellite traffic model can be derived. The subsequent paragraphs describe the methods used to develop world area communications and science data forecasts for the communications and data functions, the international science and applications functions, and other national space program applications functions.

COMMUNICATIONS AND DATA TRAFFIC

The approach used to estimate world area user requirements for the communications and data traffic was to determine the number of world users compared to the number of U.S. users. Then, the U.S. user data rate models could be extrapolated to world user models. This approach was used because the technology now exists to build and implement this category of communications functions and, in many countries, the development of satellite communications systems is a commercial venture not necessarily dependent on constrained government funding levels.

References 3-2, 3-8, and 3-9 were consulted to determine world population and growth trends. Figure 3.3-1 summarizes the population trends from 1950 to 1970 and extrapolates these growth rates to the year 2000. (This is somewhat optimistic since recent growth trends in some populous countries are decreasing markedly due to the world-wide implementation of birth control techniques.) Figure 3.3-1 shows the population trends grouped into three major world areas for convenience. Each world area represents the potential surface area that can be covered by a single satellite. These three areas are: (1) North and South America including Alaska and Hawii; (2) Europe, Africa, and USSR (West) including those countries eastward to 60 degrees east longitude; and (3) USSR (East), Asia, Australia including New Zealand and those islands of the South Pacific to 180 degrees east longitude. These three world areas encompass approximately equal land areas, but populations in each area are consideraly different; e.g., area (1) above contains about 511,000,000 people; area (2) contains about 974,000,000 people; and area (3) contains about 2,150,000,000 people. The approximate world total is presently about 3,635,000,000 people compared to the 1970 U.S. population figure of approximately 205,000,000 people.

It is further rationalized that the total population would not necessarily be the principal users of many of the communications functions. The primary users are believed to be the literate population that is greater than 14 years of age. References 3-10, 3-11, and 3-12 provided these data on current literacy levels for many of the countries in each world area. Data for some

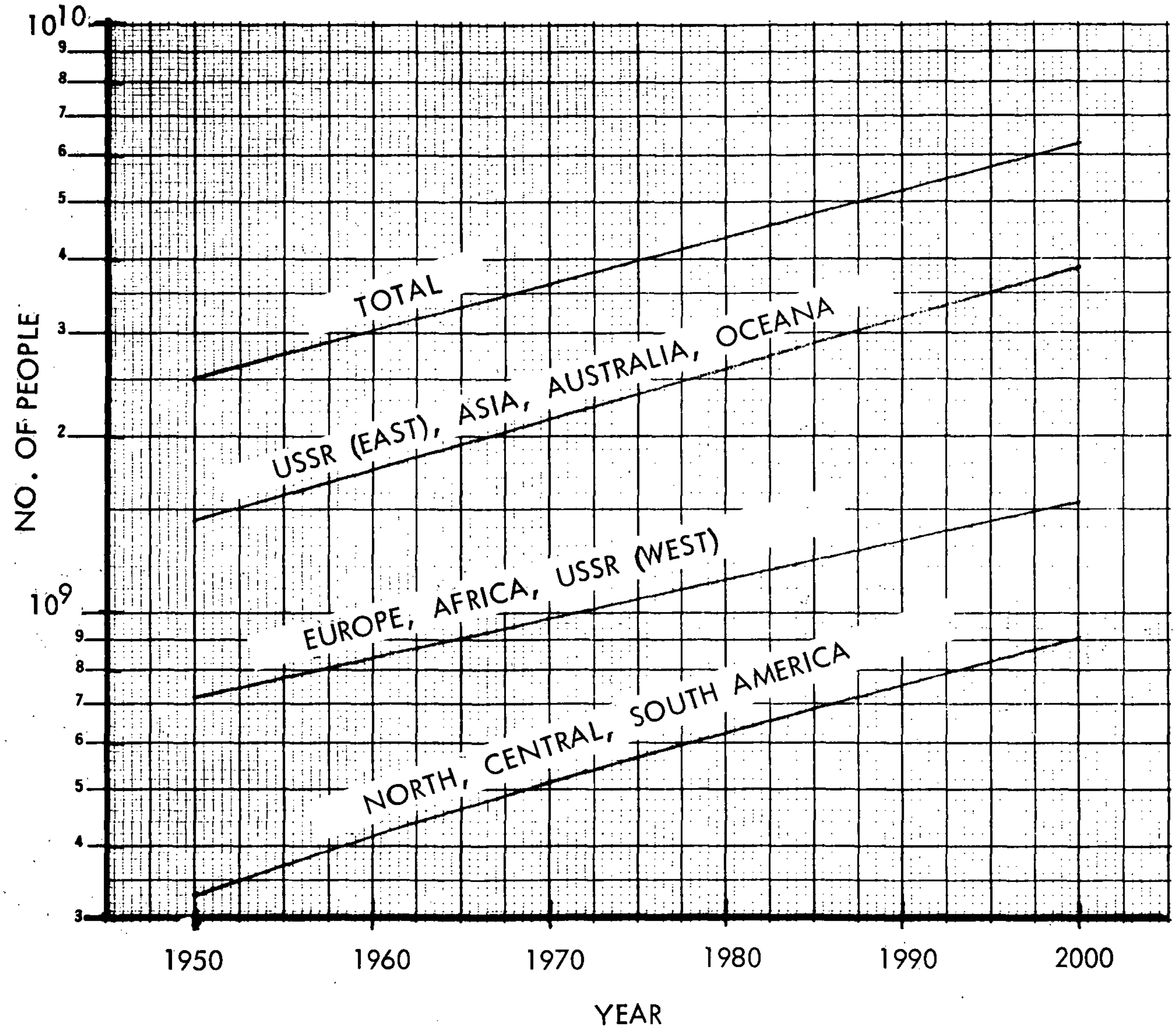


Figure 3.3-1. World Population Trend

of the countries produced educational trends which permitted the extrapolation of literacy levels to the year 2000. Using these data, an empirical expression was developed to extrapolate literacy growth rates by world area to the year 2000. This was:

[Literacy growth rate ∿ percent/year] = [Population growth rate ∿ percent/year] x [1 + 2 (Illiterate Fraction)]

Figure 3.3-2 shows how rapidly illiteracy is being eliminated. Although not apparent from the grouped areas, there are many countries in Europe and Asia that are more literate than the U.S. However, low literacy areas such as China, India, much of Africa, and some parts of South America increase the world area illiteracy averages. Based on the forecasted trend shown, the world illiterate population will still be greater than ten percent in the year 2000.

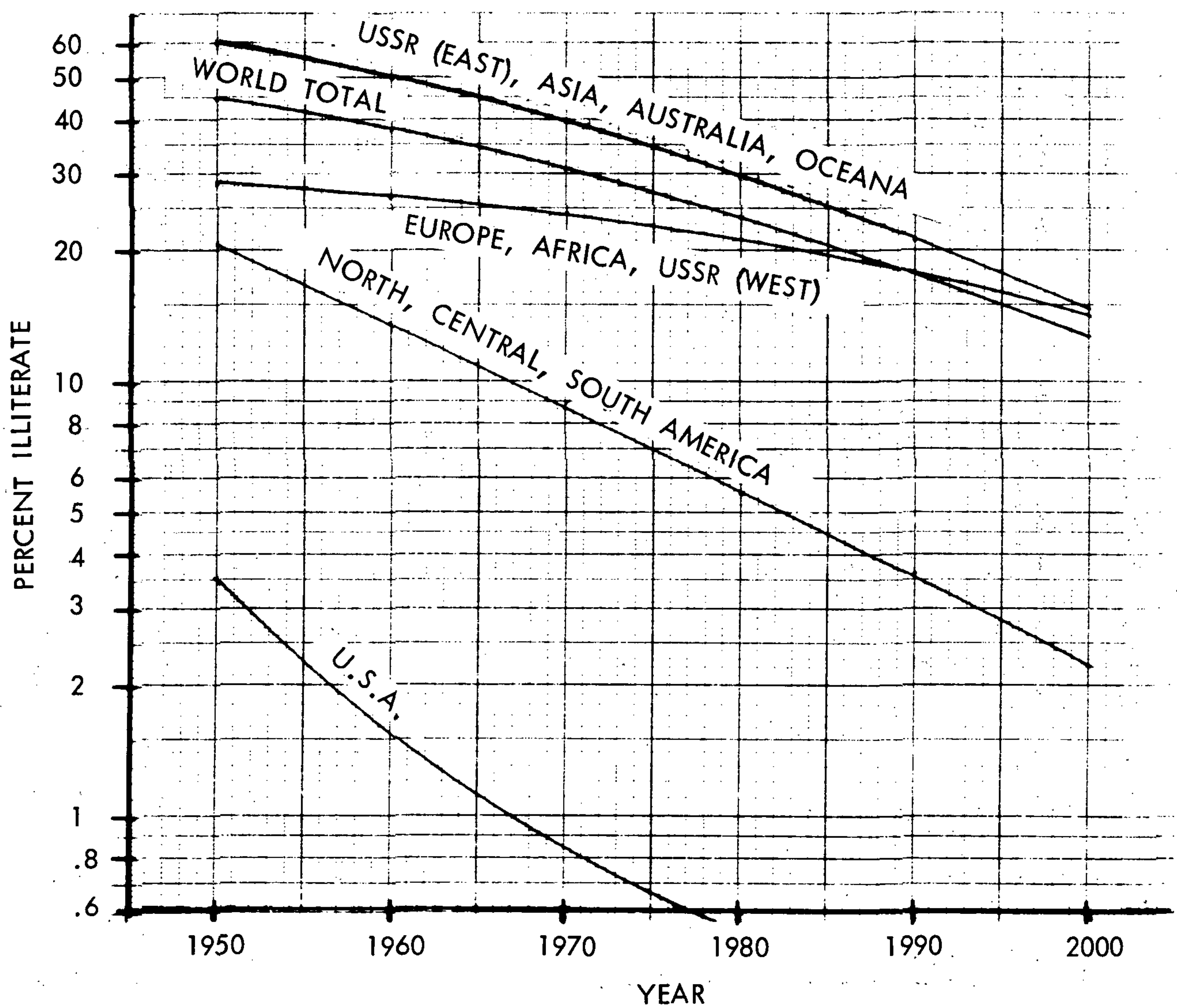


Figure 3.3-2. World Illiteracy Trends

Combining the literacy data (from Figure 3.3-2) and the world population data (Figure 3.3-1) adjusted for the age criteria (>14 years old) produces the world literate population trend shown in Figure 3.3-3. These data represent the primary potential users of communications and data transfer functions. When these data are compared to the number of potential U.S. users, the ratio of world area user to U.S. user is obtained as illustrated in Figure 3.3-4. As noted on Figure 3.3-4, these data represent the potential demand ratios.

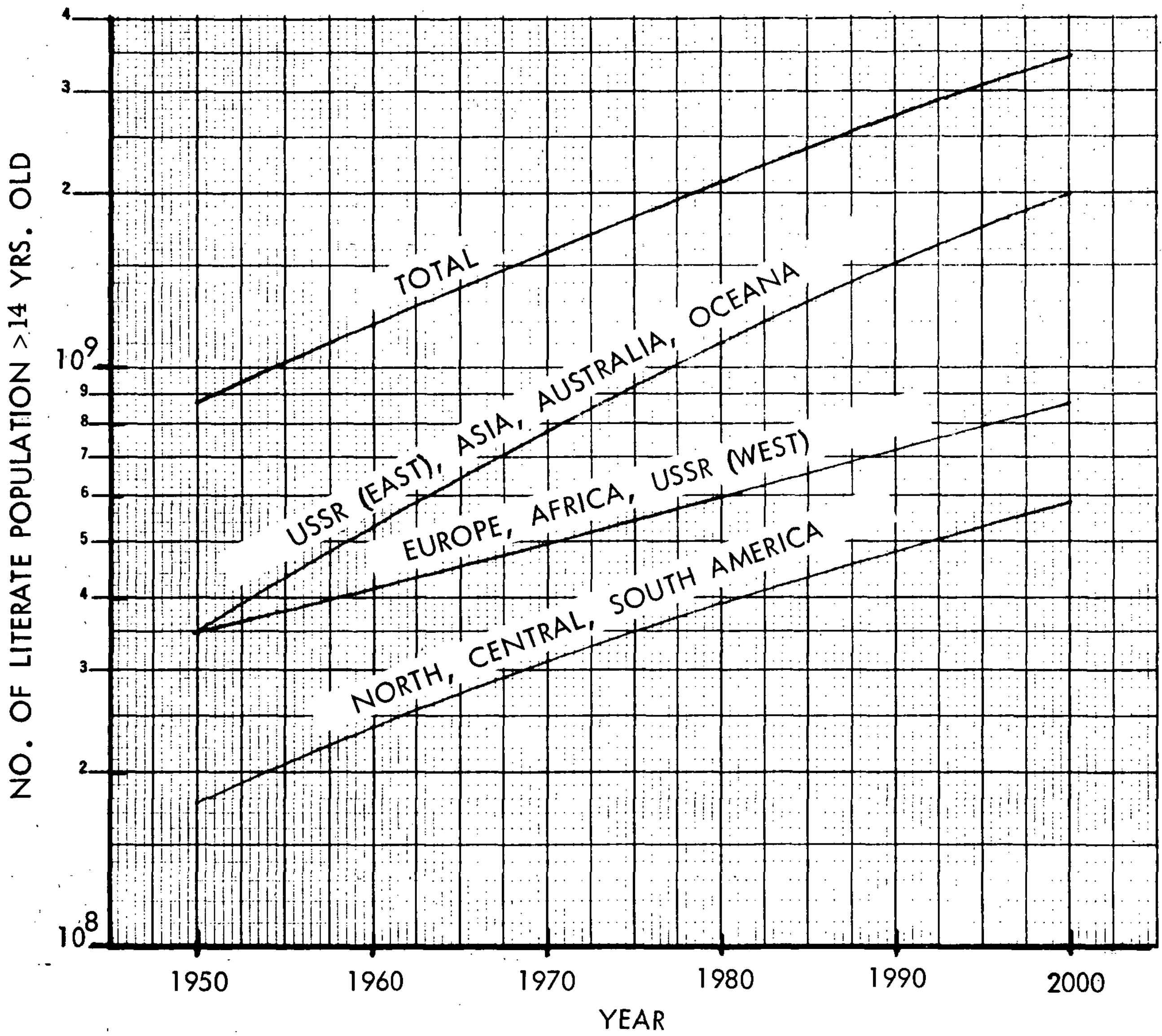


Figure 3.3-3. World Literate Population Trend

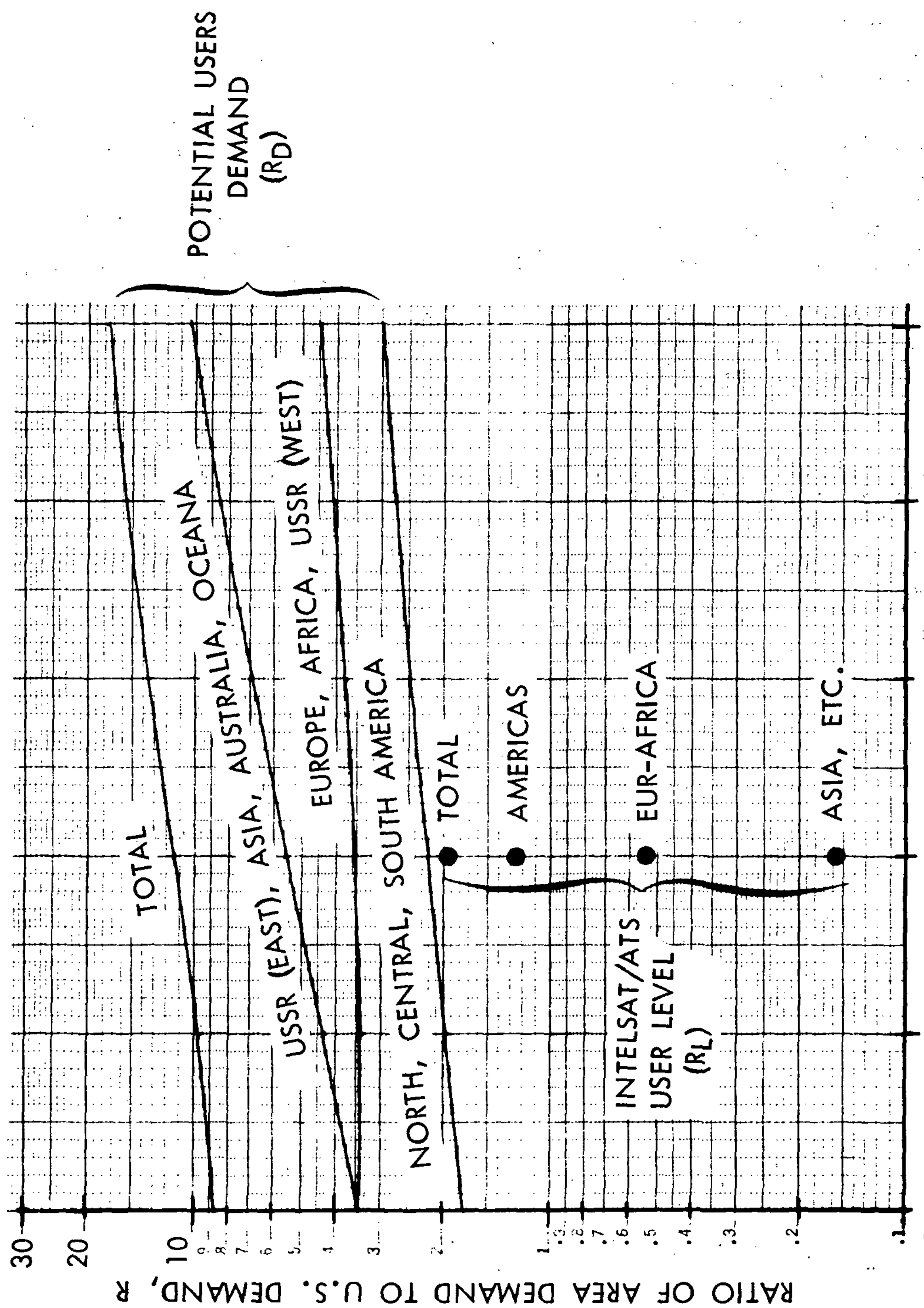


Figure 3.3-4. Demand Extrapolation Ratio Development

Actual user levels, by world area, are also shown on Figure 3.3-4. These data, for 1970, were obtained from Comsat reports on Intelsat usage and miscellaneous reports of ATS usage for various communications and data transfer functions. As more ground terminals and distribution systems are established (covering all of the functions), the 1970 user levels (by area) will increase toward the potential user demand ratios.

Past U.S. historical growth trends show that new technologies, such as the telephone, telegraph, and automobile, can usually converge on demand levels within 30 years. Recent U.S. historical growth trends in television and computers seem to show a shorter convergence period to demand levels; that being 15 years and 20 years, respectively. Feeling that technological developments in communications for some countries will lag the U.S., Europe, and Japan, a convergence period of 1970 to 2000 is assumed for each of the world areas. That is, the ratio of world area demand to the U.S. demand will increase from the 1970 actual user points to converge with the user demand level at the year 2000.

A general empirical equation was developed for the time history, user level trends from 1970 to 2000. The equation is structured to follow the standard historical growth pattern of any new technology, that is, an initial slope which decreases in time to meet the user population growth rate. The empirical equation is:

$$R_{L2} = R_{L1} (1 + \dot{R})^n$$

where, R_{L2} is the user level ratio at time 2

R_{L1} is the user level ratio at time 1

n is the number of years between time 1 and time 2

$\dot{R}$ is the rate of change in user level ratio between time 1 and time 2

$$\dot{R} = \dot{\bar{R}}_{1,e} \left[1 + \frac{R_{D1} - R_{L1}}{R_{De}} \right]$$

where, R_{D1} is the user demand ratio at time 1

R_{De} is the user demand ratio at year 2000

$\dot{\bar{R}}_{1,e}$ is the average rate of change in user level ratio between time 1 and 2000

$$\dot{R}_{1,e} = \left(\frac{R_{De}}{R_{L1}} \right)^{1/n} - 1$$

Using n equal to five years, each world area user ratio was determined based on the preceding equations. The resulting extrapolation ratios are shown in Figure 3.3-5. These ratios are used to extend the 14 U.S. communications and data functions listed in Table 3.1-1 and defined in Figures 3.2-2 through 3.2-13 to world area requirements.

As described, the extrapolation of the U.S. user requirements to world area requirements is based on the world literate population over the age of 14. To provide a point of comparison, the world to U.S. requirements ratio has been determined on forecasted population only. This disregards age and literacy. Using this simplified assumption, the world to U.S. ratio for the year 2000 is 21.45 compared to 17.5 as shown in Figure 3.3-5. This assumption would, on the average, increase user requirements 22 percent above the model developed.

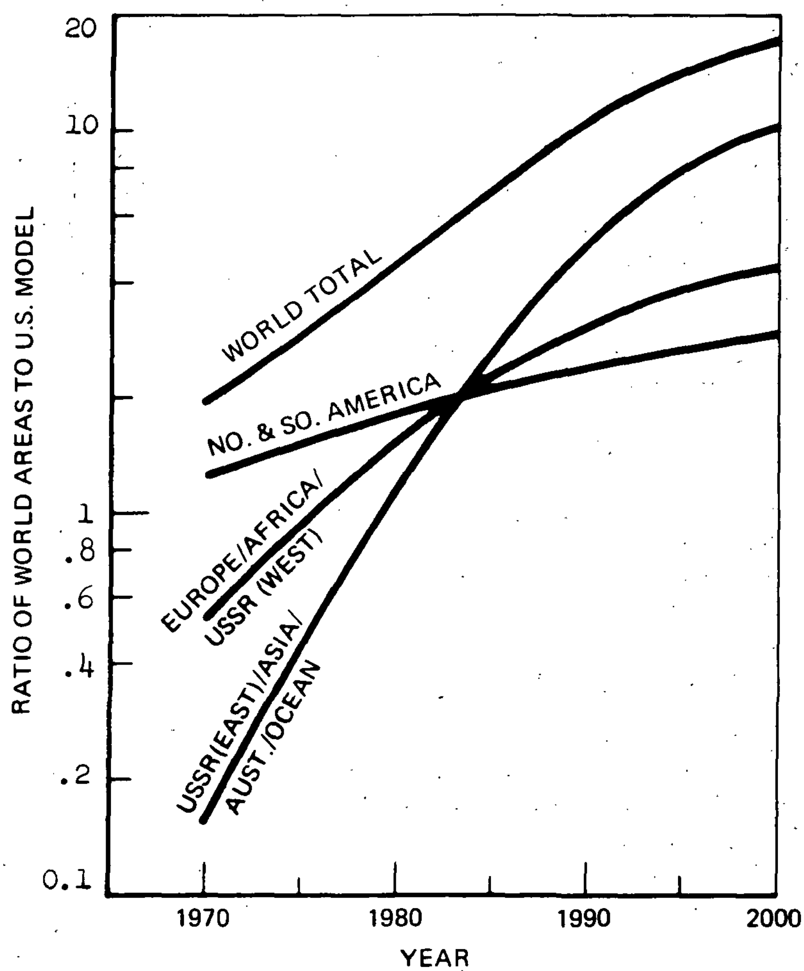


Figure 3.3-5. Extrapolation Ratios for Principal World Areas

INTERNATIONAL SCIENCE AND APPLICATIONS

The science and applications functions which lend themselves most to international sharing of costs and data results are meteorology, earth resources, navigation, and aircraft control. In time, probably beyond the year 1990, international consortiums may be established to operate and maintain geosynchronous power relay satellites.

The extrapolation of meteorology and earth resources functions from U.S. user needs to world area user needs is based specifically on the area that can be effectively covered by a satellite. World coverage between 76 degrees north and south latitudes can be obtained with four satellite locations. Sufficient longitudinal overlap is provided between satellites to permit a single nation (in many cases) to obtain all its data from a single satellite. Larger nations such as the U.S., USSR, and China would probably obtain data from two or three of the satellites. World area requirements for meteorology and earth resources, therefore, will be four times the level shown on Figures 3.2-14 and 3.2-15.

The navigation and aircraft control functions, as described in the previous section, were initially defined for world user needs. No extrapolation of U.S. user needs were required to obtain the forecasted world user requirements because readily available data were documented in terms of world user needs.

A quantitative forecast of world user requirements for space power relay has not been determined because this space application function will occur beyond the 1990 time period (and is beyond the period of the current Geosynchronous Platform Definition Study). However, the subsequent section on world user requirements by functional spacecraft type will show a potential number of 10 gigawatt satellites for world use based on a number of candidate remote power sites. The first operational satellites to be placed into service are not expected until after the year 2000.

NATIONAL SPACE APPLICATIONS PROGRAM

Some of the science and applications functions are of such a specialized nature that they are most likely to be developed and operated by international consortiums or under an individual national space program. The science and applications functions which are considered as candidates for national (or consortium) space program sponsorship are communications and systems tests, astronomy, tracking and data relay, and solar illumination (Lunetta).

The definition of world user needs for these functions based on the U.S. user requirements have been forecasted based on national space program funding trends. In the 1972 Forecast and Inventory Issue of Aviation Week and Space Technology (Reference 3-13), space program expenditures and historical growth rates are shown for Western Europe, ELDO, ESRO, and Japan. No data were readily located for other countries participating in space program efforts such as Canada, China, and USSR. It was, therefore, arbitrarily assumed that the USSR program would be equivalent to the U.S. geosynchronous programs, and that China's efforts would be equivalent to those of Western Europe,

and that Canada's geosynchronous participation would be equivalent to five percent of the U.S. efforts. Furthermore, it was assumed (with current optimism for the future) that the U.S. geosynchronous space program funding (government only) would grow at the rate of seven percent per year up to the year 2000. However, European and Japanese space program growth rates were extrapolated, from their historical values, at 15 percent per year to 1980, 12 percent per year to 1990, and 10 percent per year to 2000.

With these gross assumptions and ratios of national and consortium space program expenditures to U.S. funding levels, Figure 3.3-6 was developed. This shows the percent equivalence of other national programs to the U.S. program which has been shown, from a U.S. user point of view, in Figures 3.2-18, 3.2-19, and 3.2-20. It is recognized that these other nations or consortiums may not develop the same functional types of satellites which have been identified for the U.S. Even so, those functional satellites placed in geosynchronous orbit will be transmitting data at comparable data rates to ground users. In addition, it is very likely that other countries and/or consortiums may develop or buy their own tracking and data relay satellite systems. This function is particularly significant because it represents about 82 percent of the total U.S. science and applications functions data rate for 1990.

The extension of U.S. solar illumination (Lunetta) needs to world user requirements has not been quantitatively determined because, as for solar power relay, this application will occur beyond the 1990 time period. The subsequent section on world user requirements by functional spacecraft type will show some typical locations where Lunetta satellites could provide some of the needed illumination benefits.

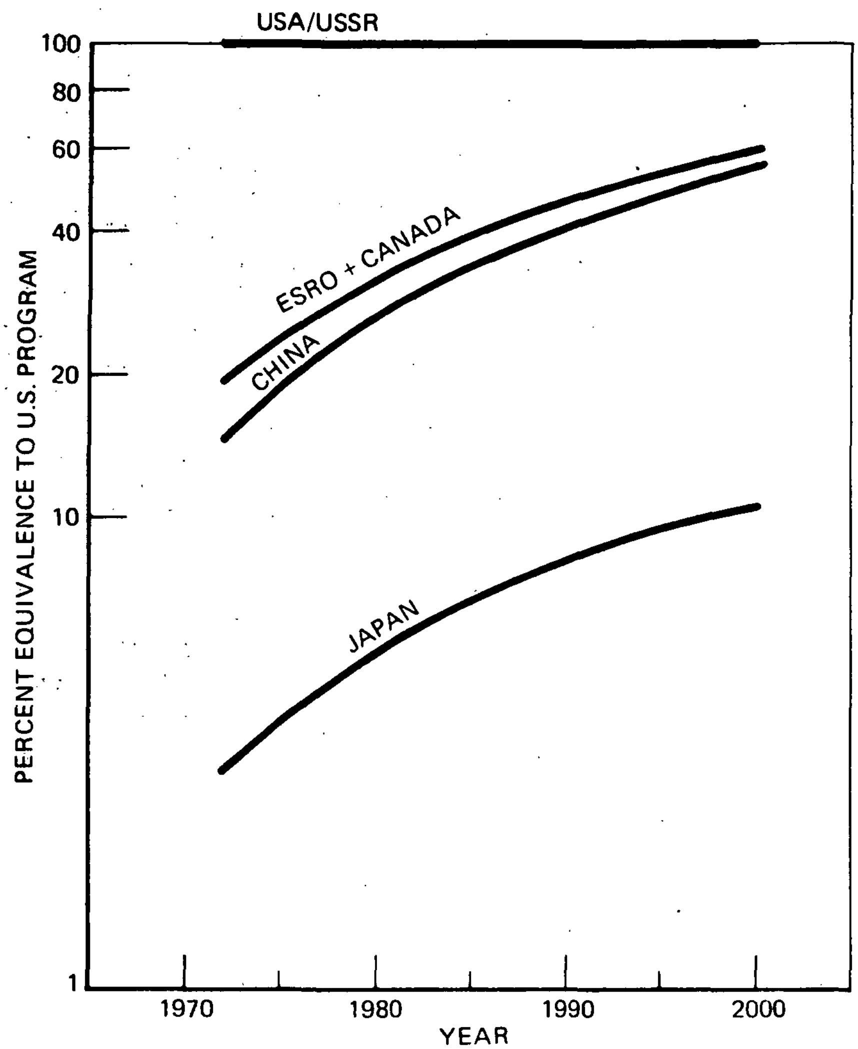


Figure 3.3-6. World National Space Applications Program Extrapolation Ratios

3.4 WORLD USER REQUIREMENTS BY FUNCTIONAL SATELLITE TYPE

Each of the functions which have been forecast have also been considered for grouping into dedicated satellite types. The grouping of functions was based on data sources and destinations, and frequency band allocations for specific functions. International frequencies have been designated for the general functions of communications, meteorology, navigation, space operations and space research. Table 3.4-1 shows the previously listed functions which could be grouped into dedicated satellite types based on these considerations.

Table 3.4-1. Functions Allocated to Dedicated Satellite Types

Satellite Type (Acronym)	Functions Allocated
Intelsat	Education Commercial broadcast Teleconference (& telegraph) Post office Medical data bank Banking/business/credit transactions Newspaper
Domsat	Education Commercial broadcast Teleconference (& telegraph) Post office Medical data bank Banking/business/credit transactions Newspaper Electronic publishing Civil defense Welfare data bank Library data bank Private record banks Telecomputations
Mersat	Meteorology Earth resources
Nacsat	Navigation Aircraft control

Table 3.4-1 shows that eight of the communications and data category functions (Table 3.1-1) are identified for international satellite (Intelsat) transmission. It is also shown that all 14 of the communications and data category functions are identified for domestic satellite (Domsat) transmission.

Excluding communications frequencies which are used in Intelsat and Domsat systems, several of the science and applications functions have been grouped on the basis of functional interrelationship and frequency assignments. Meteorology and earth resources satellite (Mersat) functions are grouped because of similarities in the earth looking functions and assigned frequencies for data transmission. Navigation and aircraft control satellite (Nacsat) functions are combined because Reference 3-6 described how voice transmisisons could be digitized along with basic navigation data. This advantageous feature, useful primarily to aircraft control, could also be useful to large harbor area ship traffic control. This could significantly reduce the collision hazard in poor visibility conditions.

No readily apparent advantages for grouping any of the other science and applications functions are recognized. The remaining functions seem sufficiently different in objectives and satellite operational requirements that these are considered (for the new traffic model) to be performed on individually dedicated satellites.

INTERNATIONAL/DOMSAT TRAFFIC DISTRIBUTION

Table 3.4-1 shows that eight of the communications and data category functions have been identified for transmission by both Intelsat and Domsat systems. In addition, the data rate demand models for these functions do not define how much of the data rate is distributed to Intelsat and to Domsat. The subsequent paragraphs describe the rationale used to determine this distribution for each of these functions. The approach used was first to estimate the year of initial operational capability (IOC) for transmission of each function by Intelsat. Second, the level or percentage of transmission of each function by Intelsat in the year 2000 was estimated (using same rationale). Finally, the percentage of use between the IOC date and 2000 was interpolated for each function.

The estimated year of initial operational capability and the year of first demonstratation is listed for each Intelsat function on Table 3.4-2. It is possible that the first demonstration of business transactions and facsimile mail transmission may have already occurred. The functions which have not reached operational capability lack the ground operation and distribution stations required.

Table 3.4-3 presents the percentage of traffic for each function that is forecast for transmission by Intelsat in the year 2000 and the rationale used.

Table 3.4-2. Intelsat Communications Functions

Communications Function	First Demonstrated	Estimated IOC Year
Teleconference (& telegraph)	1965 Early Bird	1967
Commercial broadcast	1965 Early Bird	1967
Education	1965 Early Bird	1974
Banking/business/credit trans.		1972
Medical data bank	1971 ATS-1	1974
Newspaper	1967 ATS-3	1978
Post office		1978

Table 3.4-3. Estimated Percent of
Intelsat Communications to Total

COMMUNICATIONS FUNCTION	% INTELSAT IN 2000	RATIONALE
TELECONFERENCE	10	• BASED ON (U.S.) RATIO OF INTERNATIONAL TO DOMESTIC PHONE CALLS PRIOR TO INTELSAT • RATIO INCREASED 50% TO ACCOUNT FOR INCREASED TREND IN INTERNATIONAL COMM
COMMERCIAL BROADCAST	25	• MORE INTERNATIONAL SPORTS • MORE POLITICAL & HISTORICAL EVENTS FOR NEWS BROADCASTS
EDUCATION	30	• INTERNATIONAL CO-OP EDUCATIONAL PROGRAMS • INCREASED DEMAND FOR BILINGUAL LITERACY
BANKING/BUSINESS/CREDIT TRANS	15	• RATIO OF EXPORT/IMPORT TO NATIONAL INCOME (IN U.S.)--HAS BEEN LEVEL FOR 10 YR
MEDICAL DATA BANK	15	• 30% USE BY SMALL COUNTRIES AND 3% USE BY LARGE COUNTRIES
NEWSPAPER	25	• FOREIGN TRAVEL AND READER INTEREST • INCREASED POPULATION ON FOREIGN ASSIGN.
POST OFFICE	5	• RATIO OF INTERNATIONAL TO DOMESTIC MAIL (U.S.) WITH 4%/YR GROWTH RATE • INTERNATIONAL MAIL MORE SUITABLE FOR SATELLITE TRANSMISSION

The teleconference (and telegraph) function is shown to be 10 percent international in 2000. In 1970 this was 100 percent international (this percent reflects only that carried by satellite transmission) because there were no domestic satellites at that time. This international traffic function began to decrease in 1972 when Brazil started using Intelsat as a Domsat and the Molniyas (Russian) and Canadian Telsat were launched and put into domestic operation. The predicted level is based on the ratio of U.S. international to domestic phone calls prior to the advent of communications satellites. This ratio is increased by 50 percent to reflect the present trend in increased international communications and lowered communications costs with satellite systems.

Of that portion of commercial broadcast carried by satellite transmissions, the amount carried by Intelsat in 2000 is estimated to be 25 percent. Until 1972 it also had been 100 percent. At present, there has been world coverage of Olympics, soccer, baseball, golf, boxing, track, and other sports with others to be added in the future. It is anticipated that more international events will be televised between neighboring countries. Also, major political and historical events will be broadcast internationally when added networks and reduced transmission costs occur. For these reasons it is believed that the percentage of international broadcast will remain relatively high.

The education function is expected to grow to a level of 30 percent by 2000. This estimate is based on the decreasing trend of illiteracy and the increasing trend of international cooperative programs (i.e., business and space). Because of the growth in multinational corporations, there is increasing demand for bi-lingual literacy which can be met through the Intelsat cultural exchange education function.

The ratio of U.S. export/import income to total national income has been about 15 to 17 percent from 1960 through 1969. This ratio is believed to be applicable in the forecast of the international to domestic banking/business/credit transaction function. The level of 15 percent is not expected to significantly change in the future (for the U.S.). It is noted that this forecast is for business data transactions and does not include teleconfering (which has been previously accounted for). Other countries may have higher or lower ratios. The U.S. sample is assumed to be a representative world average.

It is anticipated that low cost satellite communications will stimulate medical data transmissions on an international and domestic basis. Medium to small (area) countries will tend to pool their data in international medical data banks in contrast to large countries (like the U.S., USSR, and China, etc.) which will pool most of their own medical information into domestic medical data banks. With this premise, it is assumed that small countries will utilize international data banks in 30 percent of their transmissions whereas large countries will utilize international data bank information only 3 percent of the time. The integrated average of these assumptions results in a forecasted international to total medical data bank transmission ratio of 15 percent in the year 2000.

The international transmission of newsletters or entire newspapers for foreign distribution such as the New York Times, Wall Street Journal, Barrons, Time Magazine, and similar foreign publications is expected to be commonplace in the year 2000. The percentage of international traffic to total traffic in the newspaper function is estimated to be 25 percent. This forecasted demand is based on increasing foreign travel (and foreign reader interest) projections involving an increased percent of the world population on foreign assignments.

The international post office traffic is projected to be five percent of the total post office satellite traffic in 2000. This estimate is based on the present fraction of U.S. international to domestic mail with an annual growth rate of four percent per year. The projected growth rate is based on the fact that the characteristics of international mail are more suitable for satellite transmission than domestic mail.

Table 3.4-4 shows trend changes in percent of Intelsat traffic compared to the total traffic for each of the Intelsat functions. The trend for each function is interpolated between the IOC date and estimated level in the year 2000 as shown in Tables 3.4-2 and 3.4-3.

Table 3.4-4. Percent of Total Functional Traffic That Is International

Function	1970	1975	1980	1985	1990	1995	2000
Teleconference	100	64	55	40	25	15	10
Commercial broadcast	100	64	55	43	34	28	25
Education	0	4	15	21	25	28	30
Banking/business/credit transactions	0	5	11	14	15	15	15
Medical data bank	0	2	8	11	13	14	15
Newspaper	0	0	8	18	22	24	25
Post office	0	0	2	4	5	5	5

Intelsat data rates for each of the Intelsat functions were determined using the total function data rate and interpolated percentages from Table 3.4-4. These values for each function were summed and divided by the total to determine the average percentage level of Intelsat traffic for the seven common Intelsat/Domsat functions. This trend as a function of time is shown in Figure 3.4-1.

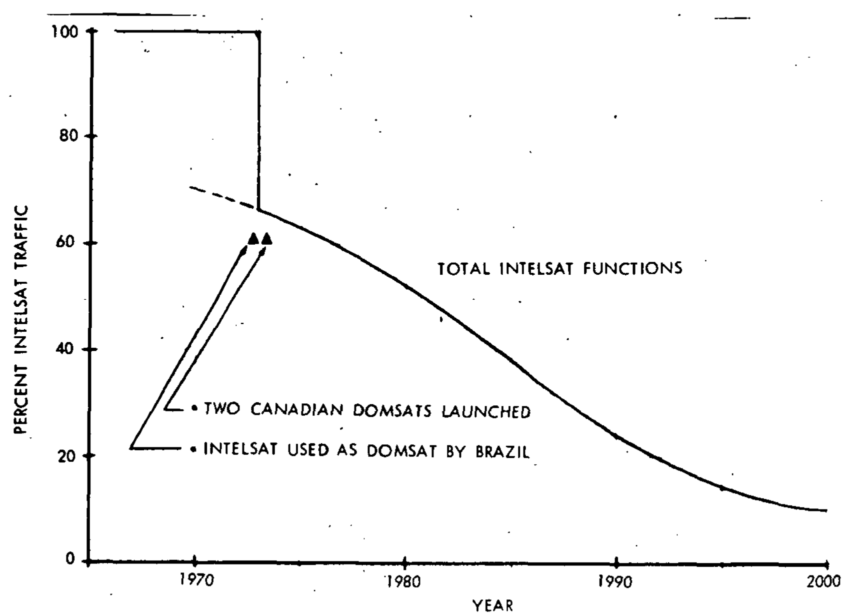


Figure 3.4-1. Intelsat Traffic Percentage for the Common Intelsat/Domsat Functions

The step down in the curve (at the end of 1972) is caused by the use of Intelsat as a Domsat and the launch of the two Canadian Domsats. This represents the step change in teleconference and commercial broadcast functions. The transition from 100 percent to about 65 percent actually occurs during the years 1972 and 1973 but has been drawn as shown for simplicity. The smooth curve from 1973 has been extrapolated backwards as shown by the dashed line to 1970. This "artificial distribution ratio" is used on the Intelsat and Domsat world data rate demand curves so that there would not be a sharp step in these curves due to the Intelsat/Domsat transition period. It is emphasized that the total data rate demand is unchanged. The resulting functional demand curves will, therefore, show slightly lower than actual demand, in 1970, for Intelsat traffic and a higher demand, that is not satisfied in 1970, for Domsat traffic.

INTERNATIONAL SATELLITE (INTELSAT)

The world Intelsat forecast by continental area has been developed by adding each of the Intelsat functions, applying the appropriate fractional distribution (for Intelsat as identified in Table 3.4-4), and multiplying by the extrapolation ratios presented in Figure 3.4-1. The resulting model is shown in Figure 3.4-2. Since international communications satellites provide communications and data links between major continental areas, the data in Figure 3.4-2 have been reallocated from continental areas to satellite location (i.e., ocean location). Figure 3.4-3 shows these data rate models by ocean location. It is noted that the 1970 data rate levels are based on Comsat reports of leased channel traffic hours for each ocean area but have been reduced as described in the previous paragraph. (The reduced amount has been added to the world Domsat model.)

The world data rate levels shown are average values for 24 hours per day. It is recognized that real demand levels will vary from the average level. Demand levels peak during the average person's awake hours and reach a minimum during normal sleep hours. A demand rate duty cycle has been estimated based on the local zone time of day. Each time zone will have its maximum and minimum rates at approximately the same local time of day. Some minor variations occur between nearby zones, however, because the long distance traffic to other time zones is primarily time coordinated to the best convenience of each party in each time zone. This effect tends to reduce daily data rate peaks in both zones.

Based on U.S. long distance telephone experience, considering time of day rate changes and recently estimated peak traffic, mean traffic, and minimum traffic, Figure 3.4-4 was constructed. This single zone duty cycle shows that peak numbers of calls per hour average about 1.75 times the mean number and minimum number of calls per hour average about 0.25 times the mean. Since telephone traffic represents more than 90 percent of all the communications and data rate traffic, this duty cycle is considered valid for use with all the other functions in the category of communications and data traffic.

Considering the time zone changes across the oceans and recognizing that traffic also occurs in a north-south direction involving the same time zone, the peak rates over the mean for each Intelsat ocean location are:

Location	Peak Rate Factor
Atlantic Ocean	1.65
Indian Ocean	1.65
Pacific Ocean	1.60

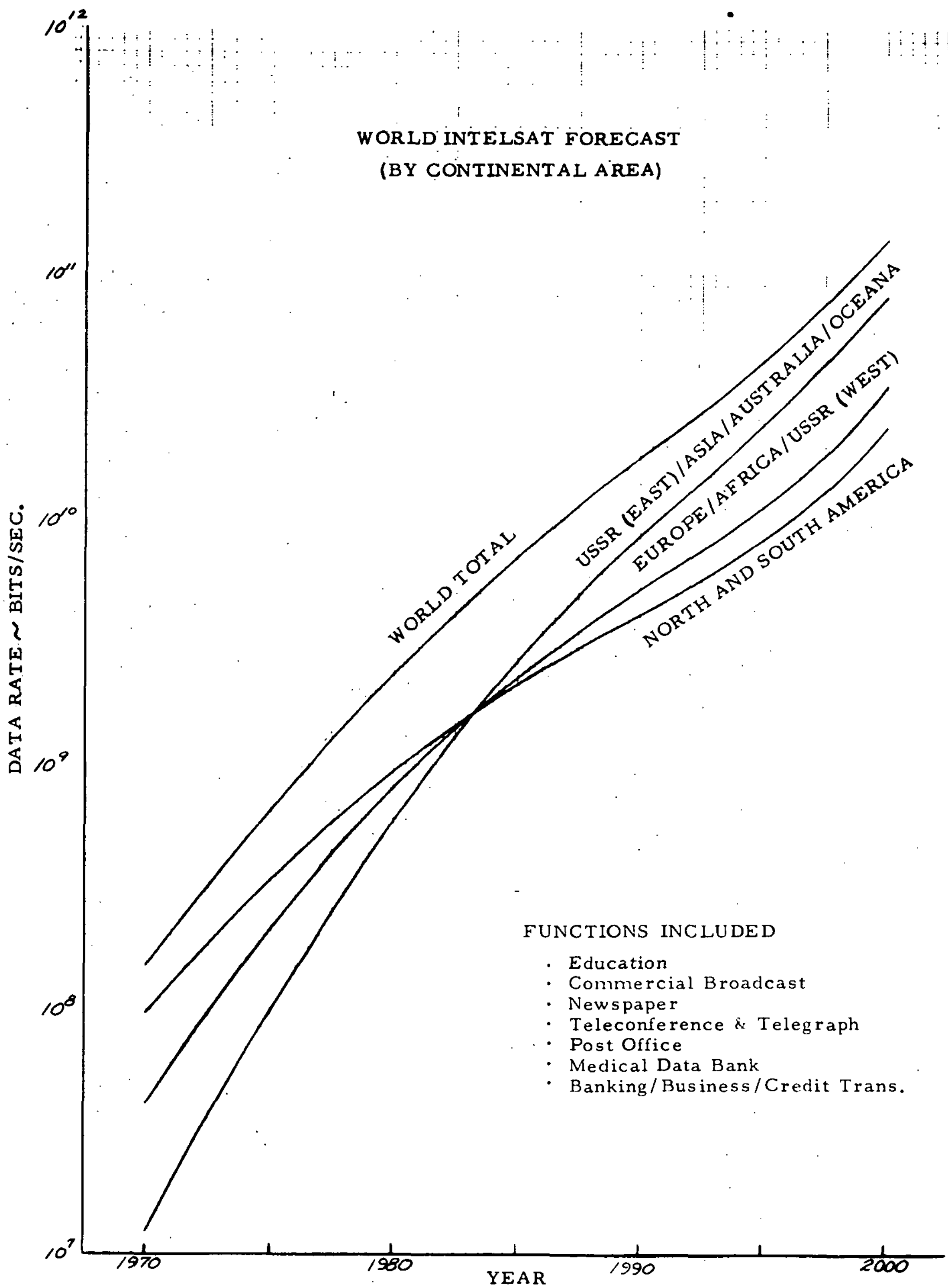


Figure 3.4-2. World Intelsat Forecast by Continental Area

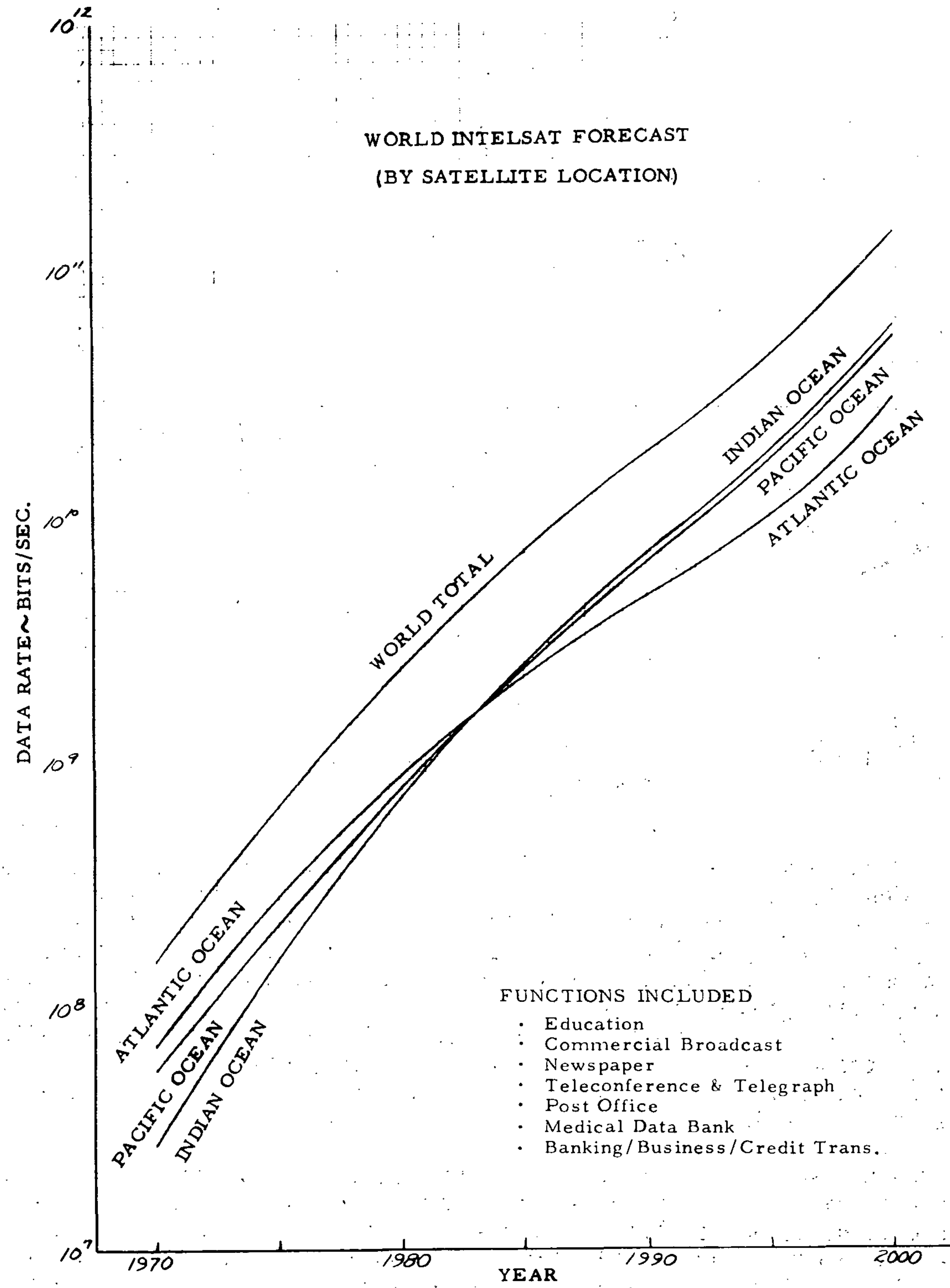


Figure 3.4-3. World Intelsat Forecast by Satellite Location

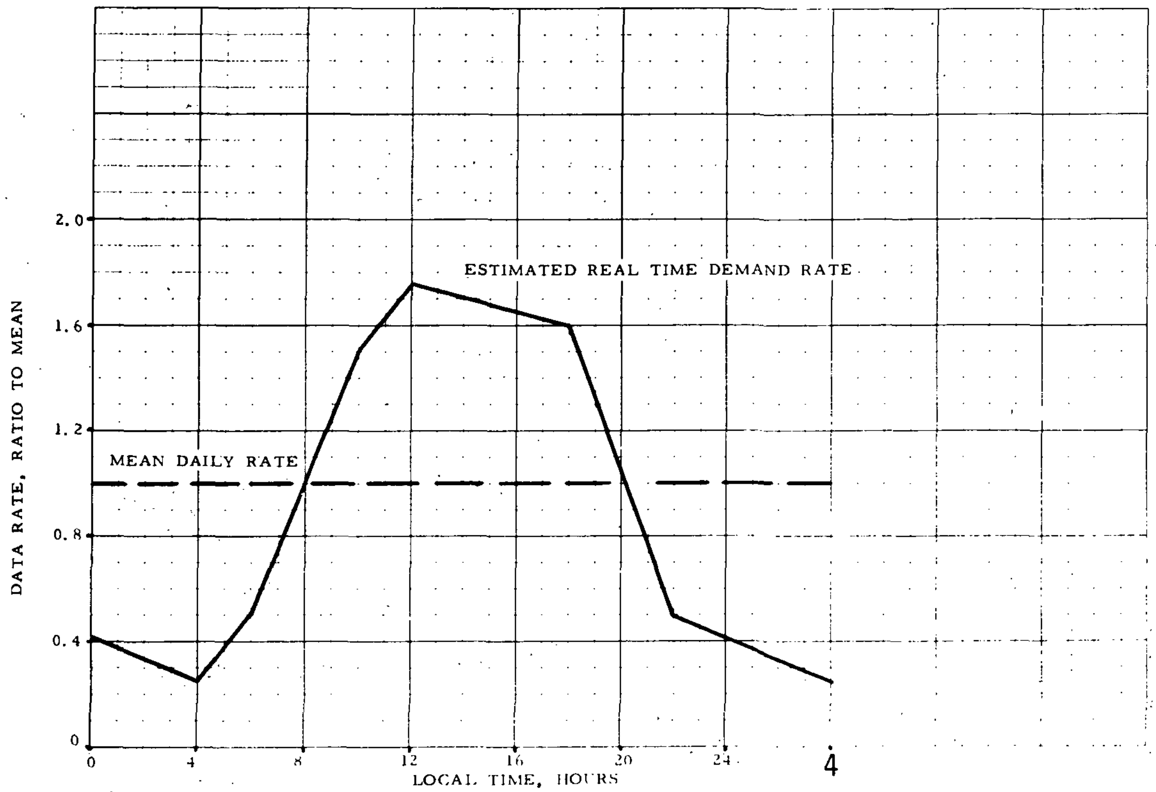


Figure 3.4-4. Real Time Communications Demand Duty Cycle for a Single Time Zone

Experience has shown that there are a small number of users who desire to have immediate access to communication satellite links regardless of other traffic levels. These users may only utilize satellite communications infrequently but due to the nature and urgency of immediate communications access, a number of satellite transponders may be dedicated for this purpose only. A typical example of this situation is the Washington to Moscow hotline via Intelsat and via Molniya satellite. This type of low volume dedicated transponder traffic is commonly referred to as thin route traffic. For Intelsat operations, thin route traffic demands are about 10 percent greater than mean data rate levels.

At the present time there are four Intelsat IV satellites in orbit, two over the Atlantic and one each over the Pacific and Indian Oceans. The data rate capacity of each satellite is 4.32 x 10^8 bits per second. Considering the peak rate factors, thin-route traffic level, and the forecasted demand level of Figure 3.4-3, it appears that the Atlantic satellites are operating at about 35 to 40 percent capacity (March 1973), the Pacific satellite at about 55 percent capacity, and the Indian Ocean satellite at 35 to 40 percent capacity. Based on the data rate demand slopes of Figure 3.4-3, peak capacities will be reached over all oceans in the 1975-1976 time period. This demand analysis is in agreement with the statement in Reference 3-14 which says,

"Comsat estimates that current and planned satellite communications capacity will be saturated by 1975". The difference in time to reach peak capacities is due to the fact that the 1970 levels were purposefully reduced (as previously described) and the Intelsat projected demand requirements increase at an annual growth rate of about 30 percent per year compared to Comsat estimates of as much as 40 percent per year. For the above reasons, it is believed that the actual current operating capacities of the Intelsat satellites is at least 10 percent higher than the demand rates shown.

DOMESTIC SATELLITE (DOMSAT)

The communications functions for the worlds domestic satellite systems include all those listed for Intelsat plus those functions specifically related to the needs of a single nation. The world Domsat demand model includes the sum total of the 14 U.S. functional demand models minus that communications and data traffic computed for the U.S. Intelsat demand model. The remaining data rates are then extrapolated to the world area demand models using data from Figure 3.3-5.

Figure 3.4-5 presents the world Domsat forecast by continental area. Comparing the level of communications and data traffic of Intelsat to Domsat demand models shows the Domsat model lower than Intelsat until mid-1982 after which the Domsat model exceeds the Intelsat model becoming almost 10 times greater by the year 2000. This trend which lags Intelsat until 1982, is expected when one considers the large amount of software programs and distribution networks that need to be established to effectively improve the functional services over present methods and to perform them utilizing the expected low transmission costs by satellite.

The peak data rate assumed applicable to world Domsats is equal to 1.71 times the mean value as shown for a single zone in Figure 3.4-4. Since Domsats will serve many individual small nations or a single large nation and many nation groups will span about four time zones, the peak rate of 1.71 seems to be most representative.

Thin-route traffic demands for domestic satellite communications services are expected to be higher than those required for international communications. For Domsat operations, thin-route traffic demands are expected to be 25 percent greater than mean data rate levels. Communications costs by satellite are expected to strongly influence this estimate; if costs are relatively high, the thin-route level may be only 10 percent, whereas if costs are low (as expected), the level may even exceed 25 percent.

METEOROLOGY AND EARTH RESOURCES SATELLITE (MERSAT)

The U.S. meteorology and earth resources demand models (Figures 3.2-14 and 3.2-15) have been combined and increased by a factor of four to cover four earth zones to obtain the world Mersat forecast model. The data rate total for these four zones is shown in Figure 3.4-6. These data rates are continuous mean values with no maximum or minimum rates during the 24-hour day. Various types of information will be sensed and transmitted for specified locations in an established sequence. The sensing sequence repeats its cycle as each data set is completed for the zone.

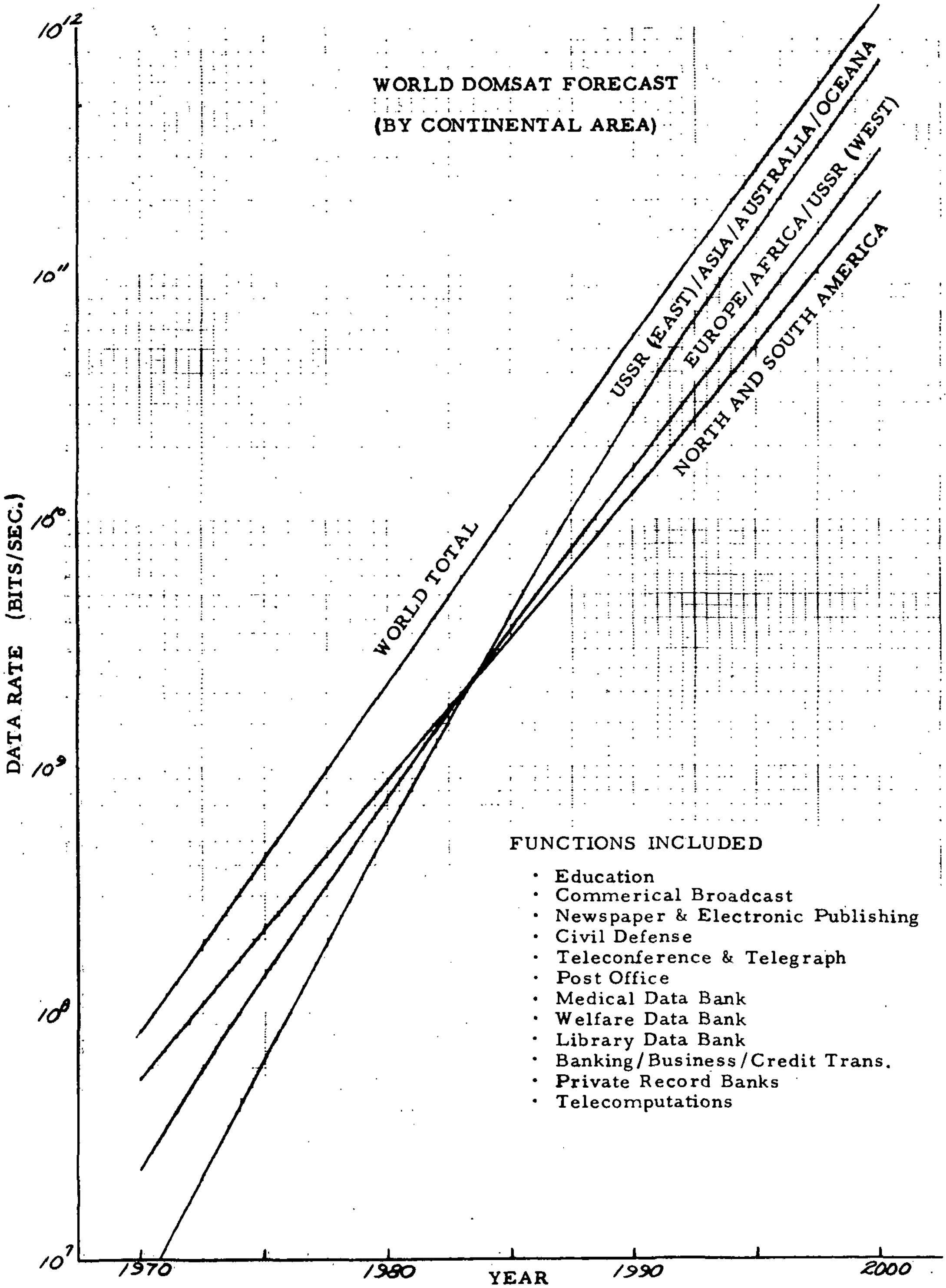


Figure 3.4-5. World Domsat Forecast by Continental Area

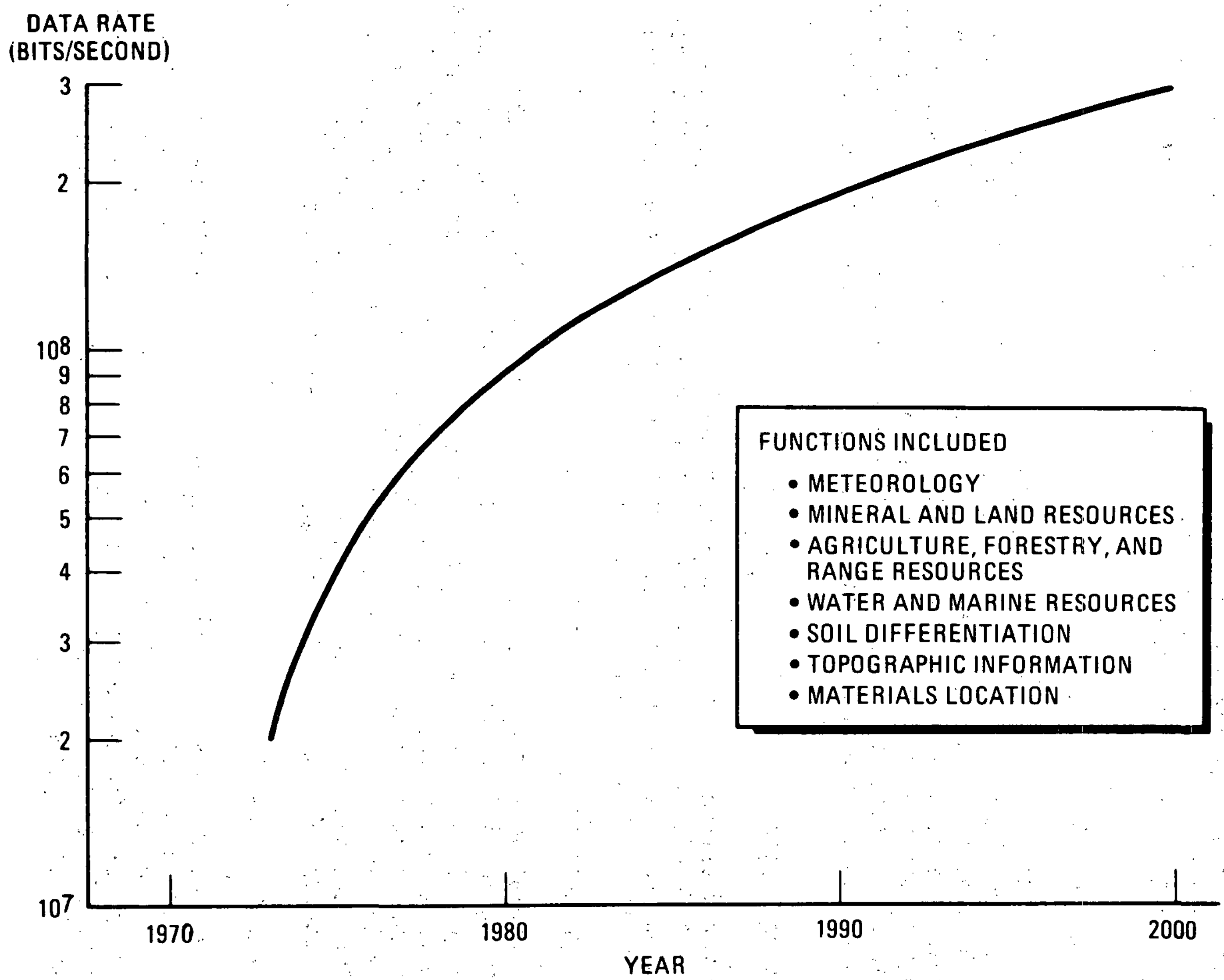


Figure 3.4-6. World Mersat Forecast

NAVIGATION AND AIRCRAFT CONTROL (NACSAT)

Combining the navigation and aircraft control models previously shown in Figures 3.2-16 and 3.2-17 provides the data rates for the world Nacsat forecast model. The required data rates for each ocean area are shown in Figure 3.4-7. These data rates are also continuous mean values with no projected peak or minimum values. Since the number of traffic elements is relatively constant during any 24-hour period, no significant data rate variations are expected.

APPLICATIONS TECHNOLOGY SATELLITE (ATS)

The U.S. ATS model has been extrapolated using the accumulated data from Figure 3.3-6 to obtain the world ATS forecast. The ratio of foreign applications technology satellite data rates to U.S. values is shown in Figure 3.4-8. Since these satellites are primarily for development and systems test, the expected transmission time for the data rates shown is 12 hours. As previously stated, satellite test transmissions at EHF and laser frequencies are expected to be shorter in duration and inversely proportional to the frequency bandwidth.

ASTRONOMY SATELLITE

The world astronomy satellite data rate model is shown in Figure 3.4-9. The ratio of foreign to U.S. data rate is also shown. The equivalent transmission time shown is four hours. Some of the functions listed may require longer durations but at proportionally lower data rates.

TRACKING AND DATA RELAY SATELLITE (TDRS)

The cumulative foreign TDRS forecast model was estimated using the data from Figures 3.2-20 and 3.3-6. These data are shown with the U.S. model data in Figure 3.4-10. For better global coverage it is assumed that the U.S. TDRS data rate demand grows from a two-satellite system to a four-satellite system in the first operational period. The equivalent transmission time per day is 12 hours. This could occasionally increase to 24 hours per day dependent on the number of manned and unmanned flights using real time television to accomplish numerous mission objectives and operations.

SOLAR ILLUMINATION SATELLITE

The development of world user requirements for the Lunetta system have not been projected in detail because the world-wide operational use of this system will occur beyond the 1990 period and, therefore, will not affect the new traffic model. The following paragraphs are presented to provide a greater insight into some of the physical characteristics and a typical world application of the Lunetta system.

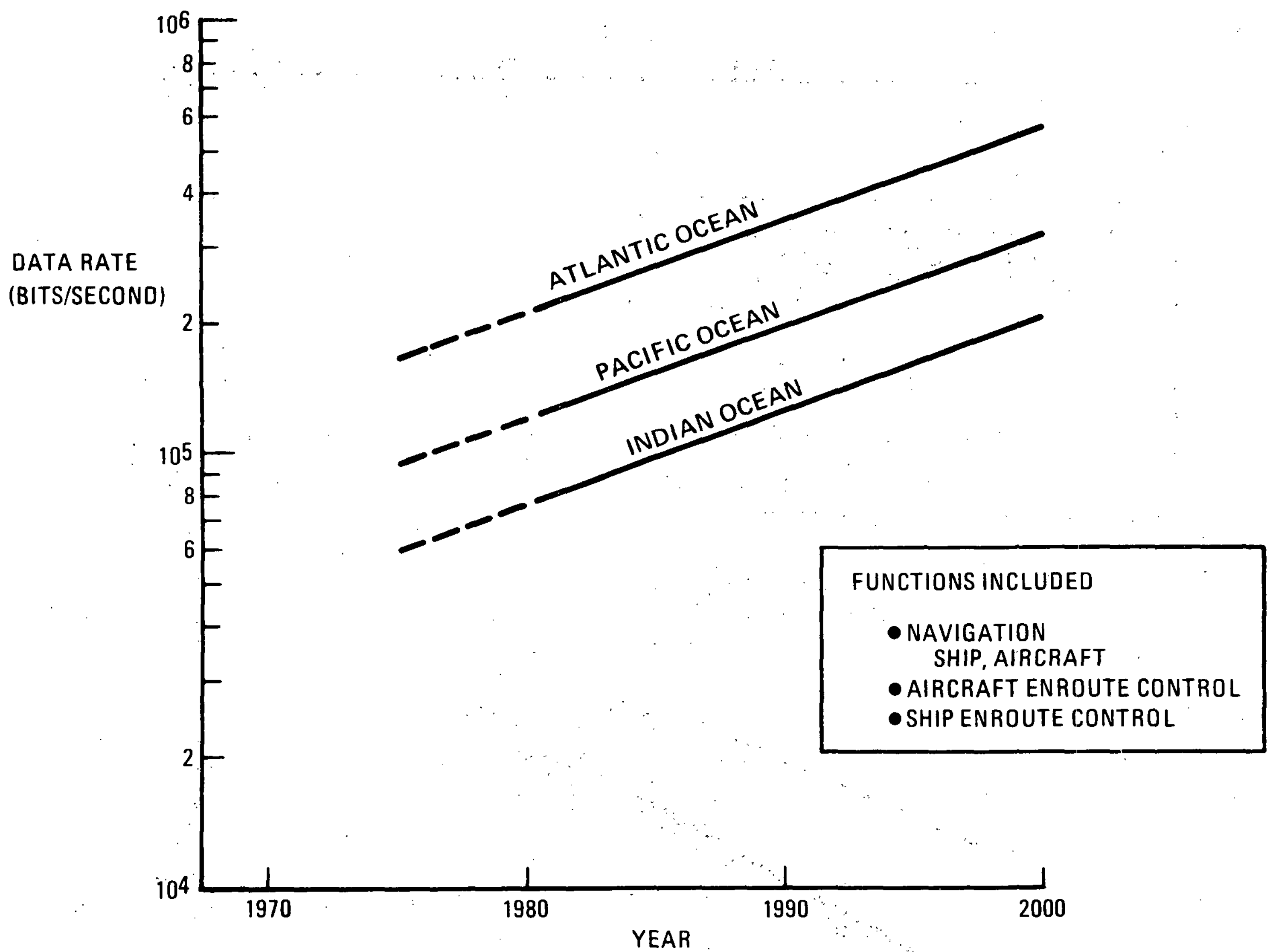


Figure 3.4-7. World Nacsat Forecast

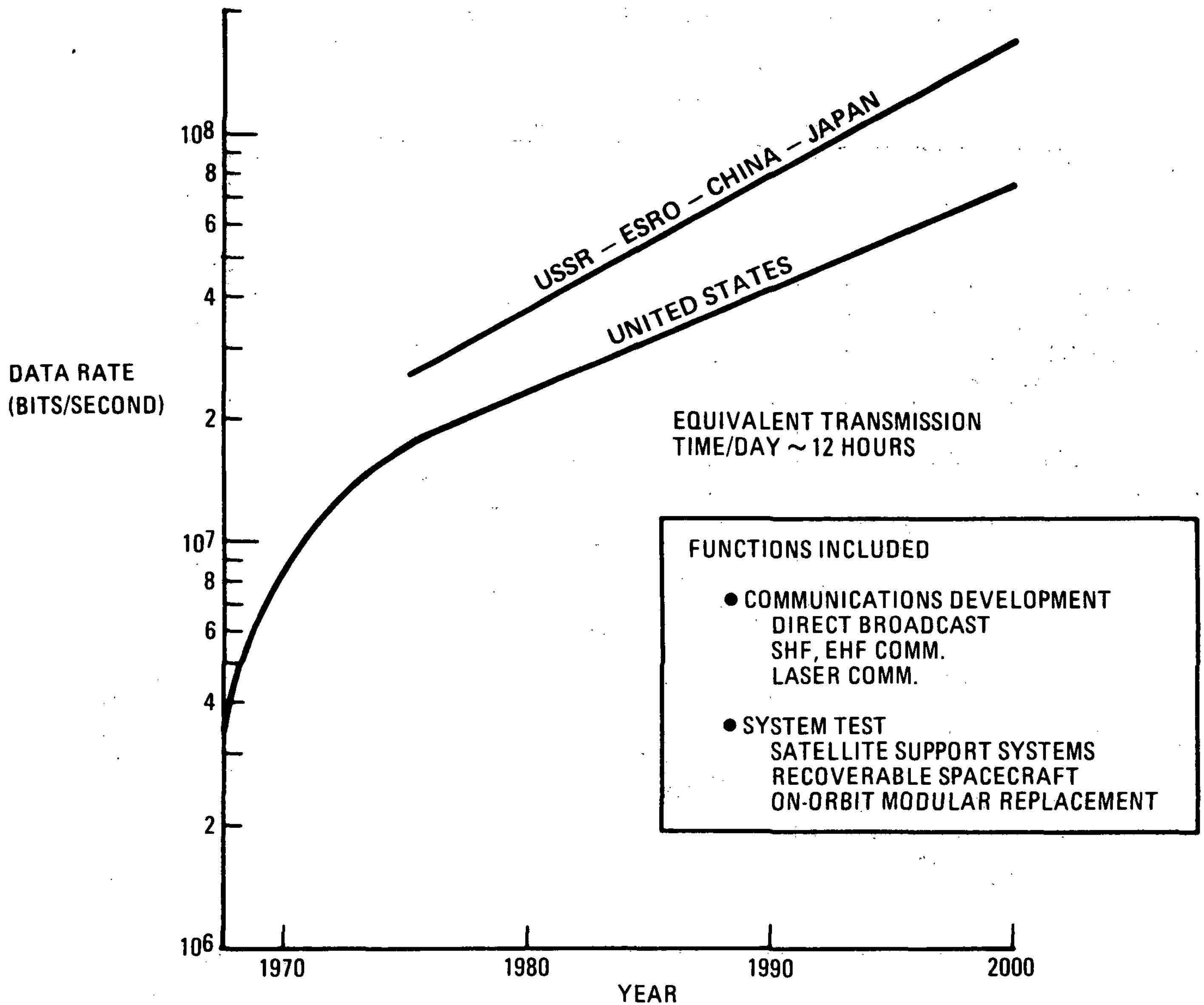


Figure 3.4-8. World ATS Forecast

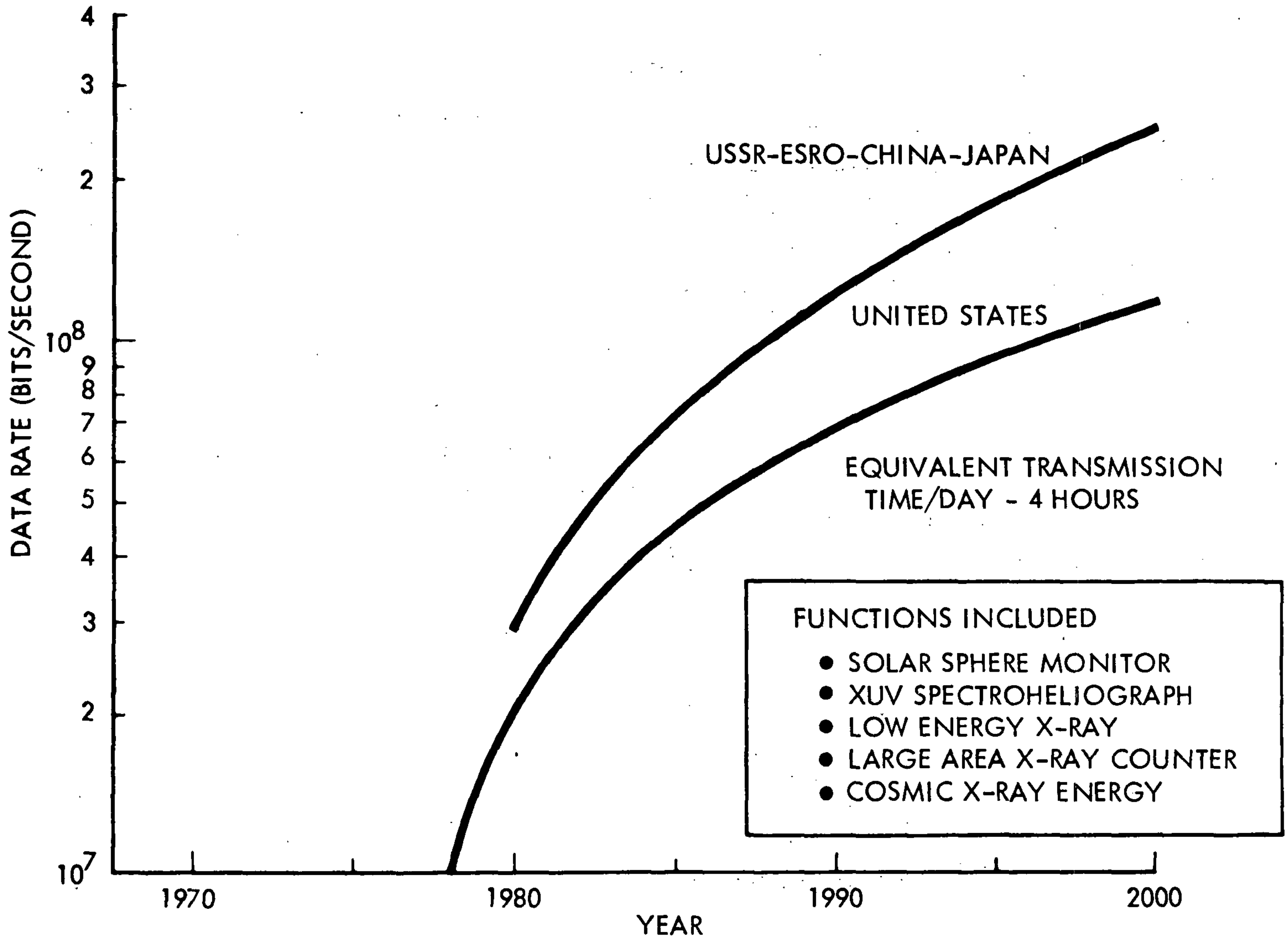


Figure 3.4-9. World Astronomy Forecast

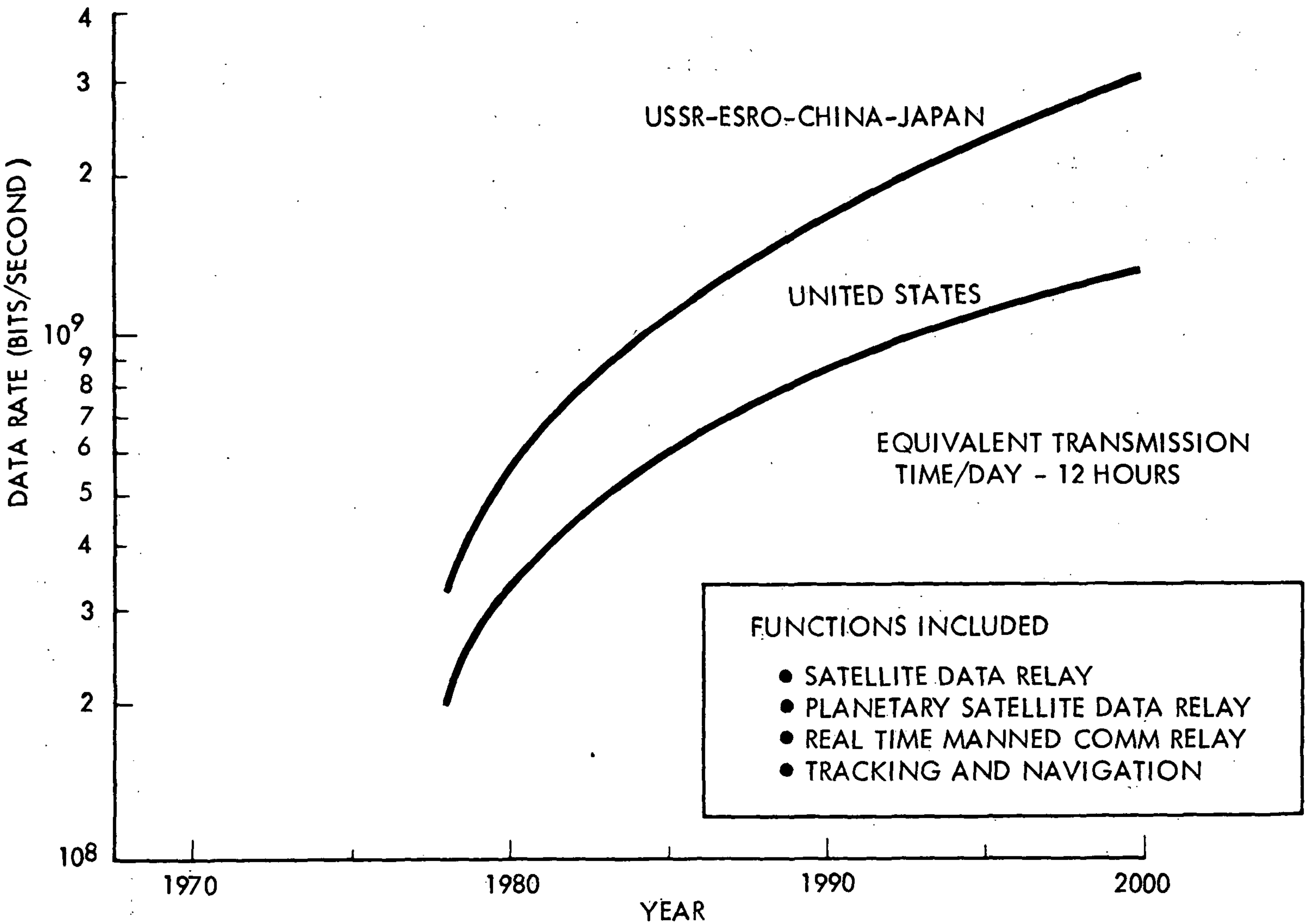


Figure 3.4-10. World TDRS Forecast

An artist's sketch of a three-satellite Lunetta system is shown in Figure 3.4-11. Lunetta's of various sizes (to meet specific area illumination requirements) would be made up by assembling a number of standardized building block reflector modules illustrated in Figure 3.4-12.. Also shown in Figure 3.4-12 is the general reflector rotation requirement of 179 degrees per earth revolution. Since the reflector satellite only completes one half of a revolution in an orbit of the earth, it must be designed to be reflective from both sides in order to provide illumination on the subsequent orbit. This can be visualized by following the A-B orientations shown in Figure 3.4-12 around two orbits of the earth.

The illumination provided by a Lunetta on the earth's surface is primarily a function of the reflector area and the latitude location for illumination on the earth's surface. The illumination obtained in "full moons" as a function of these two variables is shown in Figure 3.4-13. Listed below this figure are the desired illumination levels for various Lunetta uses.

Some of the Lunetta satellite sizing characteristics are:

Mass/reflector area	-	≤ 0.0189 lb/ft^2
Reflectivity	-	≥ 89 percent
Illumination	-	3×10^{-7} full moons/ft^2 (0° latitude)
Structure	-	Lithium framework and Lithium or Sodium foils
Consumables	-	0.0014 lb/ft^2 per year (basis - electric propulsion I_{sp} = 4500 sec)

Figure 3.4-14 illustrates a number of typical world locations which would benefit from night illumination. System operational characteristics and technical analyses in greater depth are presented in Reference 3-7.

POWER RELAY SATELLITE

As with the Lunetta system, the power relay system world user requirements have not been projected in detail since operational implementation of these satellites will probably occur beyond the period of concern (1990) for the new traffic model. However, the following paragraphs are included to provide some of this system's characteristics which could be developed on late-1980 ATS satellites.

Figure 3.4-15 depicts a microwave reflector antenna (power relay satellite), which is reflecting an energy beam from Greenland to Western Europe. The purpose of the space power relay system is to uncouple power generation from consumption and, thereby eliminate the grographic location of consumers as the primary influencing factor in locating power plants. This results in important consequences in terms of being able to utilize non-chemical energy sources (such as solar power) and in improving ecological factors (the thermal burden from nuclear and chemical power plants). With the demand for increased power generation, it becomes even more important to strive for a more even geographic distribution of thermal waste.

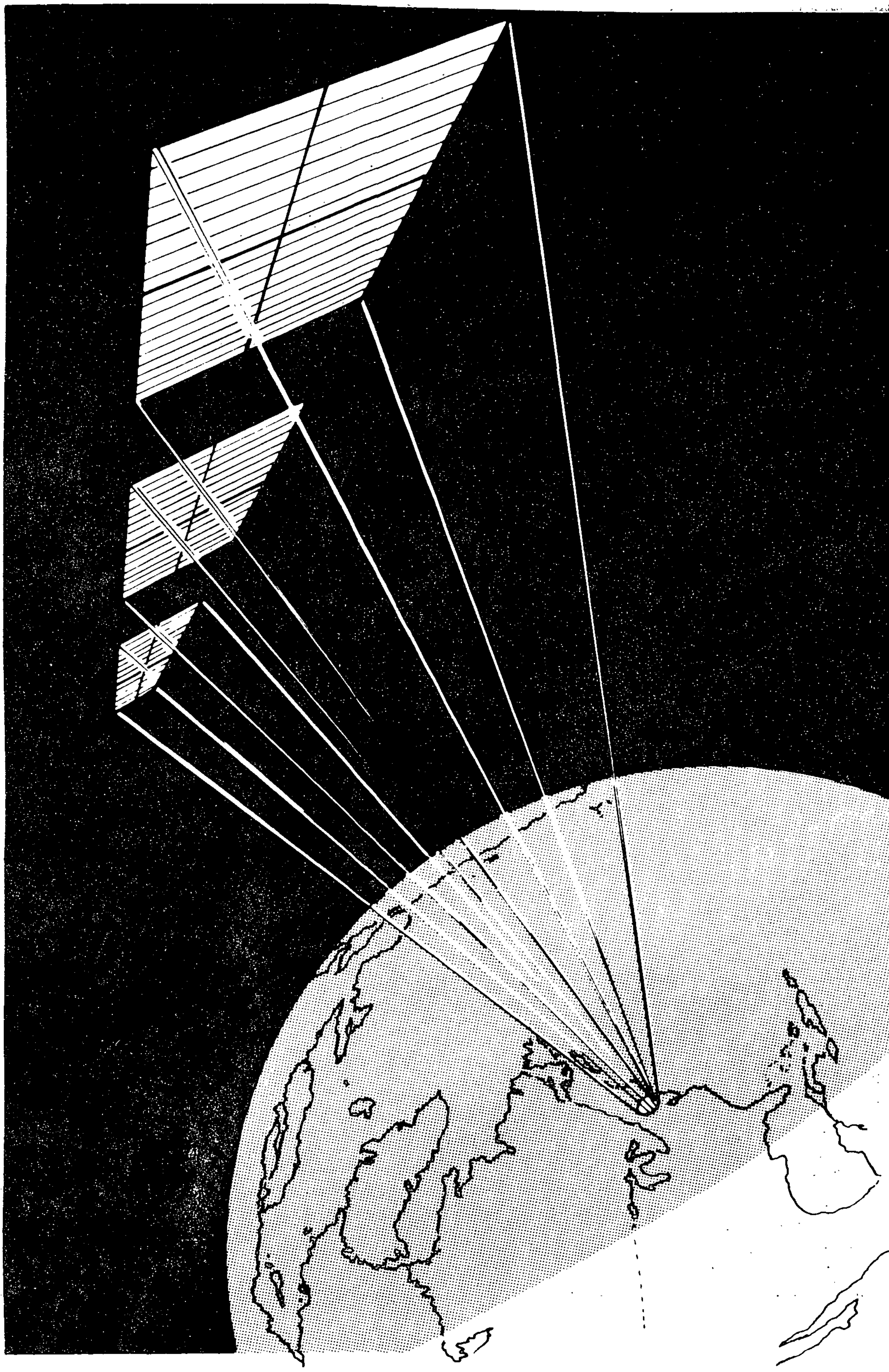


Figure 3.4-11. A Lunetta System

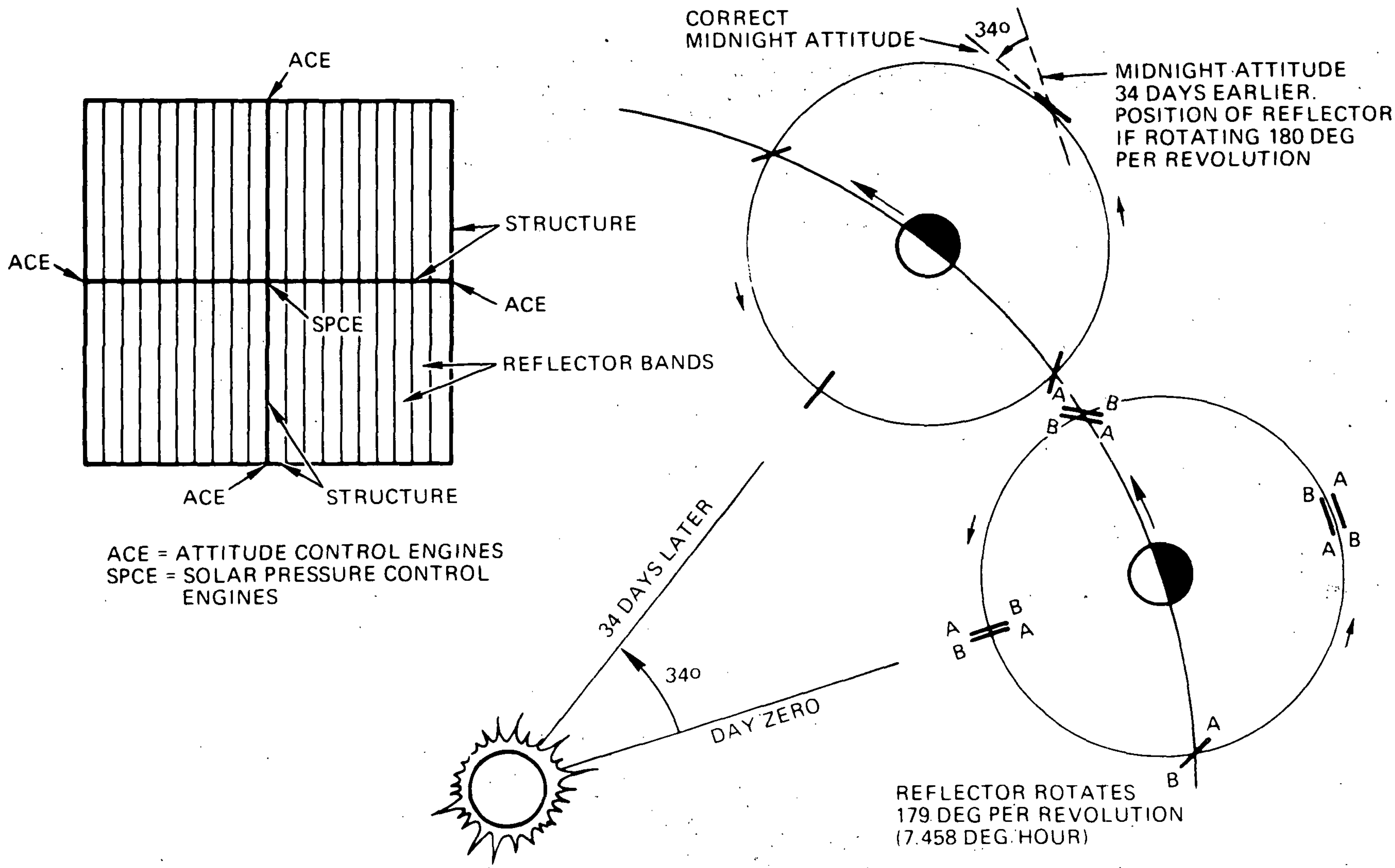
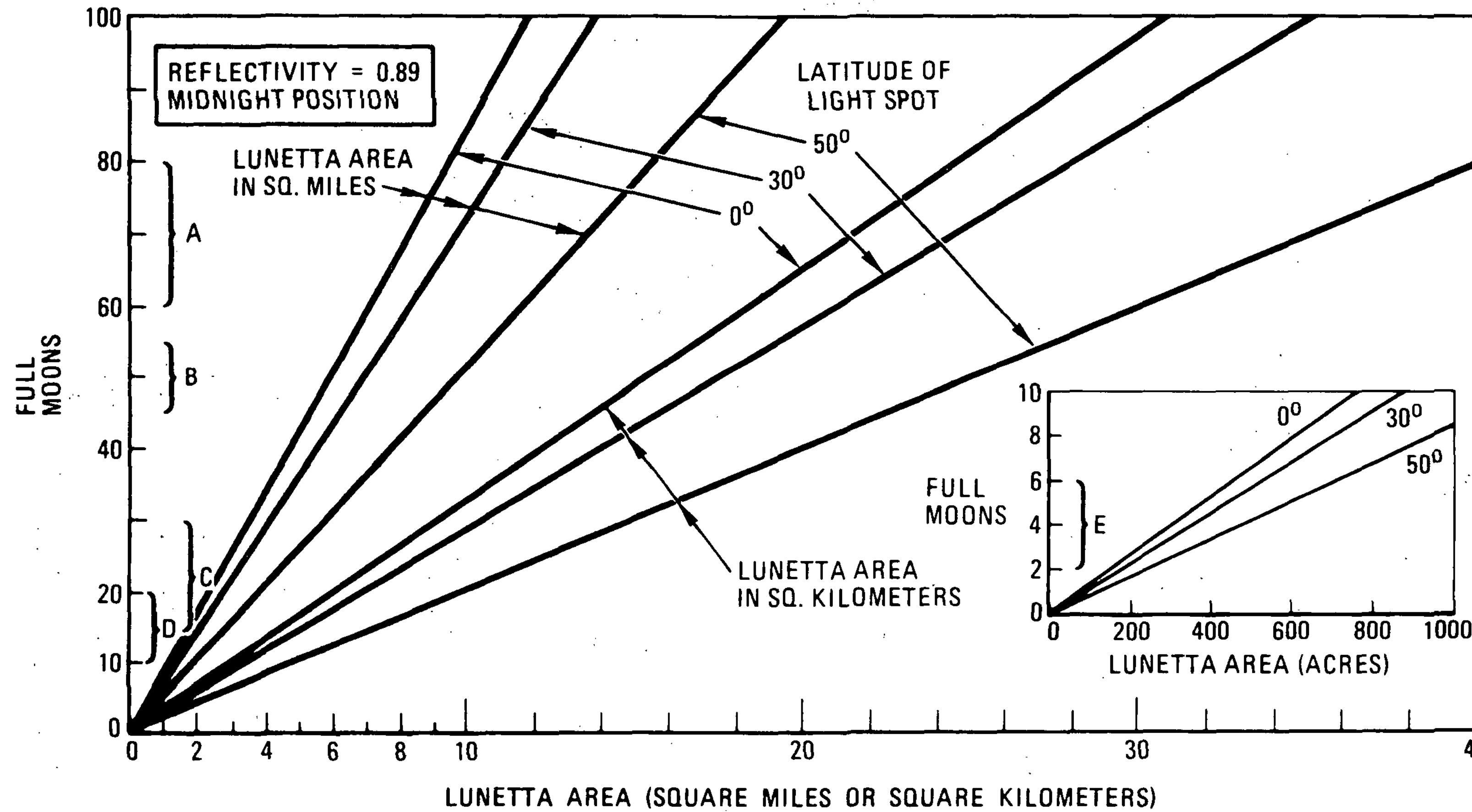


Figure 3.4-12. Reflector Design and Positioning



A INTENSE URBAN & TRAFFIC LIGHTING; AGRICULTURAL LIGHTING
B MEDIUM TRAFFIC LIGHTING
C DISASTER AREA ILLUMINATION
D CRIME CONTROL & PUBLIC SAFETY ILLUMINATION
E NIGHT METEOROLOGY & ATMOSPHERIC RESEARCH

Figure 3.4-13. Lunetta Uses and Size Requirements

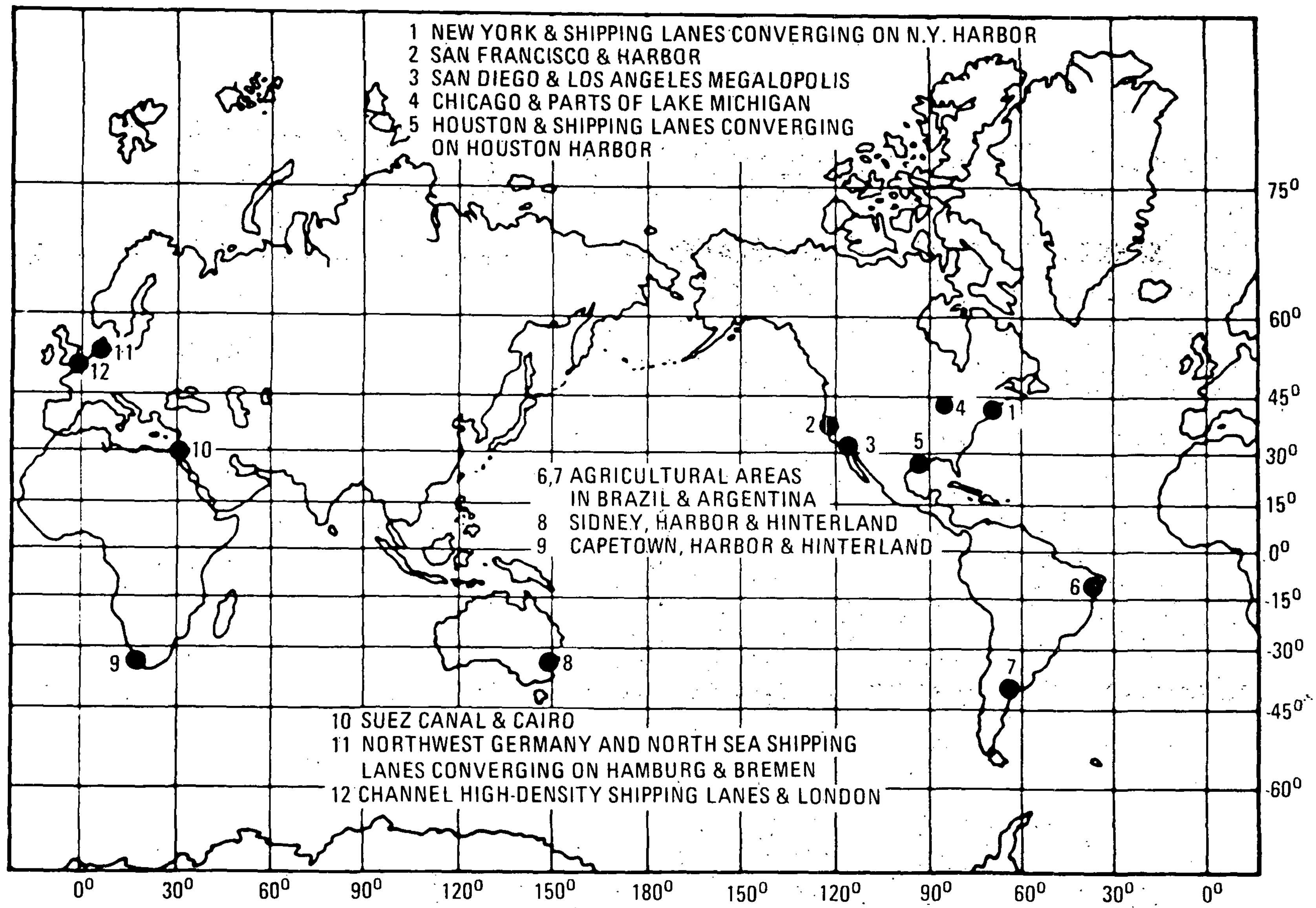


Figure 3.4-14. Typical Location of Lunetta Illumination Areas

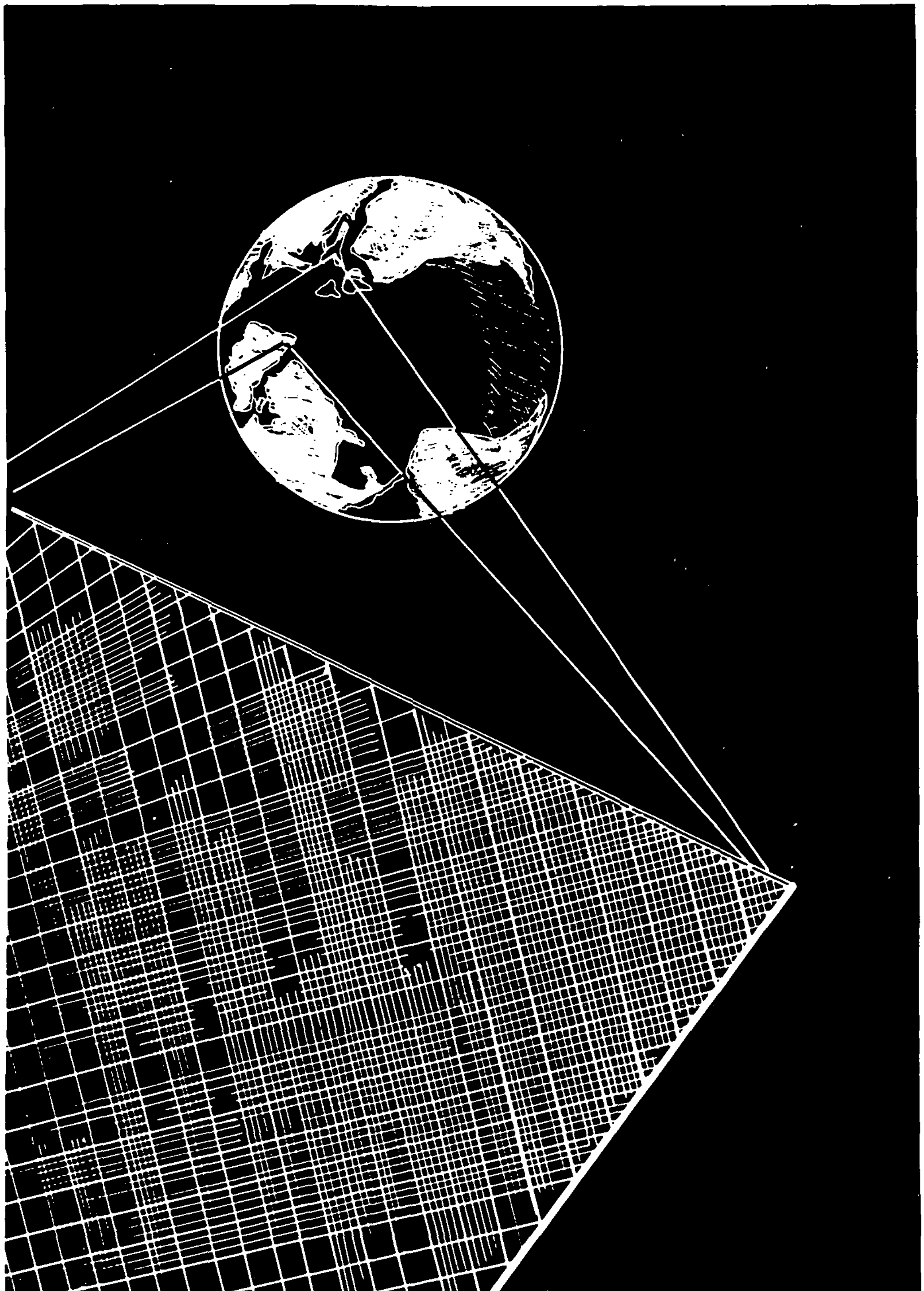


Figure 3.4-15. Power Relay Satellite

Because of thermal waste problems, far northern coastal regions, near deep ocean areas such as Greenland, are likely candidates for power plant locations. However the best suited locations for the transfer of solar energy into electrical power are found in the desert areas of the U.S., South America, North Africa, Arabia, and Australia. Figure 3.4-16 shows these global power generation regions as well as the areas requiring the use of high energy.

The power generation and transmission facility combines a power plant with a microwave transmitter system. Energy is transmitted to the power relay satellite by a convergent microwave beam with a power density of 4.65 w/ft^2 at the surface and a maximum power density of 3.40 kw/ft^2 at the power (energy) relay satellite. The reflected beam, in turn, is slightly divergent so as to provide again a safe energy density of 3.40 kw/ft^2 as the beam traverses the atmosphere for a second time. The transmission frequency could be typically 3 GHz (10 cm wavelength; S-band). The reflector can, therefore, be a wire grid arrangement. Modularized construction, attitude control and solar pressure compensation, as identified for the Lunetta would also apply to the power relay satellite.

Some of the power relay satellite sizing characteristics are:

Power/reflector area	-	3 kw/ft^2
Mass/reflector area	-	0.015 lb/ft^2
Structure	-	Wire mesh and frames
Consumables	-	9.3 x 10^{-4} lb/ft^2 per year (basis - electric propulsion I_{sp} = 4500 sec)

A 10-gigawatt power relay satellite would have a reflector area of about 3.7 x 10^6 ft^2 which includes 10 percent transmission margins each way. The weight would be on the order of 55,000 pounds and require about 3400 pounds per year of consumables. Ten gigawatts receiver power will require 11 gigawatts space relayed power and about 12.2 gigawatts transmitted power from the generation source.

Figure 3.4-17 shows the application of a global geosynchronous power relay system. The cases shown are examples rather than firm recommendations. The United States receives power for its eastern and western industrial and megalopolis complexes from a "Hudson Bay Nuclear Power Complex". The lines radiating from each receiver station symbolize the surface distribution net. From a "Pampa De Salinas Solar Power Complex" power is delivered to Brazil, Peru, Venezuela (and other South American nations) via power relay satellites located in part over the Atlantic and partly over the Pacific. England, France, and West Germany draw power from a "Greenland Nuclear Power Complex" on Danish territory (a member of the European Economic Community), while Italy and Israel are among the countries drawing power from a large "Kalahari Power Complex". Nuclear power stations in the western Soviet Union transmit power to the large industrial complexes in their West Siberian Lowlands and deliver power to northwestern India. An "Australian Solar Power Complex" delivers much needed power to the Australasian region and the western Pacific. Highly developed geothermal sources in northern New Zealand deliver power as far as Japan.

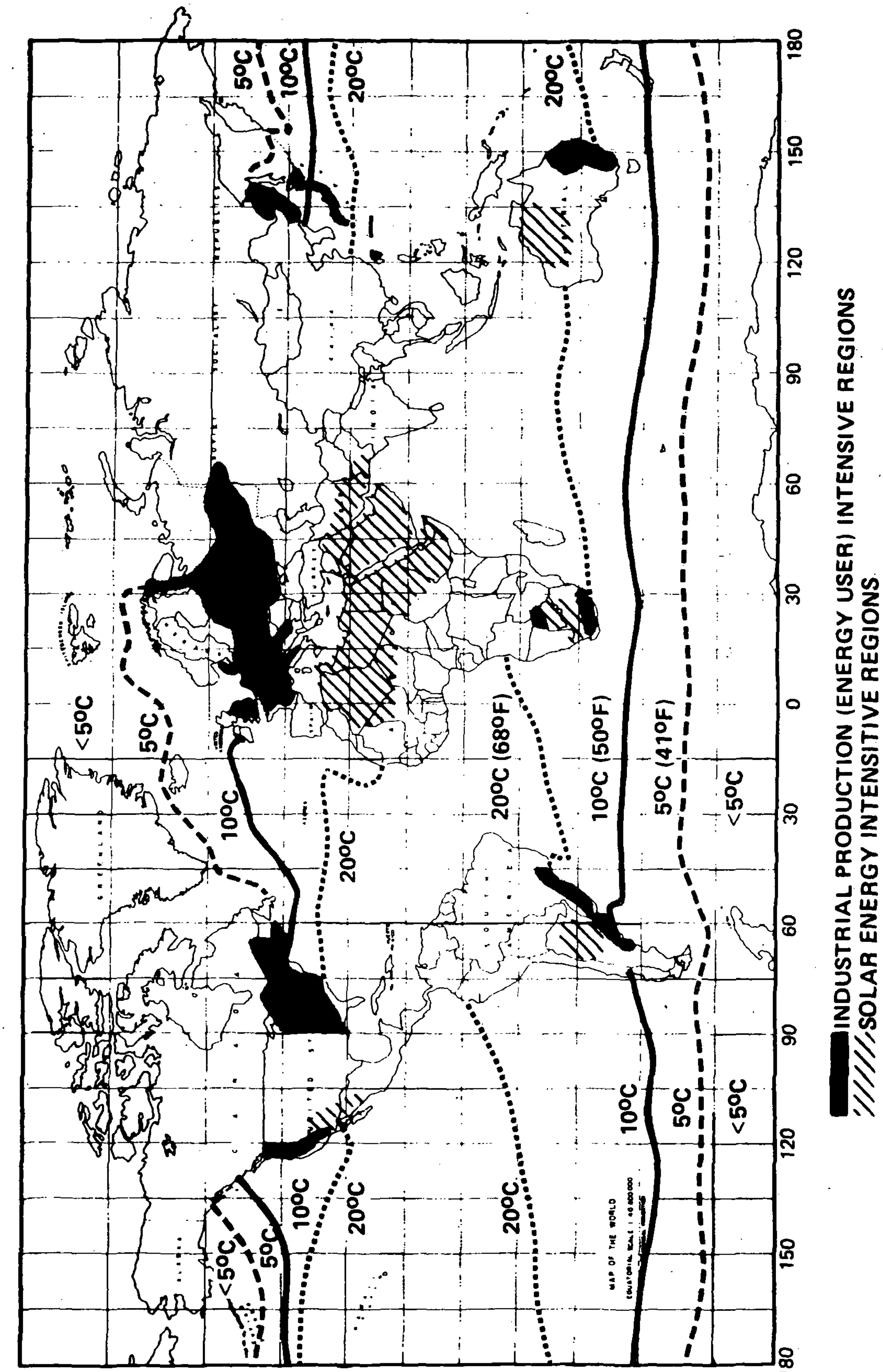


Figure 3.4-16. Global Heat Sinks, Solar-Intense and High Energy--Consumption Regions

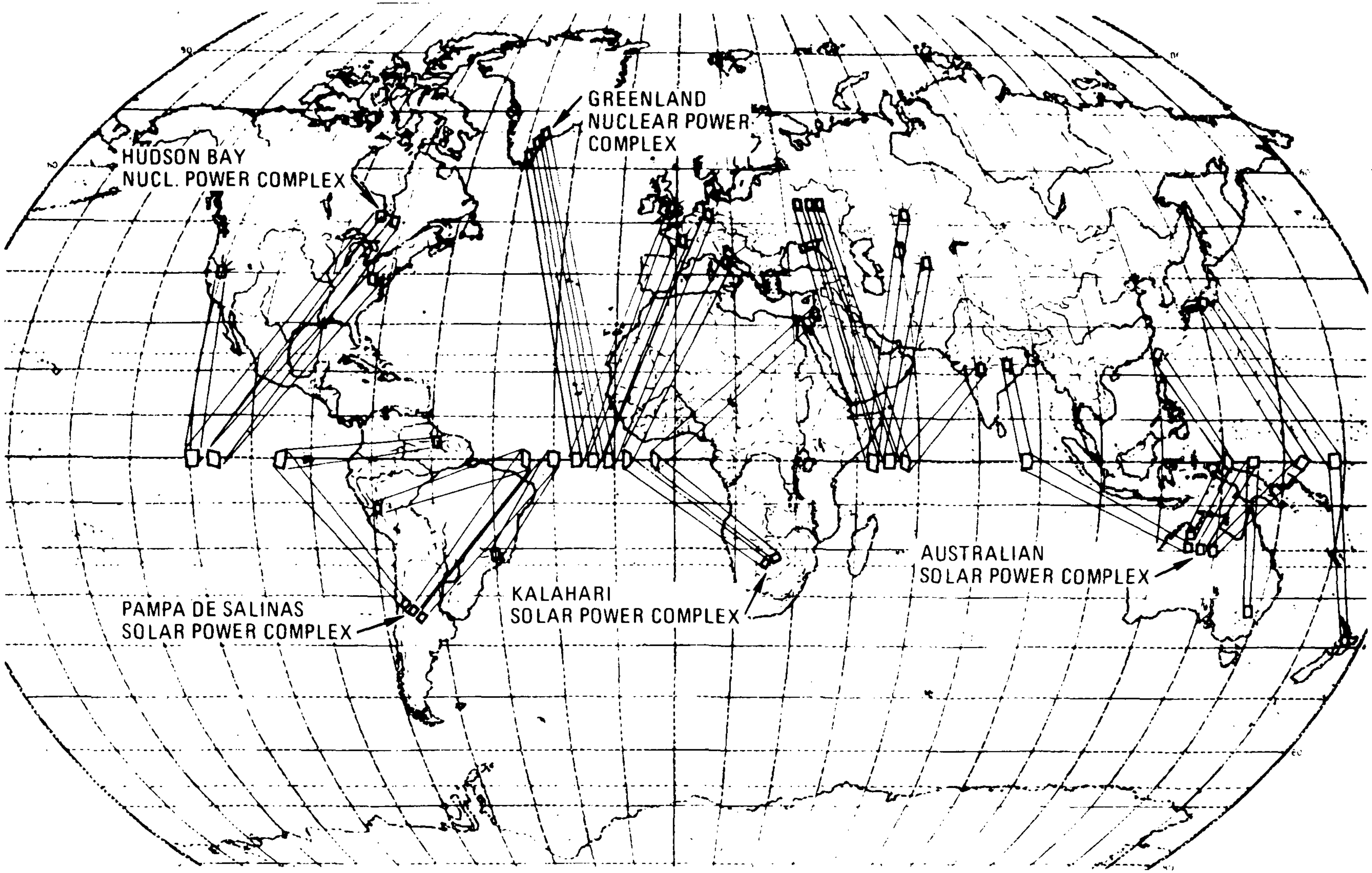


Figure 3.4-17. Typical Geosynchronous Power Relay System

3.5 FUNCTIONAL SATELLITE CHARACTERISTICS

Up to this point the basic demand requirements imposed on the geosynchronous orbit satellites in the new traffic model have been defined for the world area. The next step performed in developing the satellite traffic model was to define the specific spacecraft characteristics used to satisfy the user demand requirements.

Seven satellite types are used to describe the satellite capabilities for the baseline and new traffic models. Satellite types such as solar illumination and power relay are included in the new traffic model as Applications Technology Satellites (ATS) because the new model extends only to 1990. Operational versions of these functions are not expected to occur until after this time. The seven satellite types used are listed in Table 3.5-1 with a summary of the criteria established for each type.

For traffic model comparison purposes the criteria of earth coverage, longitudinal location, lifetime, data rate capability, redundancy, duty cycle, and thin route requirements are used with both traffic models. The number of on-orbit active traffic elements which meet demand requirements (adjusted for duty cycle and thin route demands) depends on data rate capability, lifetime, and redundancy provided. Another criterion not shown is that satellite recovery is possible in 1982 for both traffic models. This influences the inactive and on-orbit satellite population histories and recovery schedules.

Subsequent paragraphs define the satellite characteristics in greater detail and provide some of the rationale used to establish the criteria. It is important to note that the satellite characteristics defined for the new traffic model have purposely been selected to match those of the baseline traffic model. This is particularly the case for Intelsat and Domsat characteristic data rate capability. This then permits a comparison of the two models and will allow significant differences to be easily identified.

INTELSAT CHARACTERISTICS CRITERIA

Earth Coverage

Ground coverage overlap between adjacent Intelsats must permit three or more widely separated (in latitude) countries to provide communications relay services. This would prevent interruption of relay service due to a specific relay station outage (for maintenance, natural disaster, or political reasons) and alleviate some solar outage situations.

A minimum of three data links are required: (1) Americas to Europe/Africa/USSR (West); (2) Europe/Africa/USSR (West) to Asia; and (3) Asia to Americas.

Table 3.5-1. Functional Satellite Characteristics Criteria Summary

FACTOR	SATELLITE TYPE						
	INTELSAT	DOMSAT	MERSAT	NACSAT	ATS	ASTRONOMY	TDRS
EARTH COVERAGE	(1) AMERICAS TO EUR-AFRICA (2) EUR-AFRICA TO ASIA (3) ASIA TO AMERICAS	(1) AMERICAS (2) EUR-AFRICA (3) ASIA	GLOBAL BETWEEN 70°N & 70°S	COMPLETE GLOBE INCLUDING POLAR AREAS	(1) USA, HAWAII, ALASKA (2) CANADA AND EUROPE (3) USSR (4) CHINA (5) JAPAN	(1) CONT. USA (2) CANADA AND EUROPE (3) USSR (WEST) (4) CHINA (5) JAPAN	(1) CONT. USA (2) CANADA AND EUROPE (3) USSR (4) CHINA (5) JAPAN
SATELLITE LONGITUDINAL LOCATION	(1) 15°W-25°W (2) 90°E-105°E (3) 155°W-165°W	(1) 45°W-135°W (2) 10°W-75°E (3) 75°E-180°E	(1) 60°W-75°W (2) 150°W-165°W (3) 105°E-120°E (4) 15°E-30°E	CLUSTER (1) 0°W CLUSTER (2) 90°W CLUSTER (3) 180°E CLUSTER (4) 90°E	(1) 105°W-135°W (2) 0°W-15°W (3) 30°E-45°E (4) 75°E-120°E (5) 120°E-170°W	(1) 60°W-135°W (2) 15°W-30°W (3) 30°E-60°E (4) 75°E-120°E (5) 120°E-170°W	(1) 55°W, 145°W, 125°E, 35°E (2) 50°W, 55°E (3) 50°E, 140°E, 130°W, 40°W (4) 60°E, 180°E (5) 80°E, 160°W
SATELLITE LIFETIME	7 YEARS	7 YEARS	3 YEARS - 1975 - 1984 6 YEARS - 1984 & SUBS	5 YEARS - UP TO 1985 8 YEARS - 1985 & SUBS	(1) HALF - 1 YEAR HALF - 2 YRS. (3) HALF - 1 YR. HALF - 2 YRS. (2) (4) (5) } 4 - 5 YRS.	4 YEARS	5 YEARS
DATA RATE CAPABILITY	24 TRANSPONDER	24 TRANSPONDER	1 TO 5 X 10^7 BPS	10^6 BPS	0.5 TO 5 X 10^7 BPS	1 TO 4 X 10^7 BPS	2 X 10^7 TO 3 X 10^8 BPS
SATELLITE REDUNDANCY	REDUNDANT CIRCUITS - GROUND SPARES	REDUNDANT CIRCUITS - GROUND SPARES	GROUND SPARES	GROUND SPARES (CLUSTER CAN OPERATE WITH ONE FAILURE)	NONE	NONE	NONE (GROUND SPARE WHEN NEEDED)

Satellite Longitudinal Locations

To meet the above criteria for coverage the following preferred and acceptable (in parentheses) range of locations for each link are: (1) 25°W (15°W-25°W); (2) 100°E (90°E-105°E); and (3) 155°W (155°W-165°W).

Lifetime

Satellite lifetime shall be seven years. Present systems design permit an operational life for this duration. Satellites launched in 1976 and subsequent years shall be recovered beginning in 1983.

Data Rate Capability

Twenty-four active broad-beam transponders shall be provided by each satellite. This value is consistent with newly proposed systems.

Satellite Redundancy

Each satellite shall have sufficient on-board redundant circuits. Ground spares will be provided. This approach is less costly for systems that have large numbers of active on-orbit satellites.

DOMSAT CHARACTERISTICS CRITERIA

Earth Coverage

Ground coverage is required for the three major world areas including many of the larger islands. These areas are: (1) North, Central, and South America including Hawaii and Alaska; (2) Europe, Africa, and USSR (West) including all countries west of 60°E longitude; and (3) USSR (East), Asia, Australia, New Zealand, and Oceana.

Satellite Longitudinal Location

The following preferred range of longitudinal locations will provide coverage as required: (1) 135°W - 45°W; (2) 10°W - 75°E; and (3) 75°E - 180°E.

Lifetime

Satellite lifetime shall be seven years. Present systems design permit an operational life for this duration. Satellites launched in 1975 and subsequent years shall be recovered beginning in 1982.

Data Rate Capability

Twenty-four active broad-beam transponders shall be provided by each satellite. This value is consistent with newly proposed systems.

Satellite Redundancy

Each satellite shall have on-board redundant circuits. Ground spares will be provided. This approach is less costly for systems that have large numbers of active on-orbit satellites.

MERSAT CHARACTERISTICS CRITERIA

Earth Coverage

Sufficient coverage shall be provided to sense global Mersat information between 70°N and 70°S and provide desired data to all major world areas and weather centers.

Satellite Longitudinal Location

A four-satellite system meets the above criteria with location ranges as follows: (1) 60°W - 75°W; (2) 150°W - 165°W; (3) 105°E - 120°E; and (4) 15°E - 30°E.

Lifetime

In the 1975 to 1984 time period, lifetime shall be three years; beyond 1984, lifetime shall be six years. Advancements in sensors can be added to the global system earlier with the shorter lifetime criteria for the first three generations of satellites. Satellites launched in 1979 and subsequent years shall be recovered beginning in 1983.

Data Rate Capacity

Increased data rate capacity will be provided in each subsequent generation of satellites to handle increased numbers of sensed locations and detail. Each generation will increase by 10^7 bits per second (bps) such that the first generation set shall be capable of handling data at 1×10^7 bps, the second generation at 2×10^7 bps, the third generation at 3×10^7 bps, the fourth generation at 4×10^7 bps, and the fifth generation at 5×10^7 bps.

Satellite Redundancy

Ground spares shall be used for replacement.

NACSAT CHARACTERISTICS CRITERIA

Earth Coverage

Complete and simultaneous global coverage is required at all latitudes.

Satellite Longitudinal Location

Four satellite clusters with five satellites per cluster all with geosynchronous 24-hour orbits will meet the required global coverage. The four clusters shall be located at 0°W, 90°W, 180°E, and 90°E. The cluster shall be composed of one geostationary satellite (at the specified location) and four satellites uniformly distributed in 60-degree inclination orbits having an eccentricity of 0.25. Two of the inclined orbit satellites in each cluster shall maintain apogees at the maximum northern declination of the orbit whereas the other two inclined orbit satellites shall maintain apogees at the maximum southern declination of the orbit.

Lifetime

Until 1985, satellite lifetime shall be five years; thereafter, it shall be eight years. Satellites launched in mid-1977 and subsequent years shall be recovered beginning in mid-1983.

Data Rate Capacity

A capacity of 10^6 bits per second per satellite will handle all foreseeable aircraft and ship traffic based on the system proposed in Reference 3-6.

Satellite Redundancy

Each cluster can operate at full global coverage with one satellite failure per cluster. Ground spares shall be used for replacement when two failures in a cluster occur.

ATS CHARACTERISTICS CRITERIA

Earth Coverage

Applications technology satellites shall be positioned within line-of-sight communications with its sponsoring nation(s).

Satellite Longitudinal Location

The range of longitudinal locations for those countries or consortiums with active space programs are: USA, 105°W - 135°W; ESRO, 0° - 15°W; USSR (West), 30°E - 45°E; China, 75°E - 120°E; Japan, 120°E - 170°W.

Lifetime

For the U.S. and USSR, ATS lifetimes will be of short duration. Half shall be one year and the other half, two years. The remaining national space program ATS lifetimes shall be four to five years. U.S. satellites launched subsequent to 1980 shall be recoverable beginning in 1982. Foreign satellites launched subsequent to 1981 shall be recoverable beginning in 1984.

Data Rate Capacity

U.S. and USSR satellites will vary from 0.5×10^7 bits per second to 5×10^7 bits per second. Other national space program satellites will range from 0.5×10^7 bits per second to 2×10^7 bits per second.

Satellite Redundancy

None planned. Subsequent launches may repeat mission objectives of failed satellites.

ASTRONOMY CHARACTERISTICS CRITERIA

Earth Coverage

Astronomy satellites shall be positioned within line-of-sight communications with its sponsoring nation(s).

Satellite Longitudinal Location

The range of longitudinal locations for those countries or consortiums with active space programs are: USA, 60°W - 135°W; ESRO, 15°W - 30°W; USSR (West), 30°E - 60°E; China, 75°E - 120 °E; Japan, 120°E - 170°W.

Lifetime

Satellite lifetime shall be four years. This value is consistent with planned astronomy programs. All satellites launched subsequent to 1977 shall be recoverable beginning in 1982.

Data Rate Capacity

For U.S. and USSR astronomy satellites, data rate will increase from 10^7 bits per second in 1978 by 10^7 bits per second every four years; i.e., with each satellite generation. Other national programs will have data rate capacity of 2 to 4×10^7 bits per second for each satellite.

Satellite Redundancy

None planned.

TDRS CHARACTERISTICS CRITERIA

Earth Coverage

It has been assumed that the U.S. and USSR space program activities will grow to the point that total global coverage will be required to satisfy the tracking and data relay requirements. The other nations and consortiums, on the basis of funding level comparisons with the U.S. space program, will probably need (or afford) only partial world coverage to satisfy their requirements.

Satellite Longitudinal Locations

On the basis of the earth coverage requirements forecasted, it is expected that the U.S. and USSR will implement a TDRS system which will grow to four equally spaced satellites. The other nations and consortiums will each utilize two satellites located approximately 120 degrees apart and each within line of sight of the owner nation. Specific longitudinal locations are:

USA	-	35°E, 125°E, 145°W, 55°W
USSR	-	50°E, 140°E, 130°W, 40°W
ESRO	-	55°E, 50°W (visible from Canada and Europe)
China	-	60°E, 180°E
Japan	-	80°E, 160°W

Lifetime

TDRS lifetime shall be five years. All satellites are assumed to be recoverable beginning in 1983.

Data Rate Capacity

U.S. and USSR shall initially launch three R&D satellites with a capacity to relay data at 10^8 bits per second per satellite. One satellite in each system shall act as an on-orbit spare or to relieve peak demand requirements at various times. At end of life the R&D system shall be replaced by four operational satellites with the same data rate capacity. The subsequent replacement generation of satellites will grow to 2×10^8 bits per second data rate capacity per satellite. The other national space programs will also utilize satellites with initial data rate capacity of 10^8 bits per second with second generation satellites having 2×10^8 bits per second data rate capacity.

Satellite Redundancy

One on-orbit spare is used with each U.S. and USSR R&D system. Ground spares shall provide redundancy for each of the national operational TDRS systems.

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3.6 FUNCTIONAL SATELLITE LOCATIONS

The preferred satellite locations for the seven satellite types serving each country are shown in Figure 3.6-1. The Intelsat locations shown are based on a three-system set. A four-system set would result in larger longitudinal location bands approximately 90 degrees apart. The individual domestic satellites serve smaller earth coverage areas compared to the other satellite types. Therefore, there is more longitudinal space available from which this service can be provided. Also, since communications data requirements are the greatest for this satellite type, more longitudinal space will be required for the satellites (or platforms) needed to meet the demand requirements. The Mersats and Nacsats provide the desired global coverage with four longitudinal locations approximately 90 degrees apart. The other science and applications satellites are geographically located to provide line-of-sight communications with their respective owner country. The six zones shown on this chart are identical in location to those of the baseline traffic model. These zones are used to assess satellite population density and electromagnetic interference which are documented in subsequent sections of this volume.

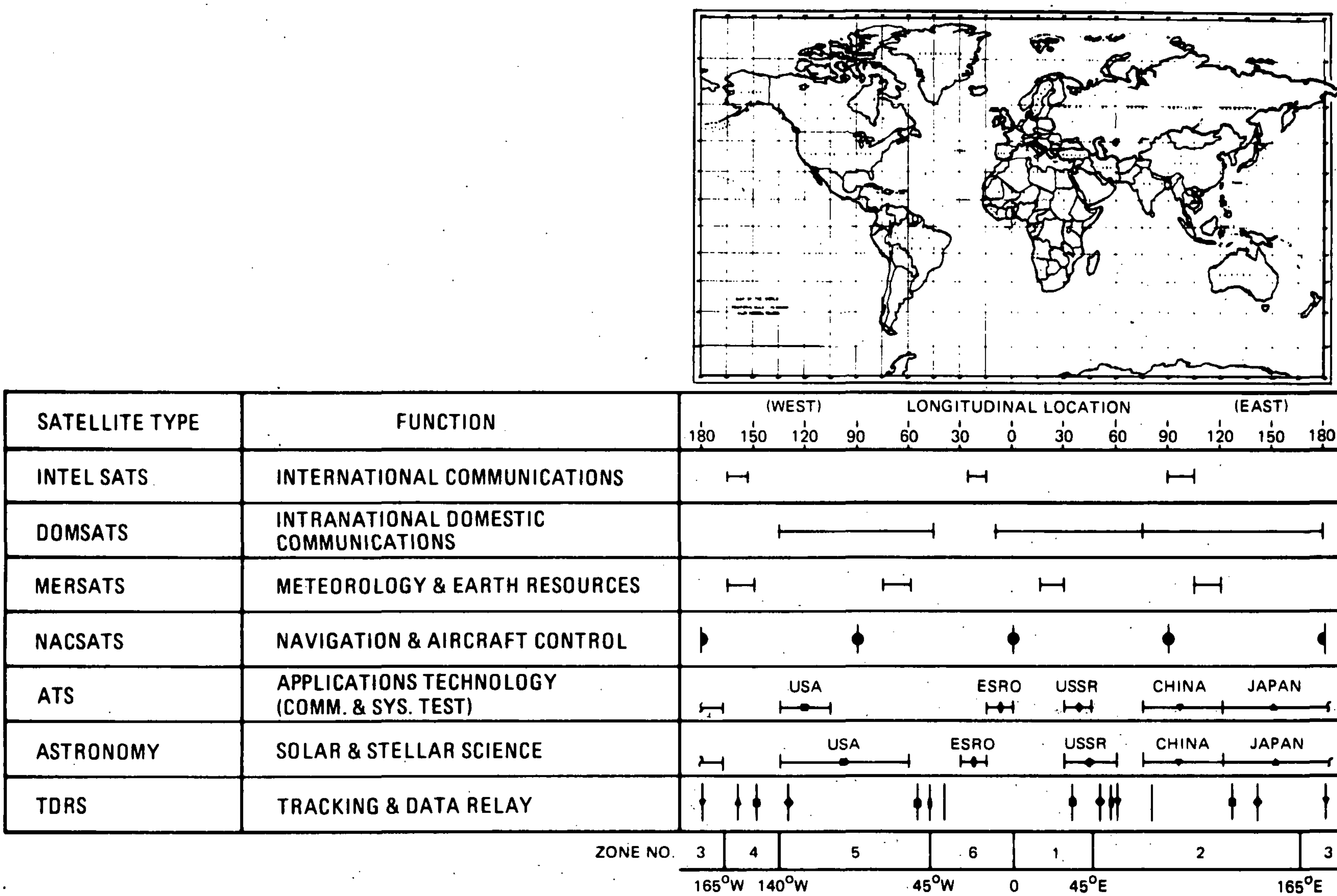


Figure 3.6-1. Preferred Satellite Locations

3.7 TRAFFIC MODEL SCHEDULES BY SATELLITE FUNCTIONS

The new traffic model was developed using the established world area demand communications and applications requirements and the functional satellite characteristics. In the determination of the number of satellites of a given data rate capability needed to satisfy forecasted demand requirements, the peak load requirements, thin-route traffic, daily operational time, and satellite lifetime dictated the number of on-orbit active satellites required for each function. As the data rate demands increased, additional satellites were added to meet the demands.

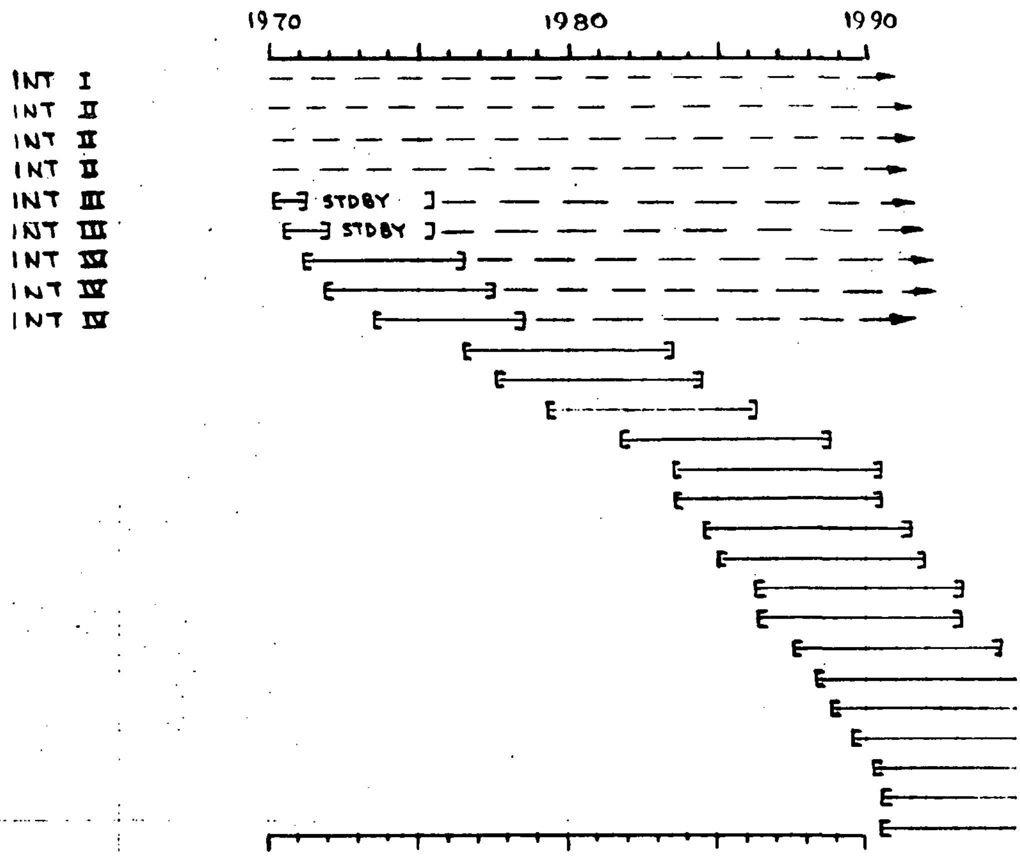
The following sets of figures (Figures 3.7-1 through 3.7-13) show the number of satellites placed on-orbit each year to meet each functional demand requirement by world area. This results in a time-phased geographic distribution of satellites for each function. Analysis of the launch time, lifetime, and satellite disposition permits the tabulation of the number of inactive satellites on orbit, the number of active satellites, the number of satellite deliveries, and the number of satellites retrieved from orbit.

For example, Figure 3.7-1 shows inactive satellites on orbit by a dashed line. Active satellites are illustrated by a solid line. The point of initiation of the solid line represents the launch year, whereas the termination point when no dashed line is shown, represents the year the satellite is recovered. Below the bar schedule is tabulated the number of inactive, active, delivered, and recovered satellites for each year from 1970 through 1990.

Figures 3.7-1, 3.7-2, and 3.7-3 show that an Intelsat IV is launched over each ocean area during the 1973 and 1974 time period. Previous discussions had shown that additional satellite capacity was not required until 1975 or 1976. These three additional satellites are included as shown to be consistent with Comsat planned launch schedules. It is believed that these early launches are to provide on-orbit backup as well as to eliminate transmission relay interruption during "solar outage" periods occurring once a day for four days during each spring and fall season. This phenomenon is described in detail in Volume III. The subsequent Intelsats having 24-transponder capacity are shown being launched to each ocean position in the 1976 to 1977 time period. These satellites are added to maintain the capability of meeting the demand requirements as well as to replace the Intelsat IV's which have reached their end of life.

Due to the large number of Domsats required to meet demand requirements, Figures 3.7-4 through 3.7-6 show the number of satellites required (on each bar) for that year either as replacements for satellites at end of life or new satellites required for increased demand.

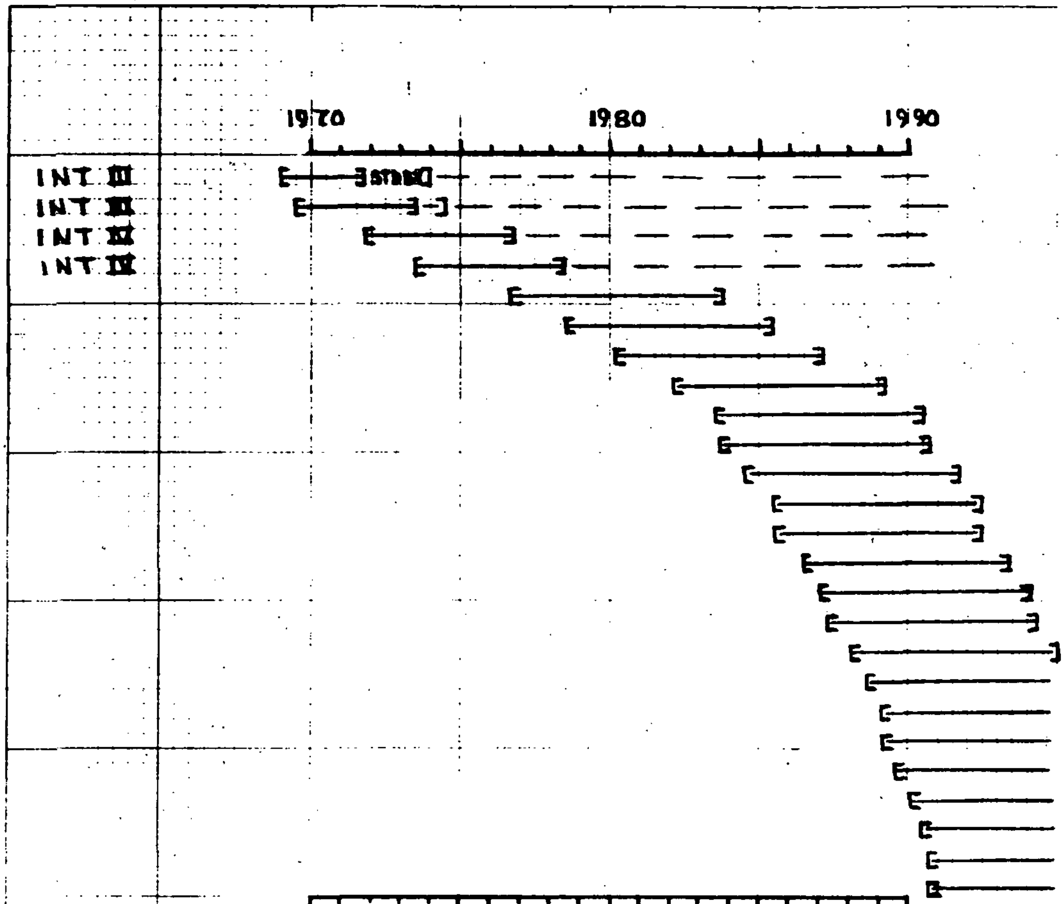
It should be noted that for five of the seven types of satellites identified, only a moderate number of satellites are required to meet user demands up to 1990. This, however, is not the case for the Intelsat and Domsat models. With a satellite capability of fixed data rate such as 24 transponders, large numbers of satellites are needed to meet world user requirements in the 1985 to 1990 period and although not shown, even many more satellites are required beyond 1990. This indicates that communication satellites in the late 1980's and 1990's need to have much larger data rate capability. In reality, communication satellites will have increased data rate capacity as communications technology advances to meet these demand requirements. The point being emphasized is that the 24-transponder fixed level capability was used here to permit comparison of the new traffic model with the baseline traffic model, and is not intended to reflect the best data rate capacity for the time period of the new traffic model. Subsequent analyses related to platform requirements will identify the recommended data rate capacity of Intelsat and Domsat platforms which better satisfy user requirements.



YEAR	1970										1980										1990
NO. INACTIVE	4	6	6	6	6	6	7	8	9	9	9	9	9	9	9	9	9	9	9	9	9
NO. ACTIVE	2	2	2	3	3	3	3	3	2	3	3	4	4	5	5	6	7	8	9	10	11
NO. DELIVERED	2	2	0	1	0	0	1	1	0	1	0	1	0	2	1	1	2	1	2	1	3
NO. RECOVERED	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	1	0	2

SATELLITE TYPE	DATA RATE CAPABILITY
INT I	3.6×10^7 BPS
INT II	3.6×10^7 BPS
INT III	7.2×10^7 BPS
INT IV	4.32×10^8 BPS
INT ?	8.64×10^8 BPS

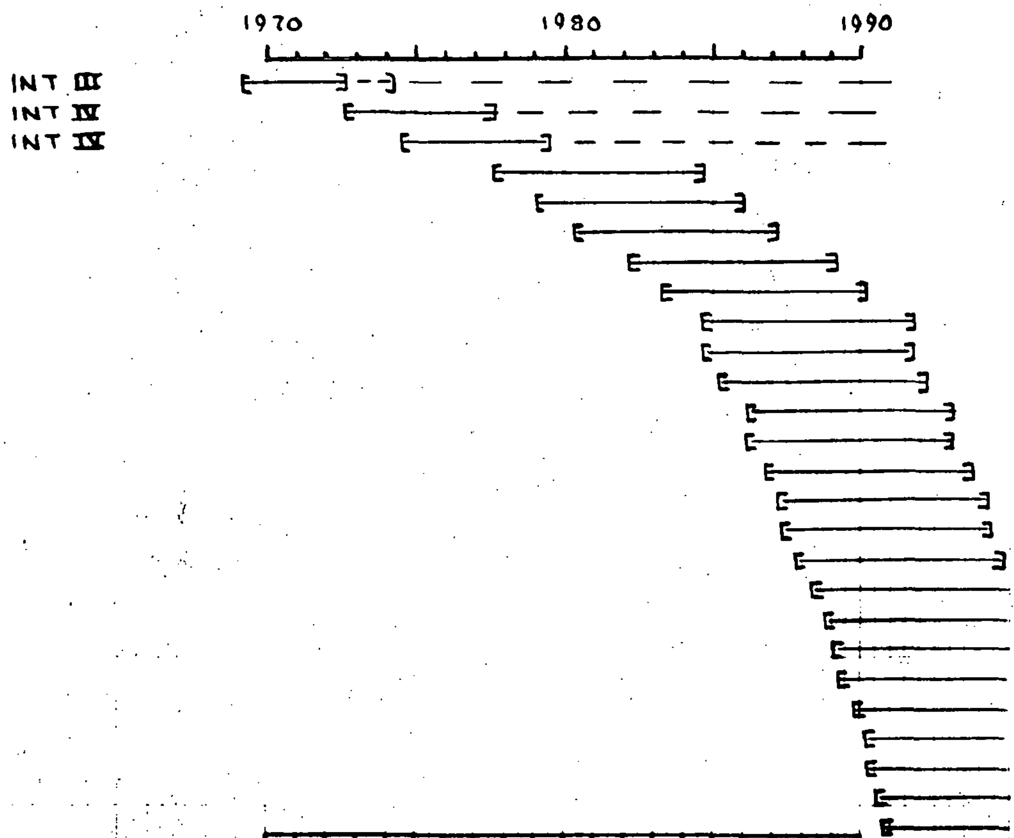
Figure 3.7-1. Intelsat Traffic Model--Atlantic Ocean



YEAR	1970 1980 1990
NO. INACTIVE	0 1 1 2 2 2 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4
NO. ACTIVE	2 2 2 2 2 2 2 2 2 2 3 3 4 5 6 7 8 9 11 13 15
NO. DELIVERED	0 1 0 1 0 0 1 0 1 0 1 0 1 2 1 2 1 2 2 3 4
NO. RECOVERED	0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 1 0 1 2

SATELLITE TYPE	DATA RATE CAPABILITY
INT III	7.2×10^7 BPS
INT IV	4.32×10^8 BPS
INT ?	8.64×10^8 BPS

Figure 3.7-2. Intelsat Traffic Model--Pacific Ocean

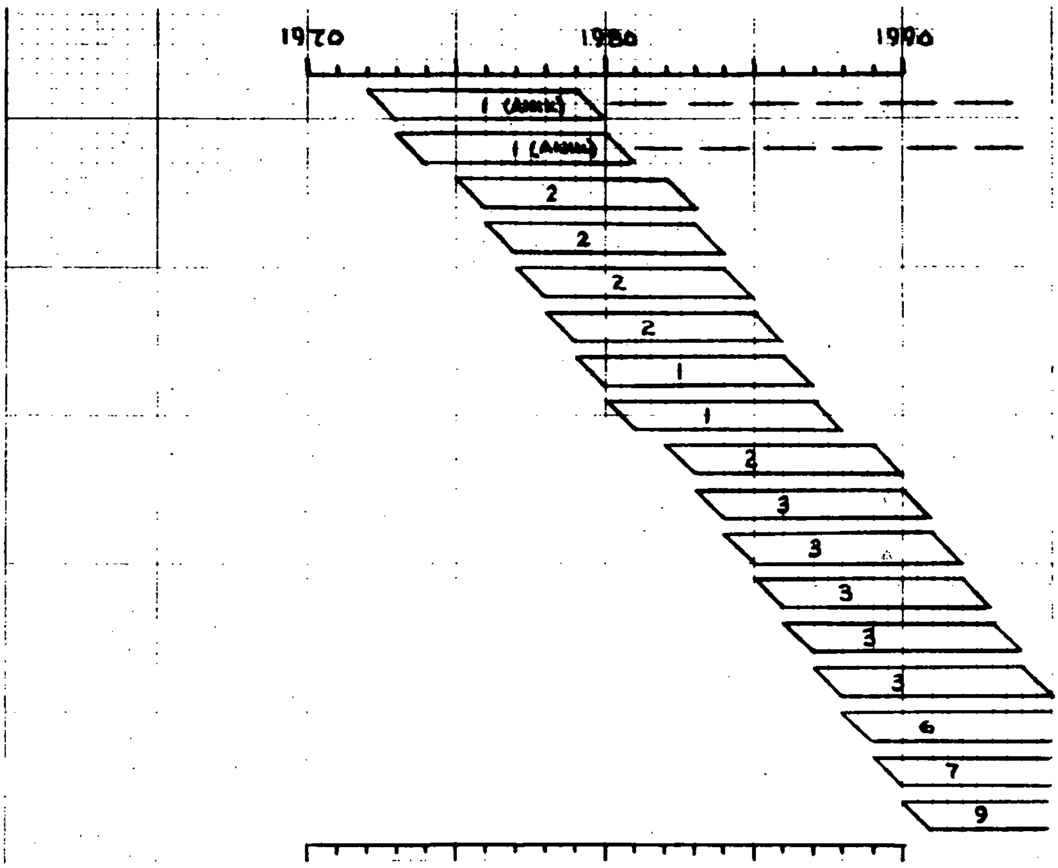


YEAR 1970 — 1980 — 1990

NO. INACTIVE	0	0	0	1	1	1	1	1	2	2	3	3	3	3	3	3	3	3	3	3	3	3
NO. ACTIVE	1	1	1	1	1	2	2	2	2	2	2	3	3	4	5	6	7	9	11	15	15	18
NO. DELIVERED	1	0	0	1	0	1	0	0	1	0	1	1	0	1	1	2	1	3	3	2	3	4
NO. RECOVERED	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	1

SATELLITE TYPE	DATA RATE CAPABILITY
INT III	7.2×10^7 BPS
INT IV	4.32×10^8 BPS
INT ?	8.64×10^8 BPS

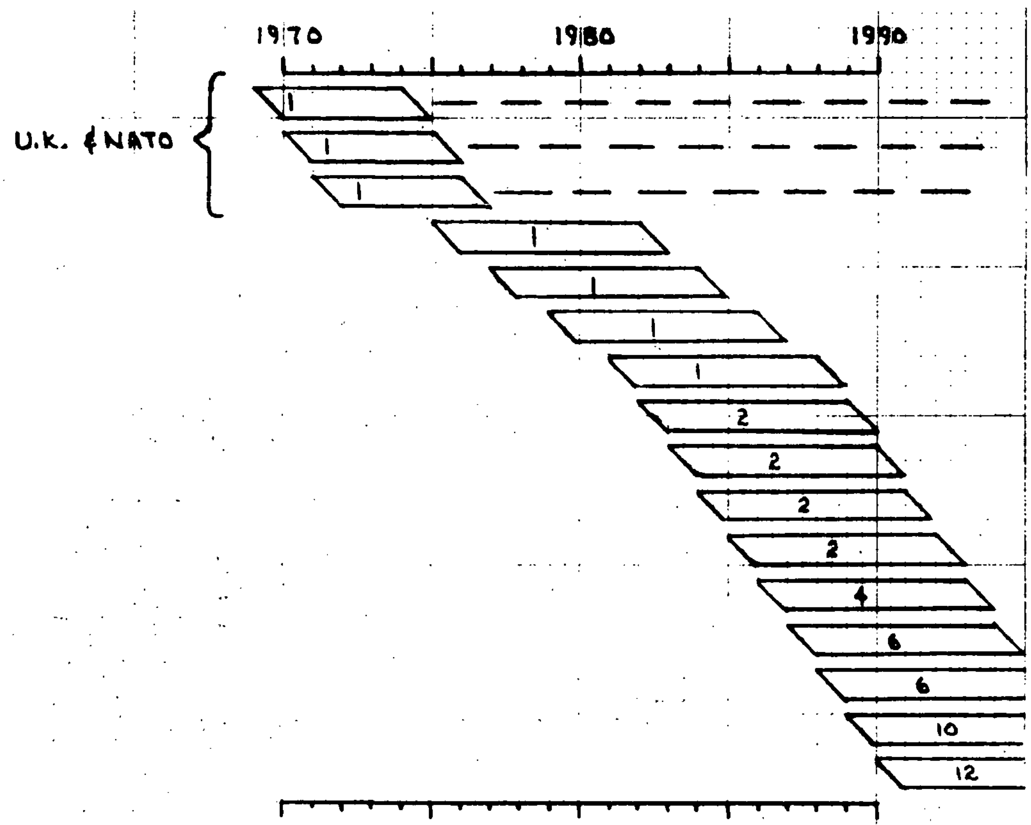
Figure 3.7-3. Intelsat Traffic Model--Indian Ocean



YEAR	1970										1980										1990
NO. INACTIVE							0	0	0	0	1	2	2	2	2	2	2	2	2	2	2
NO. ACTIVE	0	0	1	2	2	4	6	8	10	10	10	10	10	11	12	13	15	17	23	28	34
NO. DELIVERED	0	0	1	1	0	2	2	2	2	1	1	0	2	3	3	8	3	3	6	7	9
NO. RECOVERED											0	0	2	2	2	2	1	1	0	2	3

DATA RATE CAPABILITY ~ 8.64×10^8 BPS PER SATELLITE
(EXCEPT ANIK ~ 4.32×10^8 BPS)

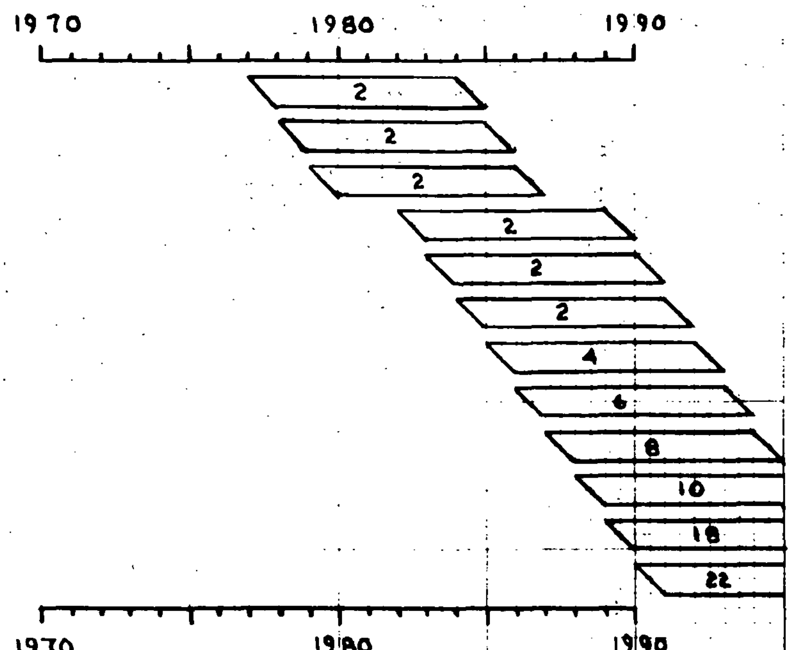
Figure 3.7-4. Domsat Traffic Model--North and South America



YEAR	1970										1980										1990	
NO. INACTIVE						1	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
NO. ACTIVE	1	2	3	3	3	2	2	1	2	2	3	3	4	5	7	8	10	13	19	24	32	42
NO. DELIVERED	1	1	1	0	0	0	1	0	1	0	1	0	1	2	2	2	2	4	6	6	10	12
NO. RECOVERED												0	0	1	0	1	0	1	0	1	2	2

DATA RATE CAPABILITY ~ 8.64×10^8 BPS PER SATELLITE
(EXCEPT UK & NATO ~ 4.32×10^8 BPS ASSUMED)

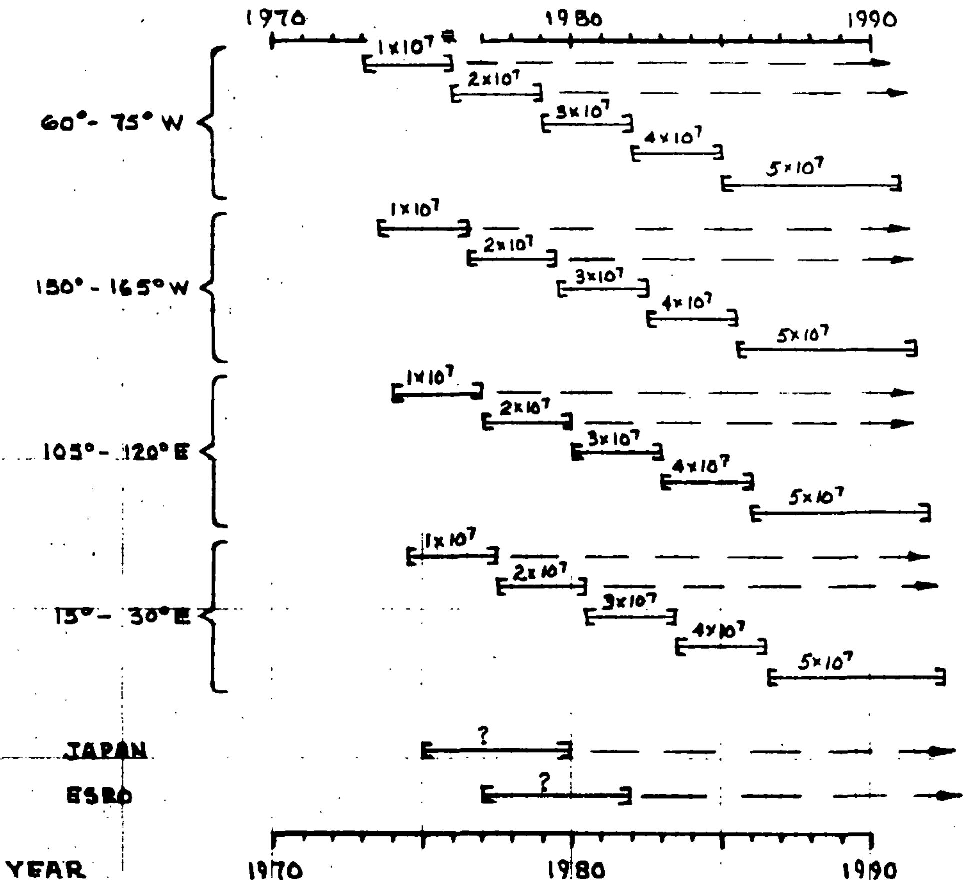
Figure 3.7-5. Domsat Traffic Model--Europe/Africa/USSR (West)



YEAR																
NO. INACTIVE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NO. ACTIVE	0	0	2	4	6	6	6	8	10	10	12	16	24	34	50	70
NO. DELIVERED	0	0	2	2	2	0	0	2	2	2	4	6	8	10	18	22
NO. RECOVERED	0	0	0	0	0	0	0	0	0	2	2	2	0	0	2	2

DATA RATE CAPABILITY ~ 8.64×10^8 BPS PER SATELLITE

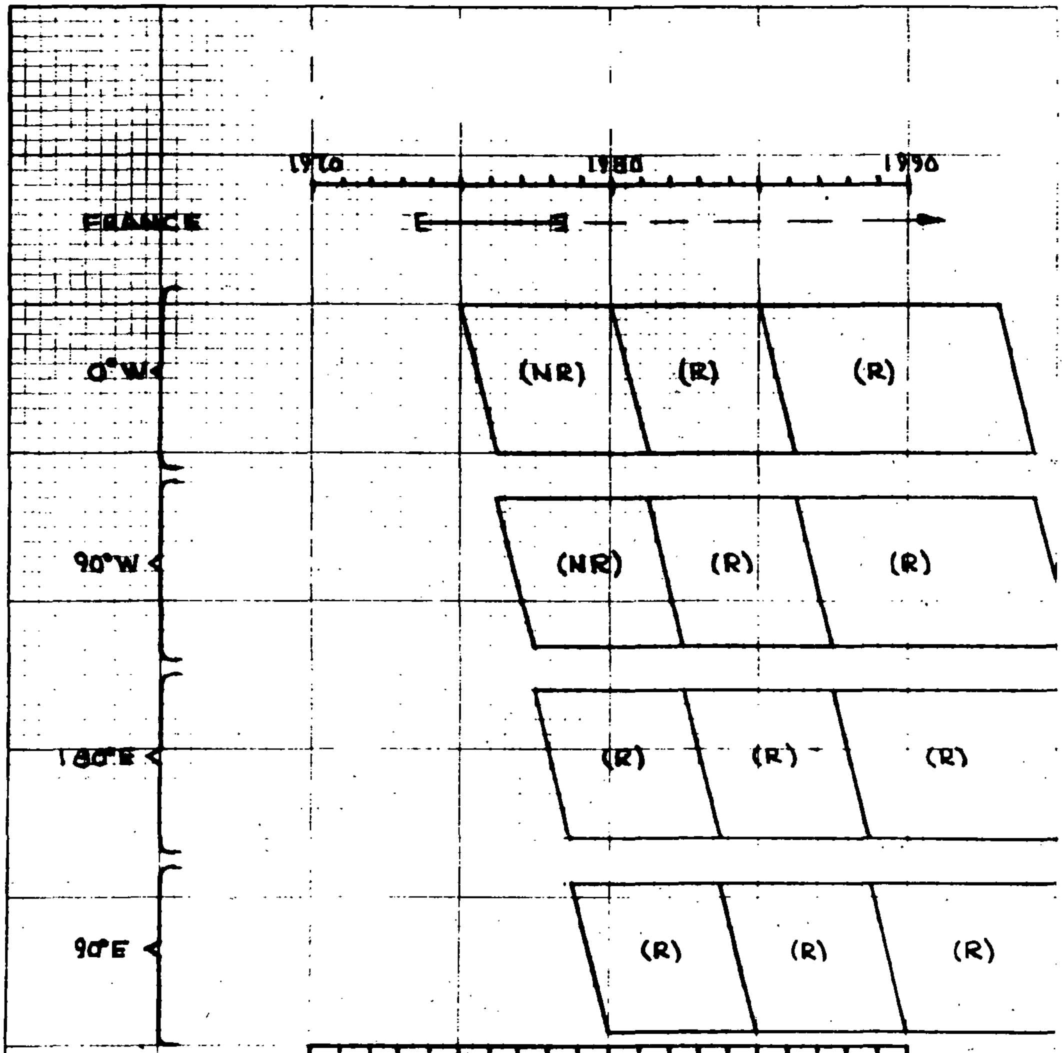
Figure 3.7-6. Domsat Traffic Model--USSR (East)/Asia/Australia/Oceana



NO. INACTIVE	0	0	0	2	4	4	6	9	9	10	10	10	10	10	10	10	10	10
NO. ACTIVE	2	4	5	5	6	6	6	5	5	4	4	4	4	4	4	4	4	4
NO. DELIVERED	2	2	1	2	3	0	2	2	0	2	2	0	2	2	0	0	0	0
NO. RECOVERED	0	0	0	0	0	0	0	0	0	2	2	0	2	2	0	0	0	0

* DATA RATE CAPABILITY ~ BITS/SECOND

Figure 3.7-7. Mersat Traffic Model



YEAR 1970 1980 1990

NO. INACTIVE	0	0	0	0	0	1	1	5	9	11	11	11	11	11	11	11	11	11
NO. ACTIVE	1	1	5	9	13	16	20	20	20	20	20	20	20	20	20	20	20	20
NO. DELIVERED	1	6	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
NO. RECOVERED	0	0	0	0	0	0	0	0	0	2	4	4	4	4	4	4	4	

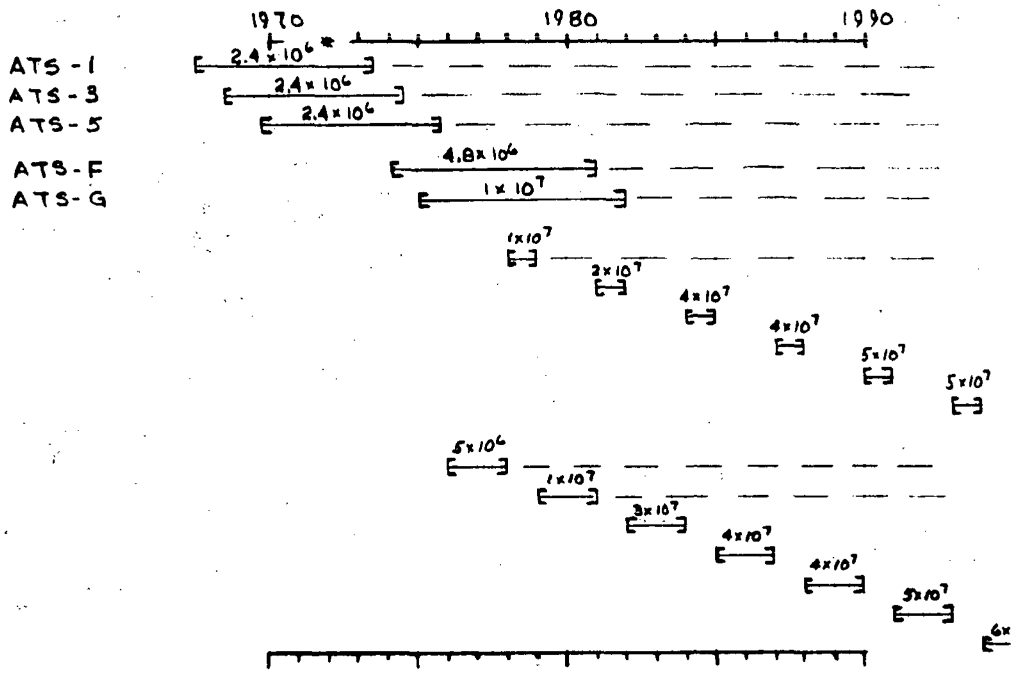
DATA RATE CAPABILITY ~ 10^6 BITS/SECOND PER SATELLITE

NOTE : 5 SATELLITE CLUSTER

NO.	INCL.	ECC.
1	0°	0
4	60°	.25

(NR) NOT RECOVERABLE (R) RECOVERABLE

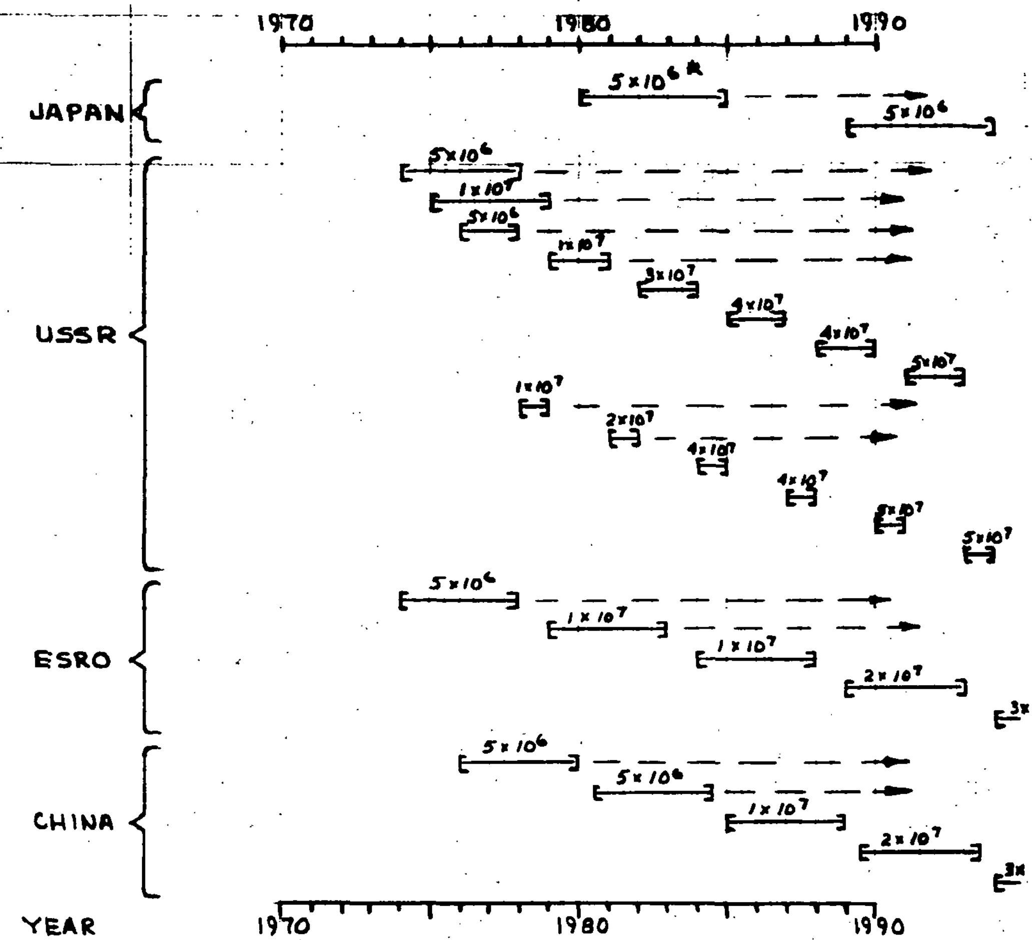
Figure 3.7-8. Nacsat Traffic Model



YEAR	1970										1980										1990
NO. INACTIVE	0	0	0	1	2	3	3	3	4	5	5	7	8	8	8	8	8	8	8	8	8
NO. ACTIVE	3	3	3	2	2	2	3	3	3	3	3	2	1	1	1	1	1	1	1	1	1
NO. DELIVERED	0	0	0	0	1	1	1	0	1	1	0	1	1	0	1	1	0	1	1	0	1
NO. RECOVERED	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	1	0	1

* DATA RATE CAPABILITY ~ BITS / SECOND

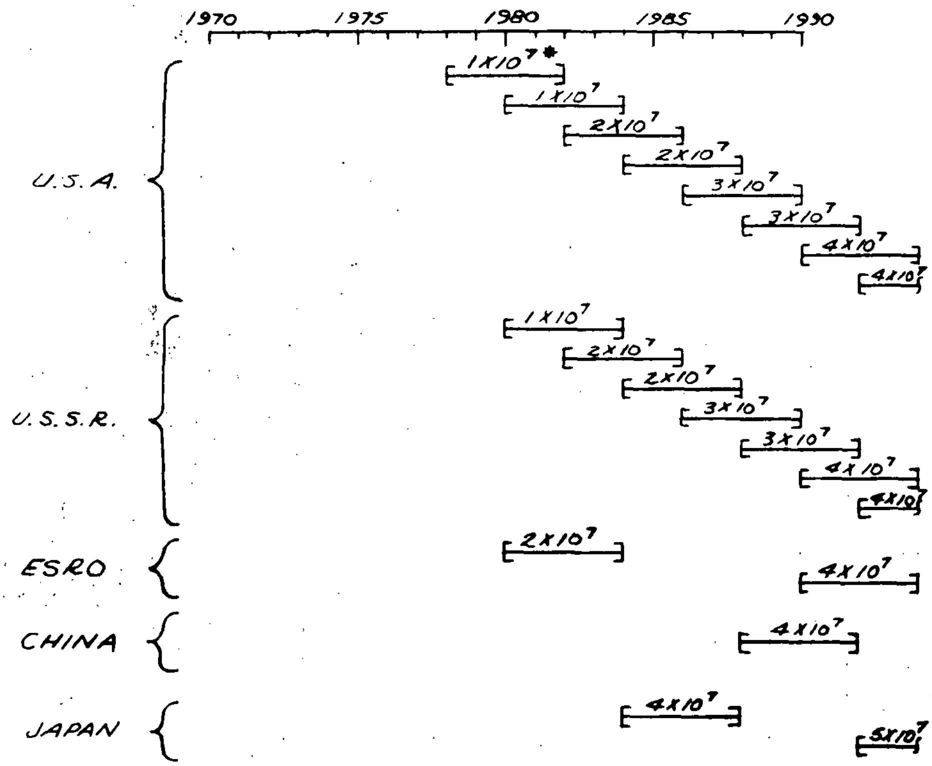
Figure 3.7-9. ATS Traffic Model--United States



NO. INACTIVE	0	0	0	0	3	5	6	7	8	9	10	11	11	11	11	11	11
NO. ACTIVE	2	3	5	5	3	3	4	4	4	3	3	3	3	3	2	4	4
NO. DELIVERED	2	1	2	0	1	2	2	1	1	0	2	2	0	1	1	3	1
NO. RECOVERED	0	0	0	0	0	0	0	0	0	0	1	1	0	1	2	1	1

* DATA RATE CAPABILITY ~ BITS/SECOND

Figure 3.7-10. ATS Traffic Model--Foreign



NO. INACTIVE	0	0	0	0	0	0	0	0	0	0	0	0	0
NO. ACTIVE	1	1	4	4	5	5	5	5	5	5	5	5	6
NO. DELIVERED	1	0	3	0	2	0	3	0	2	0	3	0	3
NO. RECOVERED	0	0	0	0	1	0	3	0	2	0	3	0	2

1970 1975 1980 1985 1990

YEAR

* DATA RATE CAPABILITY ~ BITS/SECOND

Figure 3.7-11. Astronomy Traffic Model--United States and Foreign

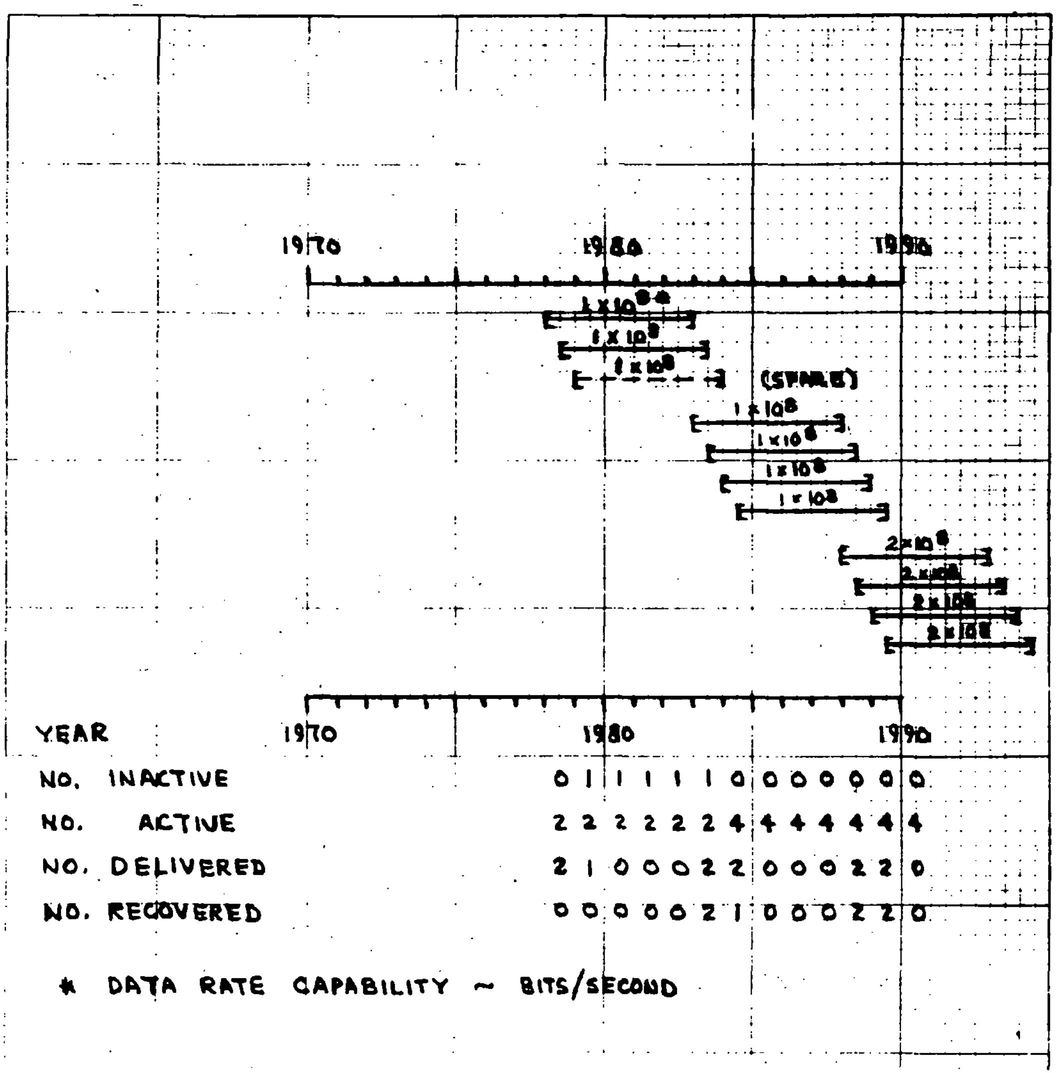
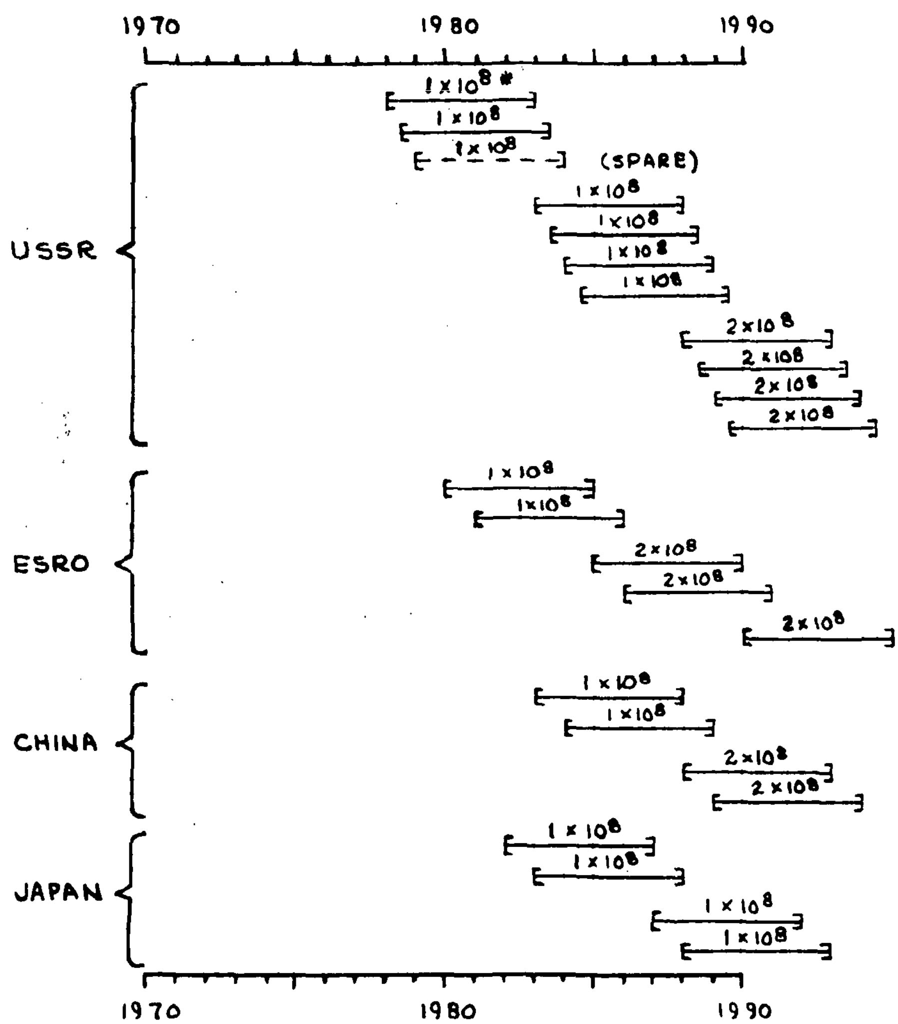


Figure 3.7-12. TDRS Traffic Model--United States



NO. INACTIVE		1	1	1	1	1	0	0	0	0	0	0	0
NO. ACTIVE	2	2	3	4	5	7	10	10	10	10	10	10	10
NO. DELIVERED	2	1	1	1	1	4	3	1	1	1	4	3	1
NO. RECOVERED						2	1	1	1	1	4	3	1

* DATA RATE CAPABILITY ~ BITS/SECOND

Figure 3.7-13. TDRS Traffic Model--Foreign

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3.8 NEW TRAFFIC MODEL SUMMARIES

Each of the functional and regional tables in Figures 3.7-1 through 3.7-13 have been summarized and are presented on Table 3.8-1. This shows by year (from 1973 through 1990) the number of active, inactive, and total satellites on-orbit. Also shown are the number of satellites delivered and recovered in each year. The basic demand requirements show the new traffic model on-orbit satellite population increasing from 26 geosynchronous satellites in 1973 to 300 satellites by the end of 1990. Satellite deliveries per year increase tenfold from 6 in 1973 to 60 in 1990. The maximum number of satellite recoveries is 18 per year with the number of recoveries per year approximately equal to the number of deliveries per year about six or seven years earlier.

As previously indicated, the reason for the large numbers of satellites on-orbit and satellite deliveries in the 1985 to 1990 time period is due to the assumption of Intelsat and Domsat fixed level (24-transponder) data rate capacity. The assumption of 48-transponder satellites would essentially reduce these numbers by a factor of two. As indicated earlier, the best selection of data rate capacity for data relay platforms is documented in a subsequent section of this volume.

Traffic model summaries, based on the previously defined satellite capability characteristics, are shown in Tables 3.8-2 through 3.8-5 for each calendar year by satellite type. A table is presented for active, inactive, satellites delivered, and satellites recovered. Tables 3.8-6 through 3.8-9 present similar data except that each major satellite type is further segregated by principal area.

The new traffic model data of primary interest in physical and electromagnetic interference analyses are the traffic model summaries by longitudinal zone. The six principal zones with respect to geographical location are identified at the bottom of Figure3.6-1. Figure 3.8-1 shows the new traffic model population distribution for these six principal zones. Table 3.8-10 shows the tabulated values that are plotted on Figure 3.8-1. The number of active, inactive, and total number of on-orbit satellites are shown as a function of year for each zone.

The largest number of satellites in the 1980 to 1990 time period is found in Zone 2, which serves the USSR and Asia. However, since the zones have various longitudinal dimensions, as shown in Figure 3.8-1, it is found for 1990 that Zone 1 is the most crowded zone (with less than one degree of longitude per active satellite) followed closely by Zones 2 and 4 (with less than 1.5 degrees of longitude per active satellite). For comparison purposes, the number of active satellites on-orbit during 1985 for the baseline traffic model is shown by the solid black symbol. In all zones the new traffic satellite populations exceed those of the baseline traffic model except for Zone 5.

Table 3.8-1. New Traffic Model Summary

	CALENDAR YEAR																	
	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
ACTIVE	16	20	28	36	46	55	63	69	71	76	85	94	102	115	135	160	196	239
INACTIVE	10	12	14	19	23	30	39	48	55	60	61	60	61	61	61	61	61	61
DELIVERED	6	6	10	13	14	16	17	15	9	19	24	26	23	28	30	43	54	60
RECOVERED										9	14	18	14	15	10	18	18	17
TOTAL ON-ORBIT	26	32	42	55	69	85	102	117	126	136	146	154	163	176	196	221	257	300

Table 3.8-2. New Traffic Model Summary - Active Satellites

Satellite Type	CALENDAR YEAR																		
	Pre 73	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
INTELSAT	13	6	7	7	7	7	6	7	9	10	12	15	17	20	24	28	33	38	44
DOMSAT	4	5	4	6	7	12	16	19	19	20	23	28	30	35	44	60	81	110	146
MERSAT		2	4	5	5	6	6	6	5	5	4	4	4	4	4	4	4	4	4
NACSAT		1	1	5	9	13	16	20	20	20	20	20	20	20	20	20	20	20	20
ATS	3	2	4	5	8	8	6	6	7	6	5	4	4	4	4	4	3	5	5
ASTRONOMY							1	1	4	4	5	5	5	5	5	5	5	5	6
TDRS							4	4	5	6	7	9	14	14	14	14	14	14	14
ANNUAL TOTAL	20	16	20	28	36	46	55	63	69	71	76	85	94	102	115	135	160	196	239

Table 3.8-3. New Traffic Model Summary - Inactive Satellites

SATELLITE TYPE	CALENDAR YEAR																	
	Pre 73	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
INTELSAT	8	9	9	9	11	13	15	16	16	16	16	16	16	16	16	16	16	16	16
DOMSAT			1	2	3	3	3	4	5	5	5	5	5	5	5	5	5	5	5
MERSAT					2	4	4	6	9	9	10	10	10	10	10	10	10	10	10
NACSAT							1	1	5	9	11	11	11	11	11	11	11	11	11
ATS		1	2	3	3	3	7	10	11	14	16	17	18	19	19	19	19	19	19
ASTRONOMY																			
TDRS								2	2	2	2	2							
ANNUAL TOTAL	8	10	12	14	19	23	30	39	48	55	60	61	60	61	61	61	61	61	61

Table 3.8-4. New Traffic Model Summary - Satellites Delivered

SATELLITE TYPE	SCHEDULE (CALENDAR YEAR)																		SUB-TOTAL	CUM TOTAL
	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90		
INTELSAT	2	1		2	2	1	2	2	1	2	5	4	4	6	6	6	7	11	64	64
DOMSAT	1		3	2	5	4	4	1	1	6	7	7	9	13	17	22	35	43	180	244
MERSAT	2	2	1	2	3		2	2		2	2		2	2					22	266
NACSAT	1		4	4	4	4	4	4	4	4	4	4	4	4	4	4	4		61	327
ATS		3	2	3		2	3	2	2	2		3	3		2	2	3	2	34	361
ASTRONOMY						1		3		2		3		2		3		3	17	378
TDRS						4	2	1	1	1	6	5	1	1	1	6	5	1	35	413
ANNUAL TOTAL	6	6	10	13	14	16	17	15	9	19	24	26	23	28	30	43	54	60		

Table 3.8-5. New Traffic Model Summary - Satellites Recovered

SATELLITE TYPE	SCHEDULE (CALENDAR YEAR)																		Sub-Total	Cum Total
	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90		
INTELSAT											2	2	1	2	2	1	2	5	17	17
DOMSAT										3	2	5	4	4	1	1	6	7	33	50
MERSAT										2	2		2	2					8	58
NACSAT										2	4	4	4	4	4	4	4		30	88
ATS										1		2	2		2	3	1	2	13	101
ASTRONOMY										1		3		2		3		2	11	112
TDRS											4	2	1	1	1	6	5	1	21	133
ANNUAL TOTAL										9	14	18	14	15	10	18	18	17		

Table 3.8-6. New Traffic Model Summary - Active Satellites by Area

SATELLITE TYPE	Pre 73	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
	CALENDAR YEAR																		
INTELSAT																			
ATLANTIC OCEAN	8	3	3	3	3	3	2	3	3	4	4	5	5	6	7	8	9	10	11
PACIFIC OCEAN	3	2	2	2	2	2	2	2	3	3	4	5	6	7	8	9	11	13	15
INDIAN OCEAN	2	1	2	2	2	2	2	2	3	3	4	5	6	7	9	11	13	15	18
SUBTOTAL	13	6	7	7	7	7	6	7	9	10	12	15	17	20	24	28	33	38	44
DOMSAT																			
NORTH & SOUTH AMERICA	1*	2	2	4	6	8	10	10	10	10	10	11	12	13	15	17	23	28	34
EUROPE/AFRICA/USSR(W)	3**	3	2	2	1	2	2	3	3	4	5	7	8	10	13	19	24	32	42
USSR(E)/ASIA/AUSTRALIA						2	4	6	6	6	8	10	10	12	16	24	34	50	70
SUBTOTAL	4	5	4	6	7	12	16	19	19	20	23	28	30	35	44	60	81	110	146
MERSAT		2	4	5	5	6	6	6	5	5	4	4	4	4	4	4	4	4	4
NACSAT		1	1	5	9	13	16	20	20	20	20	20	20	20	20	20	20	20	20
ATS																			
UNITED STATES	3	2	2	2	3	3	3	3	3	2	1	1	1	1	1	1	1	1	1
FOREIGN			2	3	5	5	3	3	4	4	4	3	3	3	3	3	2	4	4
SUBTOTAL	3	2	4	5	8	8	6	6	7	6	5	4	4	4	4	4	3	5	5
ASTRONOMY																			
UNITED STATES							1	1	2	2	2	2	2	2	2	2	2	2	2
FOREIGN									2	2	3	3	3	3	3	3	3	3	4
SUBTOTAL							1	1	4	4	5	5	5	5	5	5	5	5	6
TDRS																			
UNITED STATES							2	2	2	2	2	2	4	4	4	4	4	4	4
FOREIGN							2	2	3	4	5	7	10	10	10	10	10	10	10
SUBTOTAL							4	4	5	6	7	9	14	14	14	14	14	14	14
ANNUAL TOTAL	20	16	20	28	36	46	55	63	69	71	76	85	94	102	115	135	160	196	239

*TELSAT: CANADA **UK AND NATO

Table 3.8-7. New Traffic Model Summary - Inactive Satellites by Area

SATELLITE TYPE	CALENDAR YEAR																		
	Pre 73	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
INTELSAT																			
ATLANTIC OCEAN	6	6	6	6	7	8	9	9	9	9	9	9	9	9	9	9	9	9	9
PACIFIC OCEAN	1	2	2	2	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4
INDIAN OCEAN	1	1	1	1	1	2	2	3	3	3	3	3	3	3	3	3	3	3	3
SUBTOTAL	8	9	9	9	11	13	15	16	16	16	16	16	16	16	16	16	16	16	16
DOMSAT																			
NORTH & SOUTH AMERICA								1	2	2	2	2	2	2	2	2	2	2	2
EUROPE/AFRICA/USSR (W)			1	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
USSR (E)/ASIA/AUSTRALIA																			
SUBTOTAL			1	2	3	3	3	4	5	5	5	5	5	5	5	5	5	5	5
MERSAT					2	4	4	6	9	9	10	10	10	10	10	10	10	10	10
NACSAT							1	1	5	9	11	11	11	11	11	11	11	11	11
ATS																			
UNITED STATES		1	2	3	3	3	4	5	5	7	8	8	8	8	8	8	8	8	8
FOREIGN							3	5	6	7	8	9	10	11	11	11	11	11	11
SUBTOTAL		1	2	3	3	3	7	10	11	14	16	17	18	19	19	19	19	19	19
ASTRONOMY																			
UNITED STATES																			
FOREIGN																			
SUBTOTAL																			
TDRS																			
UNITED STATES								1	1	1	1	1							
FOREIGN								1	1	1	1	1							
SUBTOTAL								2	2	2	2	2							
ANNUAL TOTAL	8	10	12	14	19	23	30	39	48	55	60	61	60	61	61	61	61	61	61

Table 3.8-8.* New Traffic Model Summary - Delivered Satellites by Area

SATELLITE TYPE	SCHEDULE (CALENDAR YEAR) 73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL	SUB-TOTAL	CUM TOTAL
INTELSAT																					
ATLANTIC OCEAN	1			1	1		1		1		2	1	1	2	1	2	1	3	18		
PACIFIC OCEAN	1			1		1		1		1	2	1	2	1	2	2	3	4	22		
INDIAN OCEAN		1			1		1	1		1	1	2	1	3	3	2	3	4	24		
SUBTOTAL	2	1	-	2	2	1	2	2	1	2	5	4	4	6	6	6	7	11		64	64
DOMSAT																					
NORTH AND SOUTH AMERICA	1		2	2	2	2	1	1		2	3	3	3	3	3	6	7	9	50		
EUROPE/AFRICA/USSR (W)			1		1		1		1	2	2	2	2	4	6	6	10	12	50		
USSR (E)/ASIA/AUSTRALIA					2	2	2			2	2	2	4	6	8	10	18	22	80		
SUBTOTAL	1	-	3	2	5	4	4	1	1	6	7	7	9	13	17	22	35	43		180	244
MERSAT - METEOROLOGY & EARTH OBSERVATIONS	2	2	1	2	3	-	2	2	-	2	2	-	2	2	-	-	-	-	22	22	268
NACSAT - NAVIGATION & TRAFFIC CONTROL	1	-	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	-	61	61	327
ATS																					
UNITED STATES		1	1	1		1	1		1	1		1	1		1	1		1	12		
FOREIGN		2	1	2		1	2	2	1	1		2	2		1	1	3	1	22		
SUBTOTAL	-	3	2	3	-	2	3	2	2	2	-	3	3	-	2	2	3	2		34	361
ASTRONOMY																					
UNITED STATES						1		1		1		1		1		1		1	7		
FOREIGN								2		1		2		1		2		2	10		
SUBTOTAL	-	-	-	-	-	1	-	3	-	2	-	3	-	2	-	3	-	3		17	378
TDRS																					
UNITED STATES						2	1				2	2				2	2		11		
FOREIGN						2	1	1	1	1	4	3	1	1	1	4	3	1	24		
SUBTOTAL	-	-	-	-	-	4	2	1	1	1	6	5	1	1	1	6	5	1		35	413
ANNUAL TOTAL	6	6	10	13	14	16	17	15	9	19	24	26	23	28	30	43	54	60			

*Repeats Table 2.0-1

Table 3.8-9.* New Traffic Model Summary - Recovered Satellites by Area

SATELLITE TYPE	SCHEDULE (CALENDAR YEAR) 73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL	SUB-TOTAL	CUM TOTAL
INTELSAT																					
ATLANTIC OCEAN											1	1		1		1		2	6		
PACIFIC OCEAN											1		1		1		1	2	6		
INDIAN OCEAN												1		1	1		1	1	5		
SUBTOTAL											2	2	1	2	2	1	2	5		17	17
DOMSAT																					
NORTH AND SOUTH AMERICA										2	2	2	2	1	1		2	3	15		
EUROPE/AFRICA/USSR (W)										1		1		1		1	2	2	8		
USSR (E)/ASIA/AUSTRALIA												2	2	2			2	2	10		
SUBTOTAL										3	2	5	4	4	1	1	6	7		33	50
MERSAT										2	2		2	2					8	8	58
NACSAT										2	4	4	4	4	4	4	4		30	30	88
ATS																					
UNITED STATES										1		1	1		1	1		1	6		
FOREIGN												1	1		1	2	1	1	7		
SUBTOTAL										1		2	2		2	3	1	2		13	101
ASTRONOMY																					
UNITED STATES										1		1		1		1		1	5		
FOREIGN												2		1		2		1	6		
SUBTOTAL										1		3		2		3		2		11	112
TDRS																					
UNITED STATES											2	1				2	2		7		
FOREIGN											2	1	1	1	1	4	3	1	14		
SUBTOTAL											4	2	1	1	1	6	5	1		21	133
ANNUAL TOTAL										9	14	18	14	15	10	18	18	17			

*Repeats Table 2.0-2

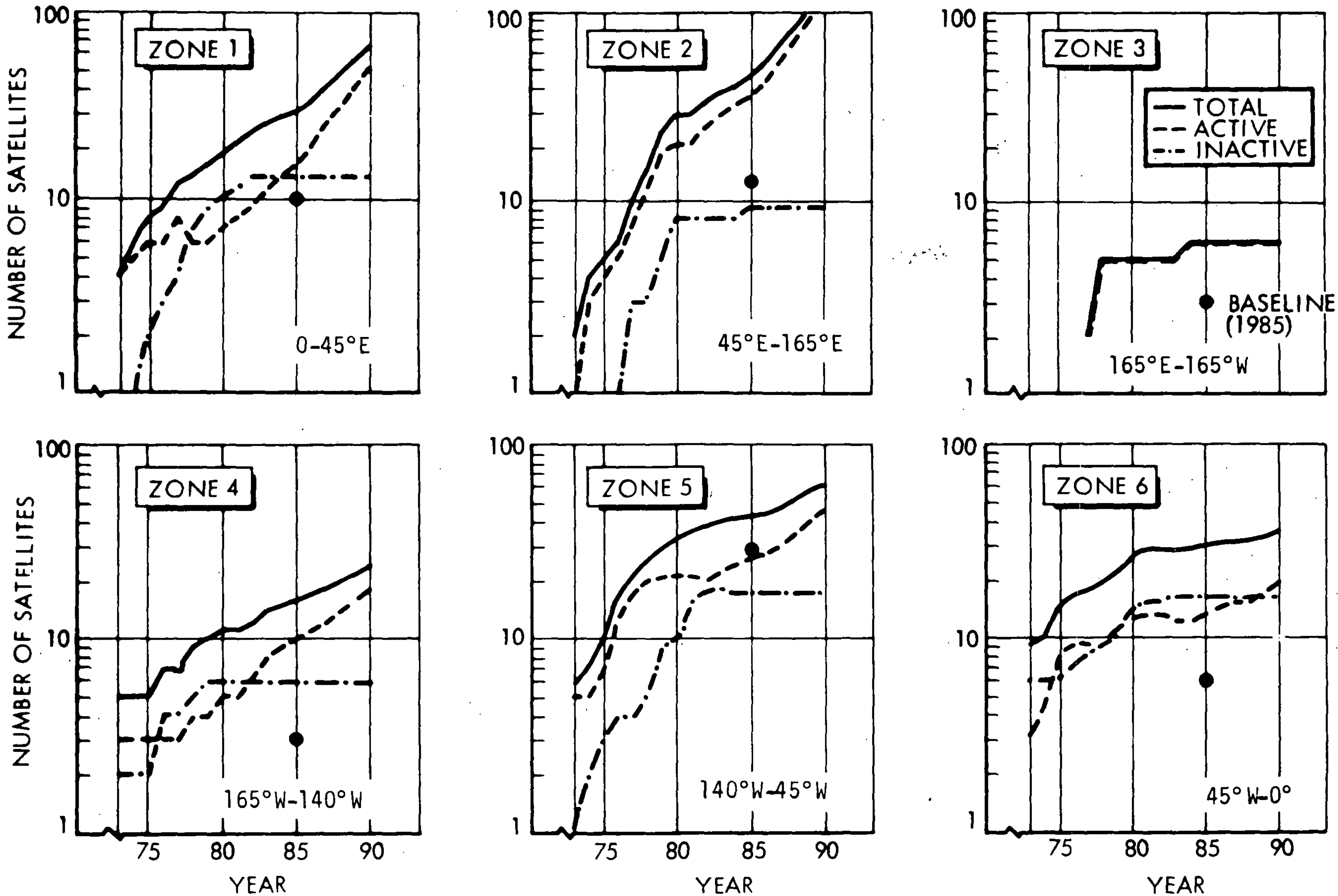

Figure 3.8-1. New Traffic Model Population Distribution

Table 3.8-10. New Traffic Model Summary - Geographic Distribution

ZONE	MODE	SCHEDULE (CALENDAR YEAR)																	
		73		75					80					85					90
1	ACTIVE	4	5	6	6	8	6	6	7	8	9	11	13	15	18	24	29	37	47
	INACTIVE		1	2	3	4	7	9	10	11	13	13	13	13	13	13	13	13	13
	TOTAL ON-ORBIT	4	6	8	9	12	13	15	17	19	22	24	26	28	31	37	42	50	60
2	ACTIVE	1	3	4	5	7	11	17	19	19	23	27	30	33	39	49	61	80	103
	INACTIVE	1	1	1	1	3	3	5	8	8	8	8	8	9	9	9	9	9	9
	TOTAL ON-ORBIT	2	4	5	6	10	14	22	27	27	31	35	38	42	48	58	70	89	112
3	ACTIVE					2	5	5	5	5	5	5	6	6	6	6	6	6	6
	INACTIVE																		
	TOTAL ON-ORBIT					2	5	5	5	5	5	5	6	6	6	6	6	6	6
4	ACTIVE	3	3	3	3	3	4	4	5	5	6	8	9	10	11	12	14	16	18
	INACTIVE	2	2	2	4	4	5	6	6	6	6	6	6	6	6	6	6	6	6
	TOTAL ON-ORBIT	5	5	5	7	7	9	10	11	11	12	14	15	16	17	18	20	22	24
5	ACTIVE	5	5	7	13	17	20	20	21	21	20	22	24	25	27	29	35	40	46
	INACTIVE	1	2	3	4	4	5	9	10	15	18	18	17	17	17	17	17	17	17
	TOTAL ON-ORBIT	6	7	10	17	31	25	29	31	36	38	40	41	42	44	46	52	57	63
6	ACTIVE	3	4	8	9	9	9	11	12	13	13	12	12	13	14	15	15	17	19
	INACTIVE	6	6	6	7	8	10	10	14	15	15	16	16	16	16	16	16	16	16
	TOTAL ON ORBIT	9	10	14	16	17	19	21	26	28	28	28	28	29	30	31	31	33	35
1-6	ACTIVE	16	20	28	36	46	55	63	69	71	76	85	94	102	115	135	160	196	239
	INACTIVE	10	12	14	19	23	30	39	48	55	60	61	60	61	61	61	61	61	61
	TOTAL ON-ORBIT	26	32	42	55	69	85	102	117	126	136	146	154	163	176	196	221	257	300
		73		75					80					85					90

4.0 GEOSYNCHRONOUS ORBIT SATURATION

The general background and objectives for orbit saturation analyses were discussed in Part 1 of this volume. The objectives remain the same here; namely, to determine the nature and degree of satellite congestion likely to occur in geosynchronous orbit if the current approach of launching individual satellites/payloads is continued through the 1990 time period. However, in this case the analyses are focused on the traffic contained in the new traffic model. It is important to determine if satellite interference reaches critical levels, thereby introducing a mandatory change in program approach. This addresses the question, "are multifunction platforms required because of fundamental technological reasons rather than economic pressures?" Part 1 of this volume treated this question for the baseline traffic model. Since the amount of traffic projected for the new model more than doubles that predicted for the baseline traffic model, the potential for satellite interference and congestion is greatly increased. Thus, the orbit saturation analyses are repeated here for the specific satellite populations and distributions contained in the new traffic model. Both satellite physical contention and EM interference factors are considered.

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4.1 PHYSICAL CONTENTION ANALYSIS

APPROACH

Because the new traffic model has many more satellites than the baseline module (413 versus 180), it requires a slightly different approach to the congestion analysis. The ultra conservative simplified model developed to establish satellite spacing requirements for the baseline traffic was restructured slightly to more closely approximate "real" satellite stationkeeping capabilities. All satellites placed in geosynchronous orbit utilize east-west stationkeeping to offset the effects of the tesseral harmonic perturbations. However, none of the satellites projected for the new traffic model employs north-south stationkeeping. Thus, the satellite spacing limits were redefined to acknowledge the three-dimensional effects of the luni-solar perturbations (orbit inclination drift). The result was applied to the satellite distributions in the new traffic model to determine if satellite spacing requirements violated the spacing available and to assess the degree of collision hazard.

SATELLITE CONGESTION EVALUATION

It can be shown that for the active satellite populsions the real physical proximity issue reduces to the consideration of individual east-west stationkeeping capabilities. Satellites placed in geostationary (synchronous equatorial) orbits at t = 0 begin immediately to be influenced by the luni-solar perturbations. Their orbits begin to precess and develop an apparent inclination with respect to the equatorial plane as shown at t = 1 year in Figure 4.1-1 below. This process repeats for the satellites placed in orbit at t = 1 year. The original satellites launched at t = 0 continue under the influence of their orbital perturbations to the conditions depicted at t = 2 years. The satellites launched at t = 0, S_0, have an orbit inclination of 1.8 degrees and a nodal shift of 13.6 degrees; those launched at t = 1 year (S_1) have an orbit inclination of 0.9 degrees and a nodal shift of 6.8 degrees. The composite picture including the satellites launched at t = 2 years is shown at the bottom of the figure.

Representative satellite ground traces are shown beside each orbital configuration to further illustrate the critical proximity geometry. Even though each satellite is maintaining its east-west position through small maneuvers applied at typical 10 to 30 day intervals, the orbit inclination produced by the luni-solar perturbations causes each satellite to follow a daily figure eight ground trace pattern as shown. Ground trace pattern characteristics are covered in greater depth in Volume III of this report. The precise geographic location of the crossover point in the figure eight pattern is dependent upon the actual satellite location within its east-west stationkeeping deadband. This varies from day to day but follows the uniform motion of the satellite through the 10 to 30 day drift interval across its

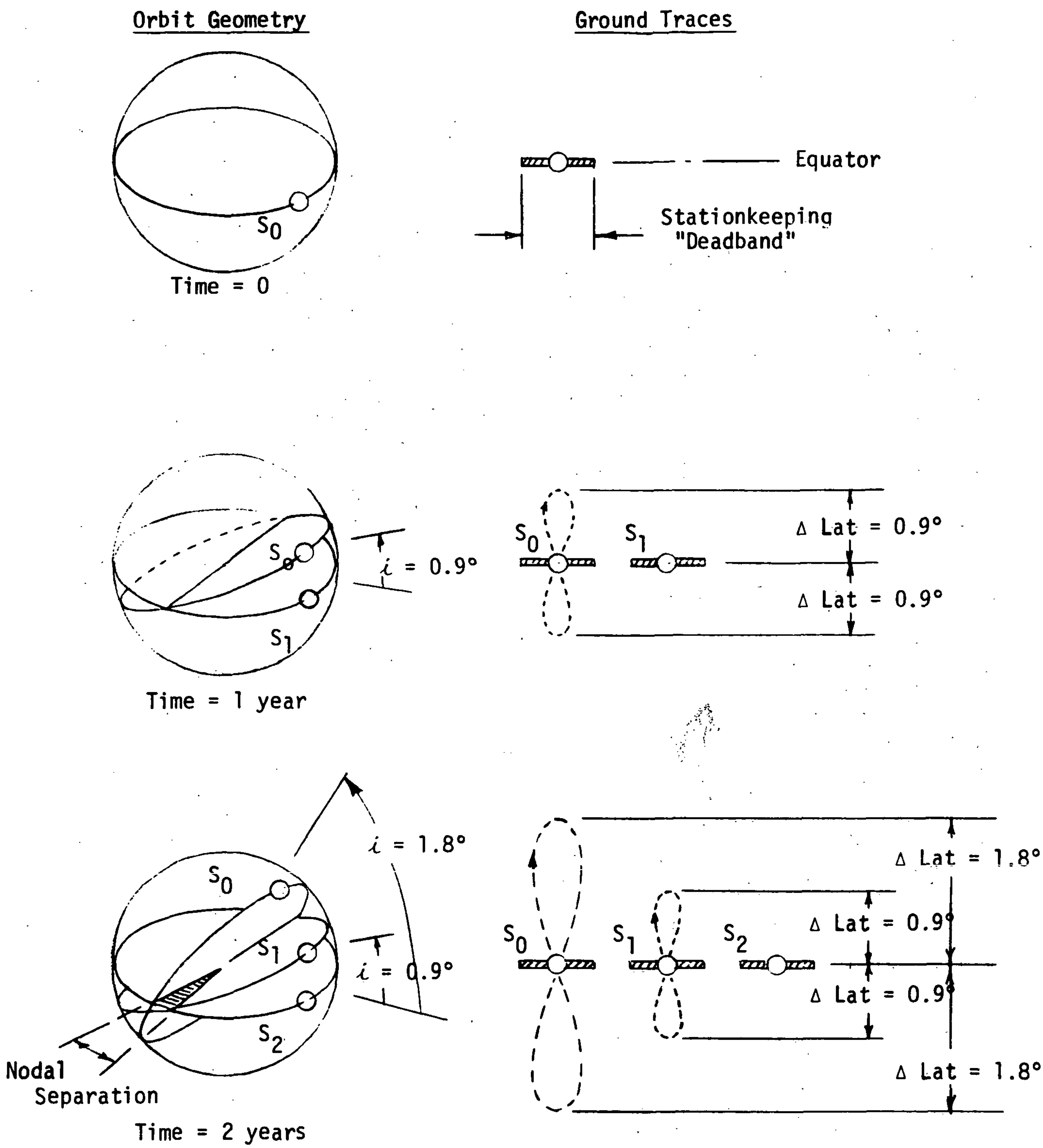

Figure 4.1-1. Geosynchronous Orbit Trends for Active Satellites

deadband. Further, the phase relationship between adjacent satellites in their respective figure eight patterns is dependent upon their relative nodal positions. "Phase relationship" is used here to describe the relative location of each satellite within the loop pattern of their figure eight traces, i.e., is one satellite at the top of a loop when the other is at the bottom, etc.? The "true" spacing limit between adjacent satellites is thus dependent upon stationkeeping capability and the phase relationship exhibited in their ground trace patterns.

As described in Volume III, the reference plane geometry about which the nodal regression pattern develops is relatively fixed along the vernal equinox and is independent of satellite location. The resultant orbital orientations are dependent only upon the time between launches and the subsequent interval over which the nodal regression effects are applied. Thus, all satellites launched on the same date will have the same nodal location and will maintain a fixed relationship in their figure eight pattern as shown in Figure 4.1-2. Ground traces are shown for satellite "A" and "B" seven years after placement in geostationary orbits (maximum active lifetimes). Each has accumulated an inclination of approximately six degrees and has a nodal location of 47.5* degrees retrograde from vernal equinox.

Satellite "A" would be in position A in its figure eight trace while satellite "B" would be at position B. In essence, they would parallel each other around their figure eight patterns such that it would be impossible for satellite "B" to be at B' when satellite "A" was at A'. Thus, the critical spacing is actually governed purely by the stationkeeping capability and is relatively unaffected by phasing mismatches which cannot occur within the normal mechanics of orbital motions.

To further illustrate these effects a second case pictured in Figure 4.1-3 was examined. In this case satellite "D" was launched into a geostationary orbit six years after satellite "C" (which was presumed lauched seven years ago). This produces a nodal separation of 40.8* degrees, the maximum which can occur within the same satellite active life constraints utilized in the case above (7 years). However, in this case the respective orbit inclinations are also different. The satellite "C" orbit is inclined six degrees while the orbit of satellite "D" has only a 0.9 degree inclination. This affects the relative sizes of their figure eight patterns which in turn influences their spacing requirements, but only slightly. For this case satellite "C" would occupy positions 1, 2, 3 and 4 while satellite "D" occupies positions 1', 2', 3' and 4'. Basically, satellite "D" leads satellite "C" around its figure eight pattern by approximately one-tenth of a day. Thus, even with the worst case phase relationship achievable within active life constraints the actual satellite proximity characteristics are only slightly affected, and the significant spacing requirements are again paced only by satellite east-west stationkeeping capabilities. As shown on the figure applying a 50 percent margin to typical stationkeeping deadband dimensions results in a realistic spacing requirement between adjacent satellites of about 0.40 degree longitude. The 50 percent margin encompasses the phase effects, orbit-determination errors, etc.

*based on 6.8 deg per year nodal regression rate.

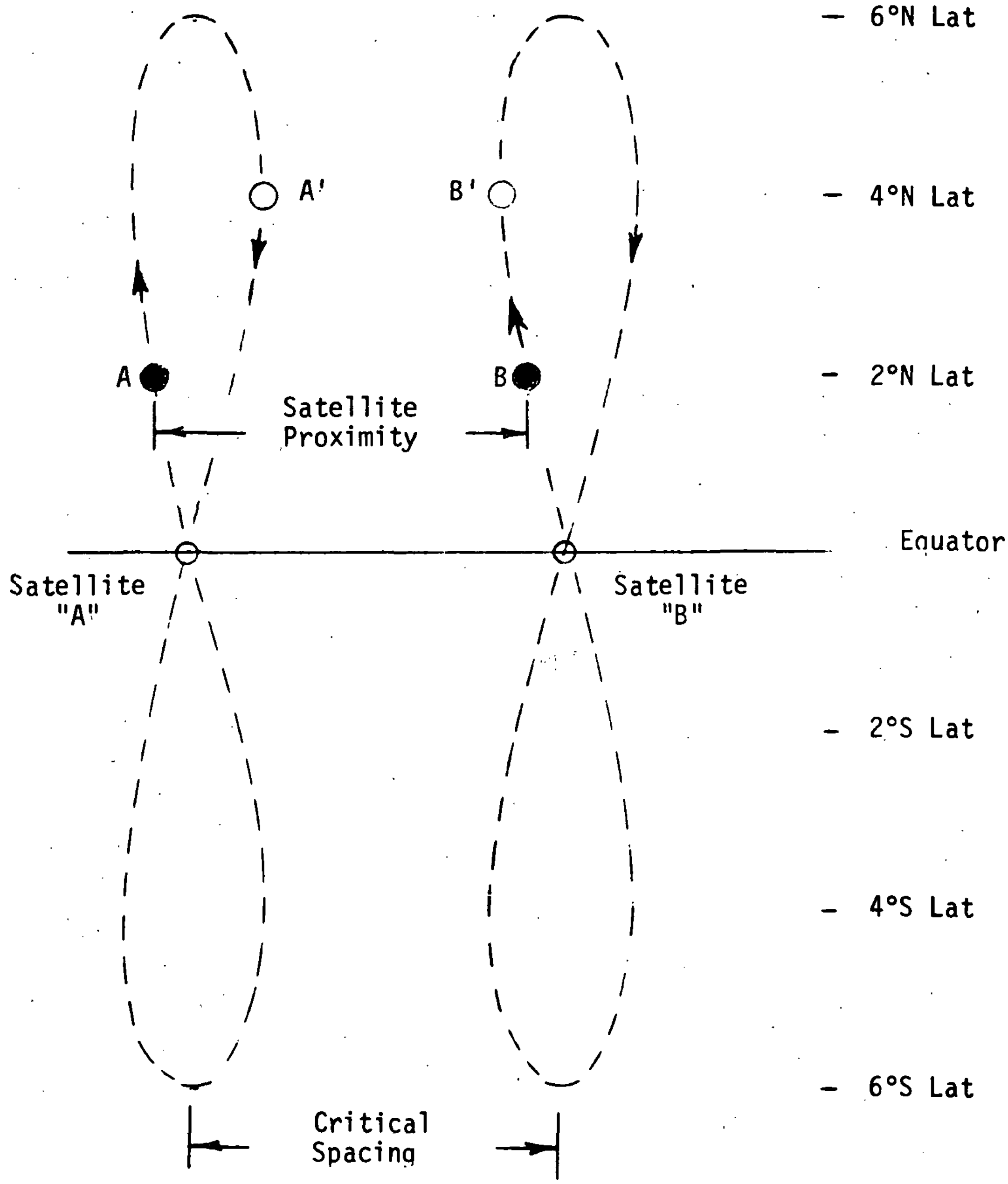

Figure 4.1-2. Typical Ground Trace Pattern for Adjacent Satellites Launched on the Same Date

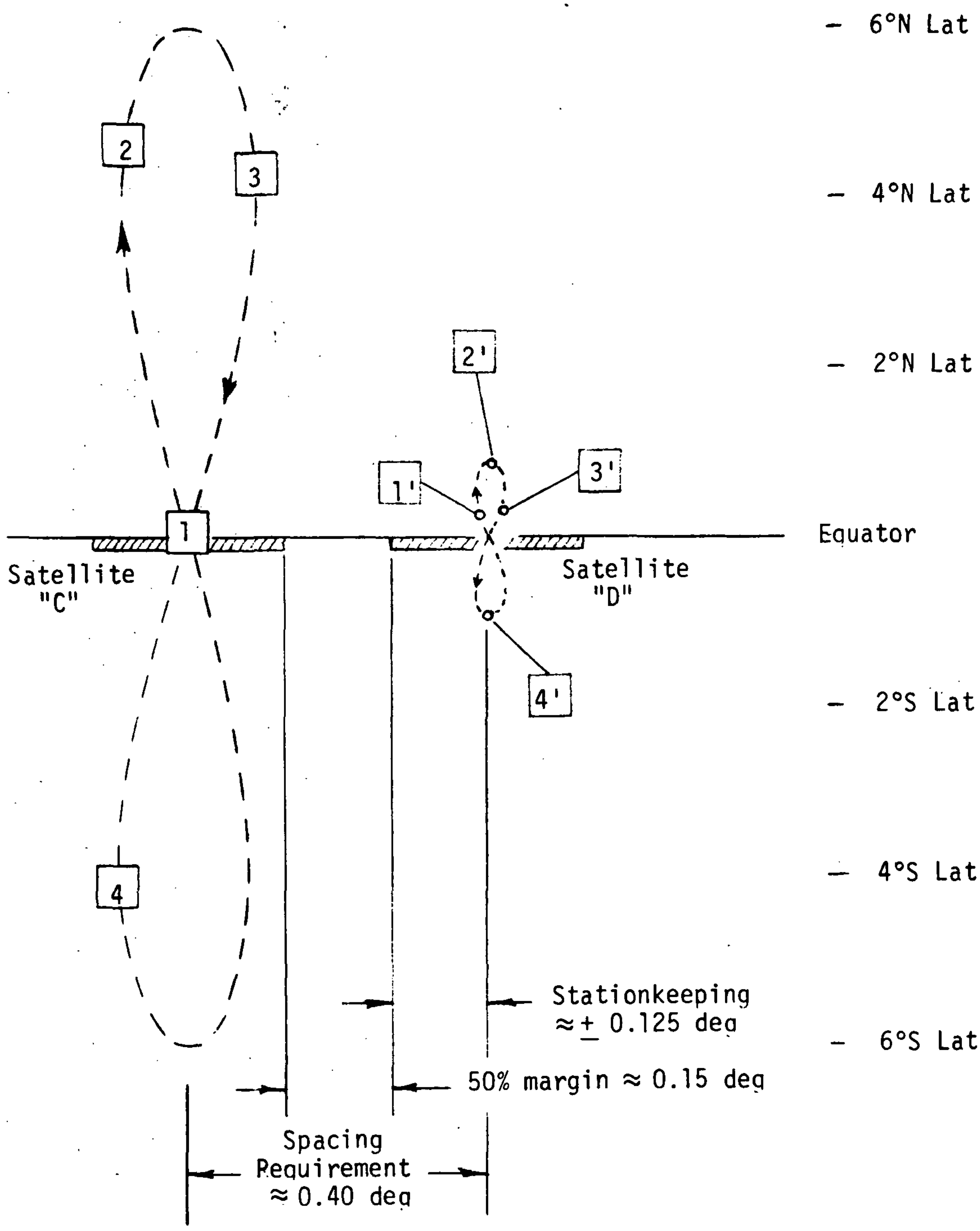

Figure 4.1-3. Typical Ground Trace Patterns for Adjacent Satellites Launched Six Years Apart

This spacing criterion was applied to the satellite populations predicted in the new traffic model. Table 4.1-1 summarizes satellite distributions by zone for each year through the 1990 time period. Both active and inactive satellite populations are shown where the presumption is made that all satellites whose design life expires after 1982 (when the reusable tug becomes available) are retrieved. First, considering only the active satellites, the resultant average spacing within each zone is shown in Table 4.1-2 for the year 1990 when maximum population densites occur. As in Part 1, Volume IV, for the baseline traffic model, the specified satellite occupancy bands were used in calculating the spacing rather than the total zonal boundary dimensions. It is shown that only zones one and two exceed the very conservative spacing limits derived from the simplified model in Part 1 of this report. Even these offer more than a two to one margin over the more realistic spacing requirements, 0.40 degrees, developed above. These average spacing characteristics are further defined in Section 4.2, EMI Contention Analysis, where individual satellite locations were juggled somewhat to minimize their EM interference potential. Although in some cases this resulted in closer physical spacing than in the table above, nowhere did the local satellite crowding violate the 0.40 degrees minimum spacing limit. Thus, it is concluded that the traffic levels forecast through 1990 in the new traffic model do not create a critical physical contention problem.

The inactive satellite population will be acted upon by the three-dimensional effects of orbit perturbations in the same manner as that shown for the baseline traffic model in Part 1. Their total "swept" volume will approach the same 3×10^{10} n mi^3 defined in Part 1. Considering the entire on-orbit populsion of satellites in Table 4.1-1, the average volume per satellite is about 100 million n mi^3. Further, assuming no satellite retrieval the total on-orbit population in the new traffic model jumps from 300 to 433. Even allowing for the existing and estimated future "DoD" missions the total becomes 499 which averages to about 60 million n mi^3 per satellite. Again, this enormous volume supports the conclusion that the satellite collision hazard is negligibly small and that physical contention is not a problem within the traffic levels and distribution patterns defined in the traffic models up to 1990.

While it is concluded that satellite physical congestion is not a critical problem with the high traffic levels predicted in the new traffic model, this conclusion applies only temporarily. At some point in the future the available space in geosynchronous orbit will be fully utilized, particularly in the zones over the land mass regions. Some form of grouping and hardware retrieval will be required. Even with the rapid advancement of communications technology and the widening of the usable EM spectrum, thus providing major increases in unit capabilities, the available geosynchronous space is finite and eventual crowding will occur. Long before this, however, rigorous planning, coordination, and internation cooperation will be required to preclude serious interference conditions even within the traffic levels projected by the study.

Table 4.1-1. Satellite Distribution for the New Traffic Model

ZONE	MODE	SCHEDULE (CALENDAR YEAR)																	
		73		75					80					85					90
1 0-45°E	ACTIVE	4	5	6	6	8	6	6	7	8	9	11	13	15	18	24	29	37	47
	INACTIVE		1	2	3	4	7	9	10	11	13	13	13	13	13	13	13	13	13
	TOTAL ON-ORBIT	4	6	8	9	12	13	15	17	19	22	24	26	28	31	37	42	50	60
2 45°E-165°E	ACTIVE	1	3	4	5	7	11	17	19	19	23	27	30	33	39	49	61	80	103
	INACTIVE	1	1	1	1	3	3	5	8	8	8	8	8	9	9	9	9	9	9
	TOTAL ON-ORBIT	2	4	5	6	10	14	22	27	27	31	35	38	42	48	58	70	89	112
3 165°E-165°W	ACTIVE					2	5	5	5	5	5	5	6	6	6	6	6	6	6
	INACTIVE																		
	TOTAL ON-ORBIT					2	5	5	5	5	5	5	6	6	6	6	6	6	6
4 140°W-165°W	ACTIVE	3	3	3	3	3	4	4	5	5	6	8	9	10	11	12	14	16	18
	INACTIVE	2	2	2	4	4	5	6	6	6	6	6	6	6	6	6	6	6	6
	TOTAL ON-ORBIT	5	5	5	7	7	9	10	11	11	12	14	15	16	17	18	20	22	24
5 45°W-140°W	ACTIVE	5	5	7	13	17	20	20	21	21	20	22	24	25	27	29	35	40	46
	INACTIVE	1	2	3	4	4	5	9	10	15	18	18	17	17	17	17	17	17	17
	TOTAL ON-ORBIT	6	7	10	17	31	25	29	31	36	38	40	41	42	44	46	52	57	63
6 0-45°W	ACTIVE	3	4	8	9	9	9	11	12	13	13	12	12	13	14	15	15	17	19
	INACTIVE	6	6	6	7	8	10	10	14	15	15	16	16	16	16	16	16	16	16
	TOTAL ON ORBIT	9	10	14	16	17	19	21	26	28	28	28	28	29	30	31	31	33	35
1-6	ACTIVE	16	20	28	36	46	55	63	69	71	76	85	94	102	115	135	160	196	239
	INACTIVE	10	12	14	19	23	30	39	48	55	60	61	60	61	61	61	61	61	61
	TOTAL ON-ORBIT	26	32	42	55	69	85	102	117	126	136	146	154	163	176	196	221	257	300
		73		75					80					85					90

Table 4.1-2. Active Satellite Spacing for New Traffic Model (1990)

Zone	Maximum Number of Active Satellites	Actual Satellite Spacing
1 Europe/Africa (0° - 45° E)	47	0.9 deg/satellite
2 Asia/Australia (45°E - 165°E)	103	0.8 deg/satellite
3 West Pacific (165°E - 165°W)	6	2.4 deg/satellite
4 East Pacific (140°W - 165°W)	18	2.4 deg/satellite
5 North/South America (45°W - 140°W)	46	1.9 deg/satellite
6 Atlantic (0° - 45°W)	19	1.7 deg/satellite

4.2 EMI CONTENTION ANALYSIS

The EMI contention analysis for the new traffic model followed the same logical flow as that performed in Part 1 for the new baseline traffic model. A more complex problem existed because of the much larger number of active satellites. Adjustments to the zonal locations were necessary to arrive at the best spacing -- again for the C-band data relay satellites -- to ensure that the most favorable conditions existed for use in the EMI analysis.

The results show that an all C-band data relay system cannot function within the limits of interference levels recommended by CCIR. Only Zone 5 could be made to perform within the limits. This would require 97-foot (instead of 60-foot) ground antennas. It is necessary, therefore, to examine alternate solutions. One solution is to utilize two higher frequency bands, each on different satellites, and alternate the frequencies from one satellite to the next. Sufficient spacing can be accomplished to provide interference levels under the limits with this technique. Another alternate is to combine the capabilities of all three bands (C, K_{LO} and K_{HI}) on a platform and service the traffic with a greatly reduced number of satellites. This technique provides the capability for even greater spacing. However, careful planning must be exercised to ensure the proper traffic distribution service.

The baseline traffic model comments for other frequencies and DoD-type satellites apply also to the new traffic model. Only one new type mission is projected for this model; that is the added navigation data in the Nacsat--navigation and traffic control satellite. Its characteristics are covered in the following section.

SATELLITE RF CHARACTERISTICS

The basic RF characteristics of the new traffic model elements are the same as those of the baseline traffic model with the exception of the Nacsat. The baseline system for aircraft navigation and traffic control was based on an Aerosat-type system. Aerosat supported the traffic control and communications function with only geostationary orbital satellites. In the new traffic model, a system utilizing both geostationary and inclined orbit satellites in a constellation-like system of 4 to 11 satellites was projected. Both DoD and FAA are presently studying such systems. More details for this system are included in Section 4.4 of Volume V. Table 4.2-1 outlines the basic RF characteristics of a projected system.

Table 4.2-1. Navigation and Traffic Control System Characteristics

MISSION/FUNCTIONAL GROUPING: Navigation and Traffic Control	Operating Frequency	
	5.0 to 5.25 GHz	1.54 to 1.66 GHz
SATELLITE	GROUND LINK	AIRCRAFT LINK
Antenna gain (dB)	29.8	26.0
Antenna field of view (degrees)	5.0	6.0
Antenna polarization	--	--
System noise (degrees K)	600.0	600.0
Trans. output power (dBw)	3.0	24.0
EIRP (dBw)	32.0	50.0
GROUND STATION		SHIPS AND AIRCRAFT
Antenna gain (dB)	40.0	0.0
Antenna field of view (degrees)	1.8	OMNI
System noise (degrees K)	150.0	--
Trans. output power (dBw)	20.0	30.0
EIRP (dBw)	60.0	30.0
SYSTEM		
Bandwidth	250.0 kHz	250.0 kHz
Modulation	DPSK-FM	DPSK-FM
Geography	MANY LOCATIONS	MANY LOCATIONS

SATELLITE DISTRIBUTIONS BY FREQUENCY BAND

The satellite distribution process for the new traffic model was considerably more complex than the baseline model. A total of 239 active satellites is projected by 1990 for the new traffic model. This compares to 68 for the baseline traffic model. Of the 239 satellites considered for the new traffic model, 190 are data relay types, either Domsat (146) or Intelsat (44). More detailed distribution analysis was necessary to optimize the spacing in each of the six zones.

A further breakdown of the traffic model to define the specific area coverages required was performed. Figure 4.2-1 shows this breakdown. Results of this analysis allowed redistribution of the 70 Domsats for USSR (east), Asia, Australia and Oceana from a spread of 105 degrees (75°E to 180°E) to 154 degrees (16°E to 170°E). Similar expansion of distribution was accomplished for other zones.

Figures 4.2-2 through 4.2-6 display the results of distribution analyses of the C-band data relay satellites for optimum spacing. These figures also show the satellites operating on other frequency bands (S, VHF, UHF and Ku). Their distribution was controlled to provide maximum overall physical spacing consistent with mission location requirements.

Table 4.2-2 lists the resultant spacings by frequency band and overall physical density. Minimum C-band satellite spacing of 0.8 degree was present in Zone 2 for the 18 Indian Ocean satellites. If these were spread into adjoining areas (a possibility), the minimum spacing could possibly be increased to 0.9 degree. At the same time, the spreading would impact the adjacent areas and reduce their spacing from the 1.5 degrees and 1.3 degrees as presently projected in Figure 4.2-3.

An examination of the individual zonal charts indicates that the minimum physical spacings exist only at very few locations. The 0.4-degree minimum in Zone 2 exists at only two positions: where the TDRS and astronomy satellites are interspersed with the Indian Ocean Intelsats. S-band satellite minimum spacings were shown. Maximum spacings were not meaningful with the small numbers of satellites projected.

EMI MODEL, CRITERIA AND ANALYSIS

The 11-satellite C-band model described in the baseline traffice model (Section 4.2) was used as the basis for the new traffic model EMI analysis. As indicated by Table 4.2-2, the maximum spacing for C-band satellites was 3 degrees and the minimum was 0.8 degree. Using the CCIR interference level criteria and referring to Figure 4.2-8 of Section 4.2, Volume IV, Part 1, it is easily shown that only the 3-degree spacing sections could be supported within acceptable interference levels. At this spacing, a 97-foot antenna would be required at the ground stations. Other lesser spacings could not be supported with feasible size ground antennas at C-band. Table 4.2-3 lists the interference levels for various spacings utilizing 98-foot antennas.

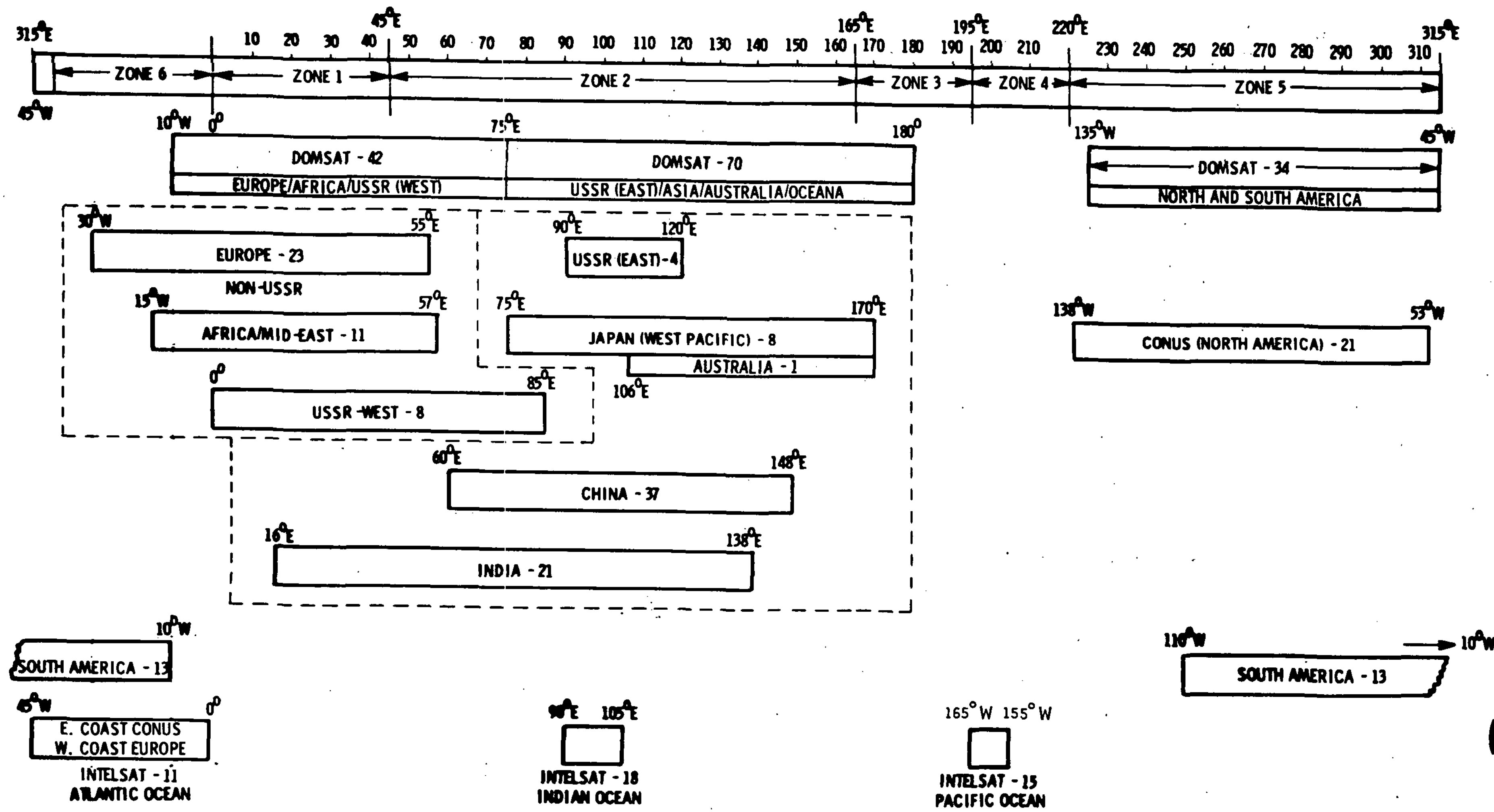

Figure 4.2-1. New Traffic Model Zonal Distribution

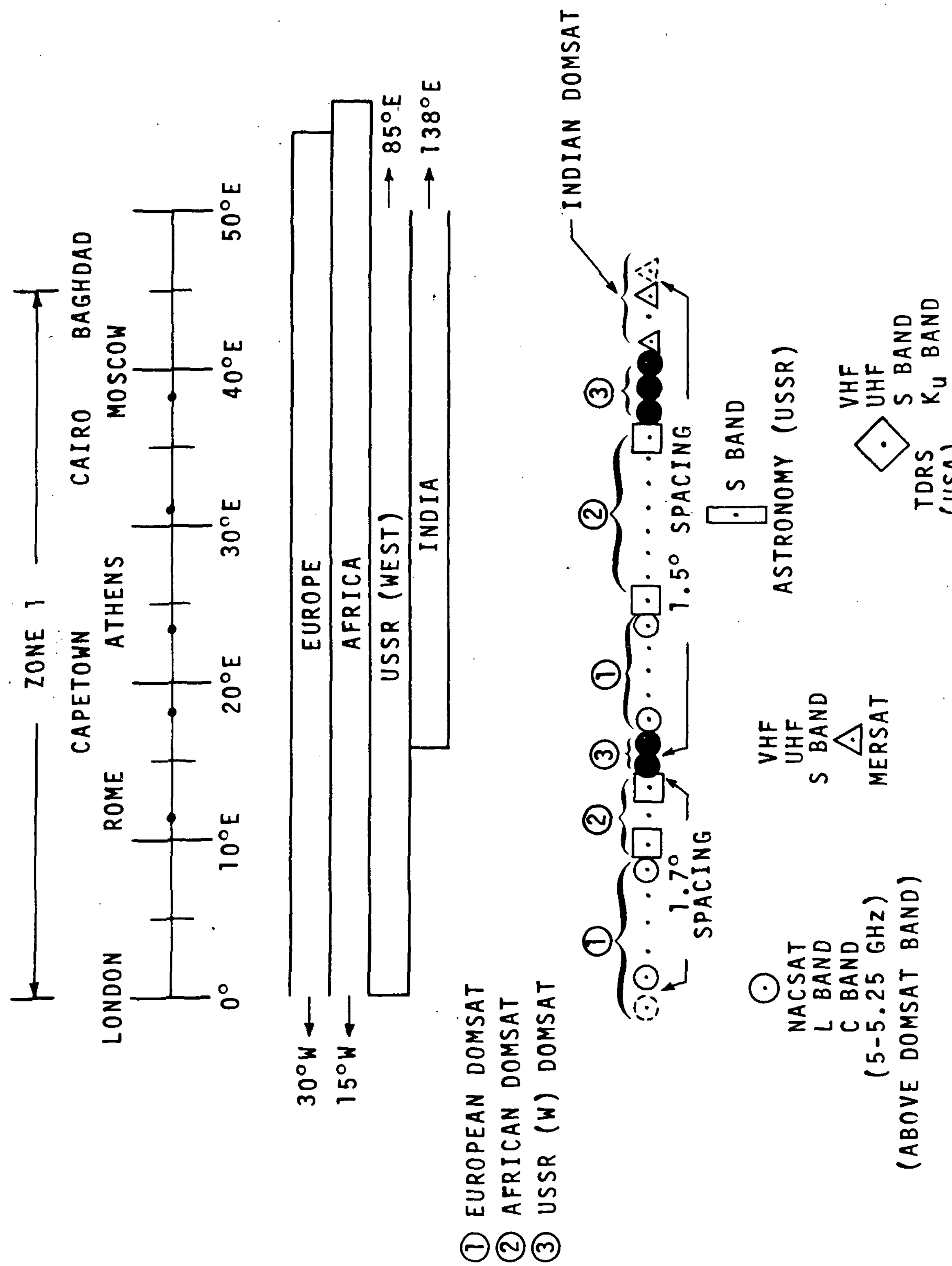

Figure 4.2-2. Zone 1 Satellite Distribution Chart

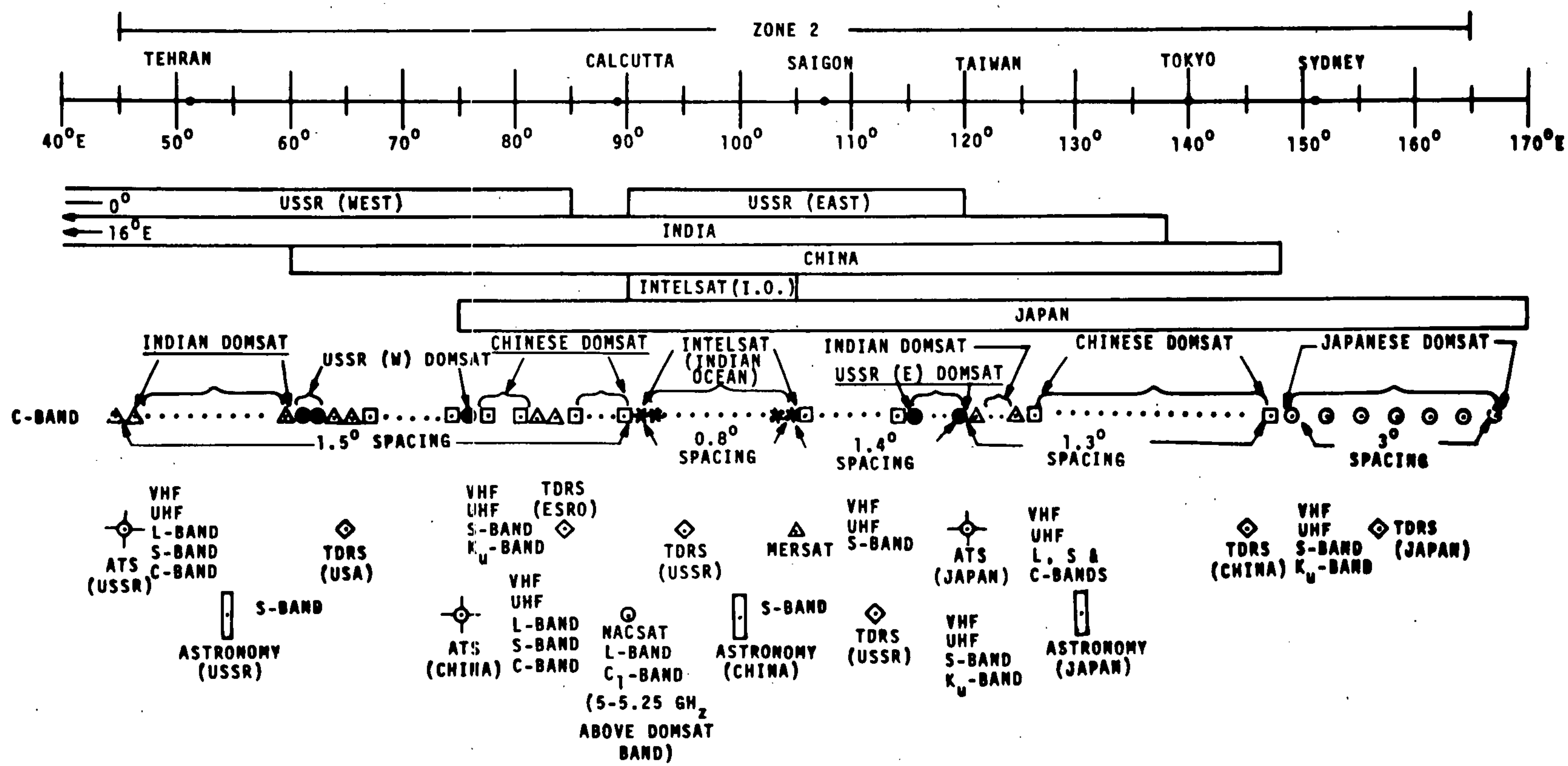

Figure 4.2-3. Zone 2 Satellite Distribution Chart

(Repeats Figure 2.0-3)

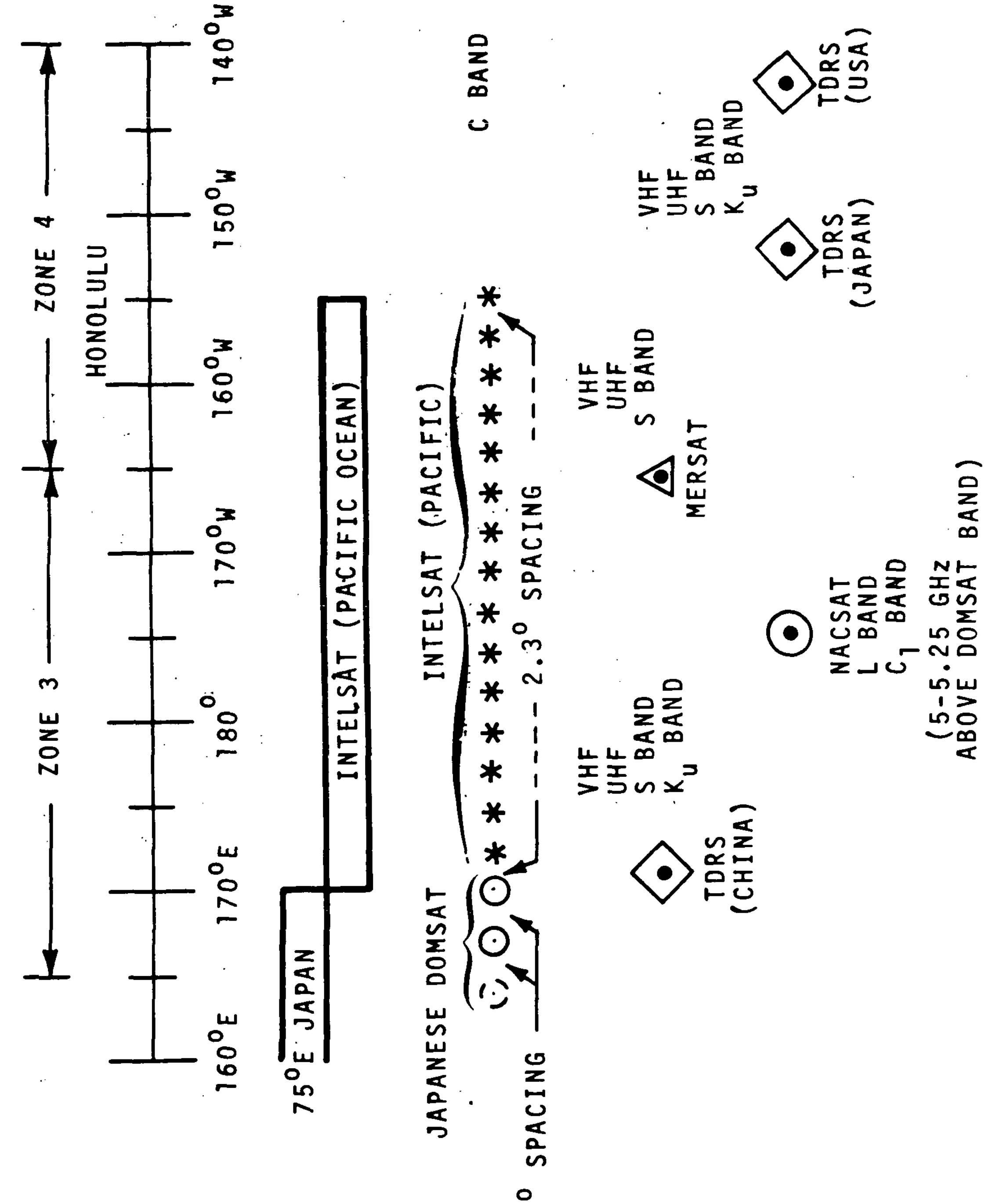

Figure 4.2-4 Zone 3 & 4 Satellite Distribution Chart

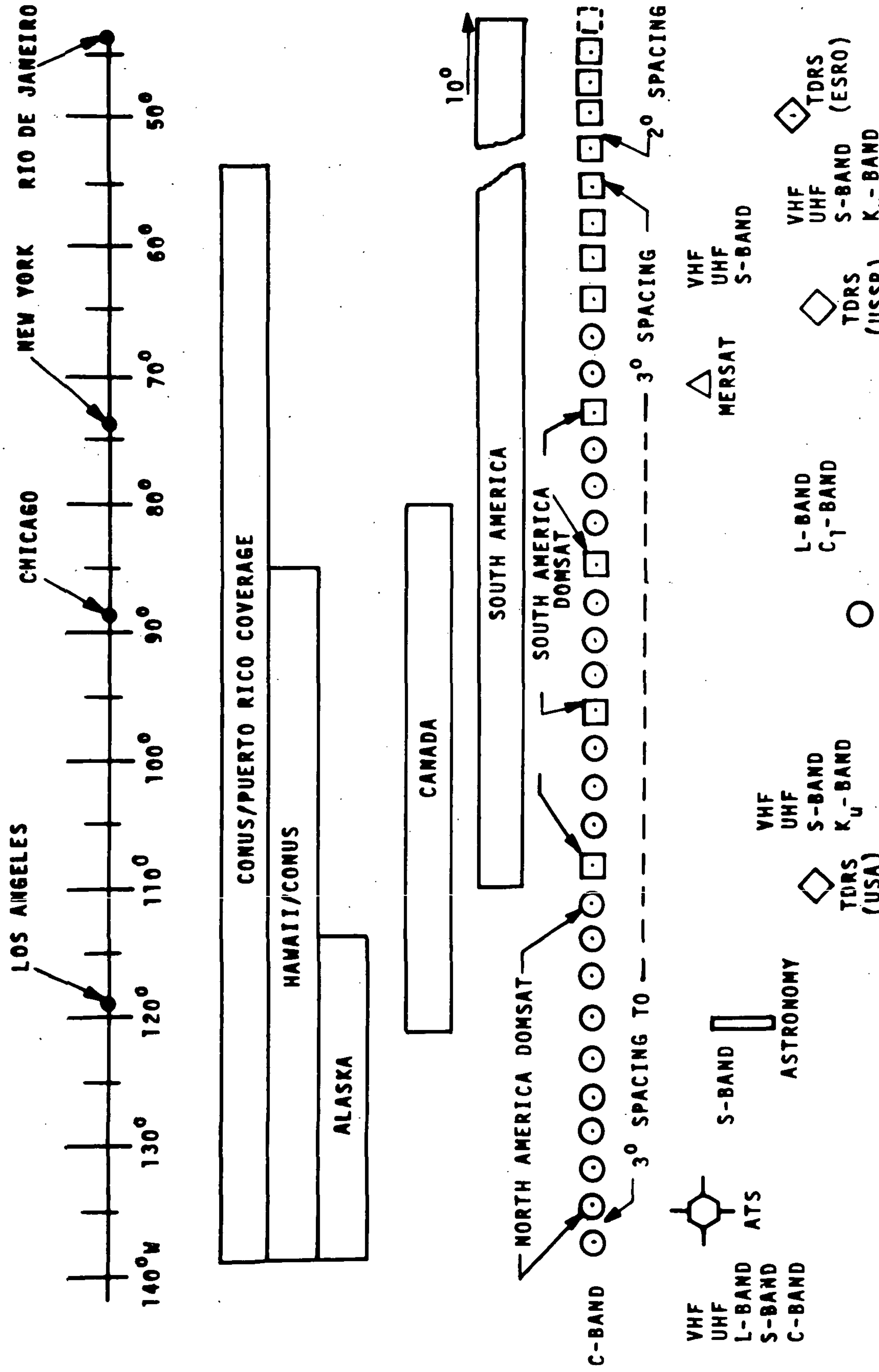

Figure 4.2-5 Zone 5 Satellite Distribution (Zone 5 140°W - 45°W)

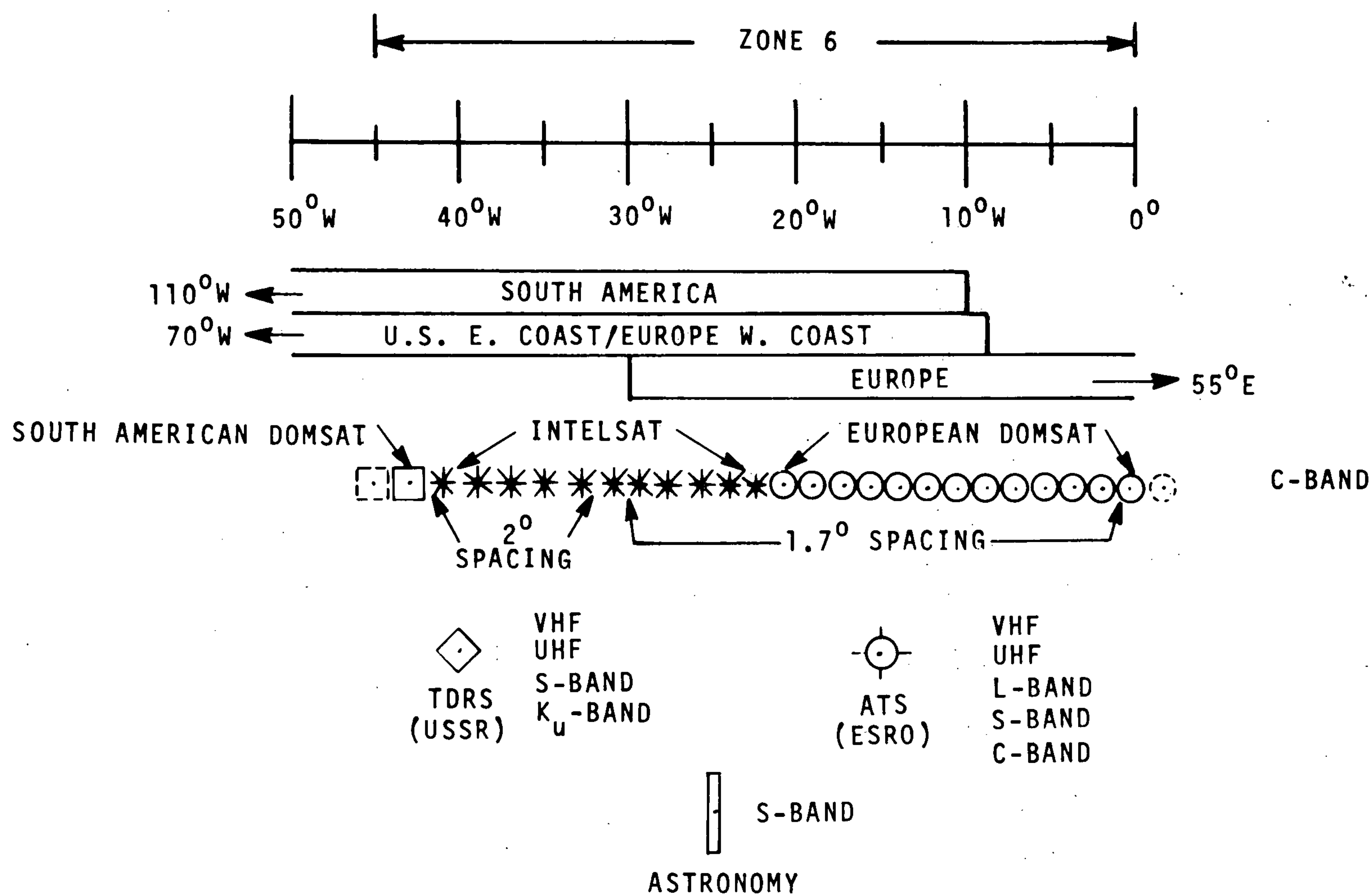

Figure 4.2-6. Zone 6 Satellite Distribution Chart

Table 4.2-2. Zonal Satellite Distribution Spacings

	Zonal Spacings (degrees)					
	1	2	3	4	5	6
C-Band Data Relay Satellites						
Maximum	1.7	3.0	3.0	2.4	3.0	2.0
Minimum	1.5	0.8	2.4	2.4	2.0	1.7
S-Band Satellites						
Minimum	5.0	5.0	9.5	10.0	8.5	10.1
Overall Physical						
Maximum	1.7	3.0	3.0	2.4	3.0	2.0
Minimum	0.75	0.4	1.2	1.2	1.0	0.85

Table 4.2-3. Interference Levels Versus Zonal Spacings (98-foot Ground Antennas)

Spacing (degrees)	Interference Level pWOp	Zones
0.8	>10,000	2
1.5	6,500	1
1.7	5,000	1,6
2.0	3,200	5
2.4	2,000	3,4
3.0	1,015	2,3,5

The EMI analysis therefore results in the conclusion that the projected satellite densities cannot be operated in the 1990 time period with all C-band units. Other techniques must be used to allow operation without interference in this time period.

RECOMMENDED SOLUTIONS

Since it is feasible in the 1980-1990 era to utilize higher frequency bands for data relay systems, an alternate multiband system could provide a solution. One solution would be to alternate satellites using C-band, K_{LO}-band and K_{HI}-band in geostationary orbital positions. Two results occur: (1) spacing between like frequency satellites increases over the minimum spacing for a singular frequency band system, and (2) the K_{HI}-band satellite gives seven times the data relay capacity. The K_{HI}-band satellite replaces seven C-band satellites, thus reducing the density and allowing greater spacing.

An example of alternate frequency band position application was developed. In this case, the minimum spacing zone (Zone 2) with 0.8 degree spacing is used where the three bands are positioned for maximum spacing at the desired bands. C-band satellites need the most spacing since ground antenna discrimination is more difficult at the lower frequency. As pointed out in Section 5.5 of Volume III, sharper beamwidth antennas can be obtained at the higher frequencies. The factor, antenna diameter over wavelength, determines the beamwidth and thus the allowable spacing of satellites.

In Zone 2, the new traffic model shows 18 C-band satellites between 90°E and 105°E. The equivalent total traffic is 432 transponders (18 x 24). This traffic requirement can be supported by two K_{HI}-band (168 transponders each), two C-band (24 transponders each) and two K_{LO}-band (24 transponders each) satellites as shown in Figure 4.2-7.

C-band satellites were used to obtain the broader earth coverage that results at the lower frequency. Broader coverage is needed for some channels to provide broadcast-type service. The resultant alternate solution in Zone 2 provides 15-degree spacing for the C-band satellites and 6-degree spacing for both the K_{LO}- and K_{HI}-band satellites. These spacings (see Figure 4.2-8 of Part 1) provide interference levels well within the CCIR recommended limits.

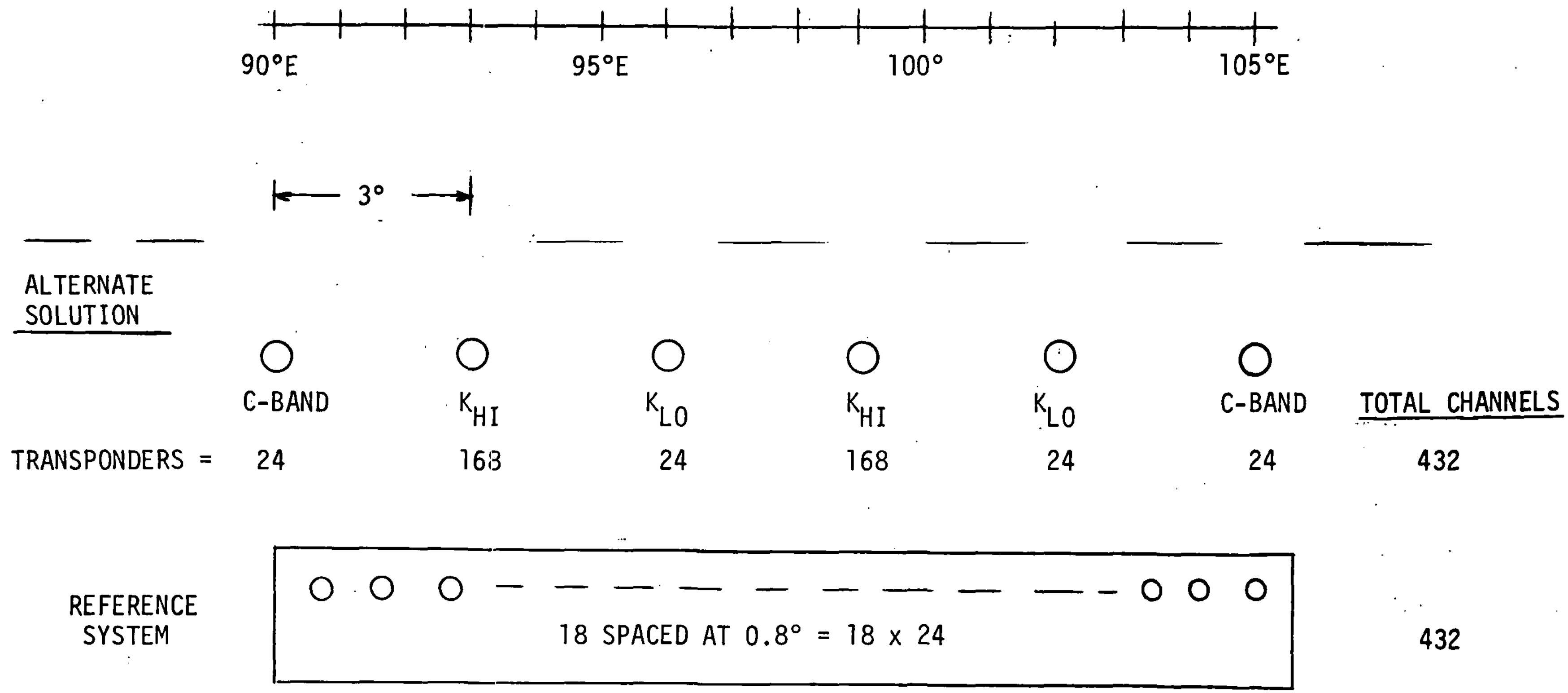

Figure 4.2-7. Recommended Alternate Solution

Another alternative is to place the three frequency band systems on one spacecraft or platform. Such a platform would have a capacity of 216 transponder channels. Two of these platforms could then replace 18 of the reference C-band satellites. Spacing could be adjusted to the maximum consistent with service areas and adjacent zonal services. C-band becomes the limiting frequency band. A minimum of 4.6-degree spacing could be allocated and still remain within the allowable interference levels.

5.0 GEOSYNCHRONOUS REQUIREMENTS ASSESSMENT

Analysis of the new traffic model indicates that other than a large increase in the numbers of satellites, the only fundamental change is in the navigation and traffic control satellite (Nacsat). The new traffic model reflects the potential entrance of many nations of the world into geosynchronous programs. Additional Intelsat (Comsat), Domsat, TDRS, and astro-physics satellites are proposed to reflect this multi-national interest. In the case of the Nacsats, the concept is significantly different from the baseline traffic model. Instead of only data relay service, the Nacsats also provide navigation and surveillance functions.

Section 5.1 reiterates the satellite characteristics, by functional group, that were used in establishing the traffic model. The only significant difference between the characteristics of the inventories of the two traffic models is the power requirements of the Nacsats which is approximately 2 kilowatts. The characteristics associated with the astro-physics satellites reflect the observational platform synthesized for the baseline traffic model.

Grouping criteria such as global coverage, solar noise outage, unique orbital placement, orientation, and mission equipment compatibility that established the minimum complement of platform types for the baseline traffic model are equally applicable to the new traffic model. One additional type of platform is identified. The Nacsat concept requires four constellations of platforms that are centered approximately 90 degrees apart in longitude. Each constellation requires one geostationary element and four elements in inclined geosynchronous orbits. Because of the unique placement requirement, the functions of Nacsat are not groupable with other geosynchronous functions.

Operational and system level requirements for the data relay and Nacsat platforms are different than for their baseline traffic model equivalent. The common support module (utilities platform), TDRS, and observational platform requirements are the same for both traffic models. Coverage requirements are essentially the same for the data relay platform but the expanding demand for data relay service results in the requirement for as many as eight platforms to service one global region. Both the expanded data relay platform requirements and the Nacsat platform requirements are presented in Section 5.3.

The on-orbit servicing design criteria are the same for both traffic models. The criteria were intentionally developed to reflect the idiosyncrasies of the servicing mode rather than the type of platform or configuration. An abbreviated summary of the criteria developed in Part 1 of Volume IV is presented in Section 5.4.

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5.1 SATELLITE INVENTORY ANALYSIS

As a prelude to the definition of platform requirements for the new traffic model, it is helpful to briefly examine the inventory of satellites and their important characteristics. The basic geosynchronous program requirements for the new traffic model were derived from forecasts of user needs. The satellite populations filling these needs were established principally to aid in comparing the scope of traffic represented by the two models, since the equivalent user demand data were not available for the baseline traffic model. Thus, while the satellite populations were somewhat arbitrarily constructed for the new model and their characteristics were patterned closely to those in the baseline traffic model, a further look at these characteristics will contribute to a better understanding of the differences in platform requirements for the new model traffic.

PROGRAMMATIC DESCRIPTIONS

The overall geosynchronous program requirements derived for the new traffic model included consideration of 22 major functions, many of which were structured from related groups of subfunctions. Many of these functions represent differences in the parameters treated and modes of individual user operations, but they can utilize common mission equipment installed in geosynchronous satellites. This is particularly true for communications relay services involving various types of information transfer; i.e., voice, video, digital, etc. The total population of satellites in the new traffic model was grouped into seven basic types or categories, generally reflecting common mission equipment. Also, the nature of the mission equipment,(whether it serves a mature operational function or is principally tailored for developmental functions) was considered in defining the seven categories. A brief description highlighting the important features of each satellite type is presented below. Corresponding satellite types in the baseline traffic model are identified where appropriate.

Intelsat

The Intelsat satellites provide international commercial communication services. These include:

- Telconference
- Commercial broadcast (TV)
- Business/credit transactions
- Newspaper transmission
- Postal services
- Medical data bank
- Education programming

Growing user demands through the 1990 time period are reflected in a rising satellite population (44 active satellites in 1990). Each satellite consists of a 24-transponder, C-band unit, having a total data relay rate capability of 864 mega-bits per second. The Intelsat satellites correspond to the "Comsats" identified in the baseline traffic model with one exception. The Comsats were considered to be only 12-channel transponder satellites.

Domsat

The Domsat system provides domestic commercial communications services dealing with internal traffic within individual nations or economic/cultural blocks of nations. National needs reflect an expansion of the international traffic elements to encompass functions pertinent to local activities. These include:

Teleconferencing
Commercial broadcast (TV)
Business/credit transactions
Newspaper transmission
Postal services
Medical data bank
Education programming
Civil defense
Welfare data bank
Library data bank
Telecomputations
Private record banks

Rapidly growing user demands through the 1990 time period result in the Domsat population being the largest group of any satellite type. A total of 146 active Domsats are projected for 1990. Each satellite consists of a 24-transponder, C-band unit, having a total data relay rate capability of 864 mega-bits per second. The Domsats correspond to the "U.S. domestic" and "foreign Domsats" identified in the baseline traffic model. Note that in the baseline traffic model foreign Domsats were considered to be only 12-channel transponder satellites.

Mersat

The Mersat system provides global meteorology and earth resources services. They are operational in nature and include the following functions:

Meteorology
Mineral and land resources
Agriculture, forestry, and range resources
Water and marine resources
Soil differentiation
Topographic information
Materials location

A system of four active satellites provides global coverage. Increasing data capacities are projected through the 1990 time period as the demand for specific data grows and new, more productive sensors are developed. Data rates up to 50 mega-bits per second were defined. The Mersats correspond to the "operational earth observation" satellites in the baseline traffic model.

Nacsat

The Nacsat system provides world-wide navigation and traffic control services to ships and aircraft traversing the oceans and desolate land mass regions. They are operational in nature and handle both navigation signals and enroute planning and control information. Local traffic control around harbors and airports is not included. Because of the large number of individual users (each ship and/or aircraft), simple, relatively low-cost equipment was postulated for the terrestrial elements of the system. To achieve the desired accuracy with low-cost equipment, simultaneous access to navigation signals from more than one satellite is required. This, combined with the need for coverage of the polar air routes, resulted in a Nacsat system comprised of four constella-ions of five satellites each. Four of the satellites in each constellation are in inclined elliptical orbits with the fifth located in a geostationary orbit such that it is the center of symmetry in the ground trace pattern of the remaining satellites in its constellation. Data rate capability for each satellite is projected to be one mega-bit per second. The Nacsats correspond to the "navigation and traffic control" satellites identified in the baseline traffic model.

Advanced Technology Satellite (ATS)

The advanced technology satellites provide a basic test bed for the development of space-related technologies. These include furthering design techniques and gaining experience in new modes of operation. Potential specific functions are communications development for direct broadcast operations, the design of equipment for higher frequency bands such as SHF, EHF, and laser applications, and developmental testing of satellite support systems, spacecraft retrieval concepts, and on-orbit module replacement. A total of five active advanced technology satellites is projected for the 1990 time period servicing both U.S. and foreign space program needs. Data rates up to 50 mega-bits per second for each satellite are projected. The ATS's in the new traffic model correspond to the entire family of development/test satellites identified in the baseline traffic model (advanced technology, system test, developmental earth operations, and small ATS).

Astro-Physics

The astro-physics satellites provide a basic on-going capability for conducting astronomy and space physics programs which can advantageously be implemented at geosynchronous altitudes and which supplement related terrestial and low-orbit operations. Although they are research-oriented, they are considered to be operational because their objectives are centered in data gathering rather than sensor development. Specific functions include:

Solar astronomy
Stellar/X-ray
Plasma physics
High energy physics
Radio astronomy

A total system of six active astro-physics satellites was projected to satisfy both U.S. and foreign space program needs in the 1990 time period. Data rates up to 40 mega-bits per second for each satellite are projected. These satellites correspond directly to the astro-physics satellites identified in the baseline traffic model.

Tracking and Data Relay Satellite (TDRS)

The tracking and data relay satellites provide the communications link between the ground and orbiting spacecraft for tracking signals and the relay of real-time or recorded data. This is similar to the U.S. TDRS function identified in the baseline traffic model, but has been expanded to include foreign space program needs. Growth to an active population of 14 satellites is predicted.

SPACECRAFT CHARACTERISTICS

The principal characteristics of the satellites in the new traffic model are essentially the same as those of the baseline traffic model. Certain types of satellites (ATS, TDRS, astro-physics) were considered as only U.S. sponsored in the baseline traffic model. The new traffic model expands the sponsorship to include foreign space elements also.

The one change of significance between the satellites of the two traffic models are the updated navigation and control satellites. The baseline model included only traffic control data relay functions on this satellite. The new traffic model satellite includes navigation data, surveillance, and data relay. Also, five satellites are required for each global region.

Table 5.1-1 summarizes the characteristics of the satellites of the new traffic model. The characteristics associated with Mersat and astro-physics satellites are a compilation of the most stringent characteristics of the same types of satellites in the baseline traffic model.

Table 5.1-1. New Traffic Model Satellite Characteristics

Satellite Type	No. S/C	Gross Weight (lb)	Size L x Dia (ft)	Power (watts)	Data (bps)	Pointing Accuracy (±)	Stability (0/sec)	Propellant (lb)	Orientation
Intelsat	64	1100	10 x 10	500	24 CH	0.2 deg	0.1 deg	35	Local vertical
Domsat	180	1100	10 x 10	500	24 CH	0.2 deg	0.1 deg	35	Local vertical
Mersat	22	4500	22 x 15	1800	5×10^7	2 $\widehat{\text{sec}}$	2 $\widehat{\text{sec}}$	70	Local vertical scan
Nacsat	61	1300	10 x 12	2 K	25×10^4	0.5 deg	0.1 deg	50	Local vertical
ATS	34	1700	12 x 10	2K→10K	5×10^7	0.05 deg	0.05 deg	65	Any
Astro-Physics	17	2400	18 x 10	570	5×10^7	0.1 $\widehat{\text{sec}}$	0.05 $\widehat{\text{sec}}$	65	Inertial
TDRS	35	900	12 x 8	275	20 LDR, 4 HDR	0.1 deg	0.05 deg	35	Local vertical

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5.2 MISSION OBJECTIVES GROUPING

The primary factors that influenced the mission objectives grouping of the baseline traffic model satellites are equally applicable to the satellites of the new traffic model. These factors are summarized in Table 5.2-1.

Table 5.2-1. Functional Grouping Considerations

Consideration	Impact
Global Coverage	Minimum of 4 regions
Solar Noise Outage	Minimum of 2 data relay platforms per region
Unique Placement	Non groupable-independent platform configuration of satellite
Orientation Requirement	Separation of fixed and scanning local vertical mission equipment; separation of inertial pointing mission equipment.
Sensors and System Concept Development	Independent satellites; not recommended for grouping with in-service commercial equipment.

The detailed rationale associated with each consideration is presented in Section 5.2, Part 1 of Volume IV. The resultant theoretical minimum number of platforms into which the new traffic model can be functionally grouped is summarized in Table 5.2-2. Technology and mechanization limits will expand the actual number of data relay platforms required to 23 (see Section 5.3).

The non-groupability of the Nacsat satellites stems from the unique placement requirements of the satellites. There are four constellations of five satellites each. The constellations correspond to the four global regions for world-wide coverage. One satellite out of each group is positioned in a precise geostationary orbit; the other four satellites in the group are positioned in an inclined geosynchronous orbit with predetermined separations. Figure 5.2-1 illustrates the relative location of

Table 5.2-2. Theoretical Minimum Functional Grouping Inventory

Platform Type	Satellite Equivalent	Inventory
Data Relay	Intelstat; Domsat	8
MERSAT	MERSAT	4
NACSAT	NACSAT	20
Astro-Physics	Astro-Physics	12
TDRS	TDRS	14
Total		58

the Nacsat constellations. With this arrangement, navigation, surveillance and data relay functions can be provided on a world-wide basis, including the polar air routes.

The ATS or developmental satellites are not grouped with any of the platforms for the same reason as in the case of the baseline traffic model. Identification of developmental equipment for the 1980 time frame is impractical, and even if it could be defined it is not considered advisable to combine essentially experimental equipment/operations with commercial operations that society has become dependent upon.

Theoretically, only one astro-physics platform is required for each national space program (U.S. and two major foreign powers). However, the traffic analysis and platform synthesis for the baseline traffic model indicated four independent sets of astro-physics payloads would be required to satisfy the complete program of geosynchronous astro-physics operations. The requirements for these payloads could be met either with a total inventory of 12 astro-physics platforms or by periodic changeout of mission equipment with on-orbit servicing operations (on each of three platforms).

The TDRS platform inventory also reflects the required complement of both U.S. and foreign platforms. The reduction in space element inventories between the satellites and platforms is a result of consideration of the on-orbit servicing of the platform concept.

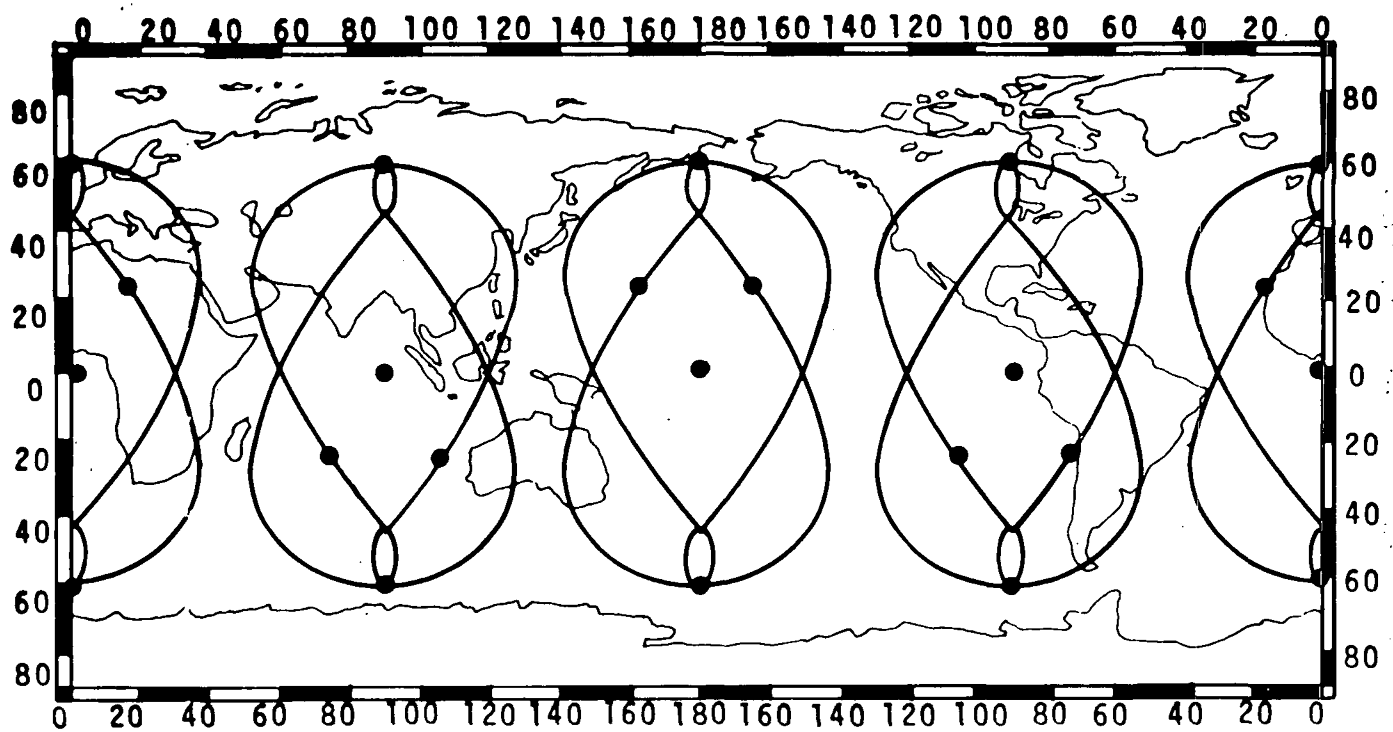

Figure 5.2-1. Nacsat Constellations

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5.3 GEOSYNCHRONOUS PLATFORM REQUIREMENTS

The common support module or utilities platform approach and the multi-function platforms were evaluated for the new traffic model just the same as for the baseline traffic model. The common support module, TDRS platform, and observational platform requirements for the new traffic model are identical to those for the baseline traffic model. The proliferation of Intelsat (Comsat) and Domsat data relay functions in the new traffic model significantly changes the requirements for this type of platform. The expanded capability of the navigation and traffic control platforms also results in some unique operational and system level requirements.

COMMON SUPPORT MODULE

The only satellite in the new traffic model that has a significantly different support requirement than its counterpart in the baseline traffic model is the navigation and traffic control satellite (Nacsat). The Nacsat requires approximately 2 kw of power. This requirement does not perturb the common support module concept derived for the baseline traffic model; it was anticipated that some satellites and platforms would require up to 2 kw power eventually. A "plateau" design requirement was specified for the electrical power system. The requirement was to synthesize 500 w, 1 kw, 1.5 kw, and 2 kw electrical power subsystems.

The other support functions to be included in the common support module are: (1) pointing, (2) stabilization, (3) data processing, and (4) impulse/propulsion. Table 5.3-1 lists the selection of the most stringent functional requirements from the inventory of satellites.

Table 5.3-1. Common Support Module Functional Requirements

Function	Requirement
Electrical power	2 kw
Pointing (1)	10 arc seconds
Stability (1)	1 arc second/second
Data handling	50 megabits/second
Propulsion	70 pounds hydrazine

(1) The pointing and stability requirements reflect the capability of centralized hardware. Accuracies more stringent than specified must be accomplished by inclusion of the sensor directly in the control loop.

DATA RELAY PLATFORMS

As expressed in the EMI contention analysis, one concept to support the new traffic model utilizes the full capability of three assigned frequency bands for data relay functions on a single space platform. Full

capability at each band is postulated by using 36 MHz transponder channels spaced 40 MHz apart, and providing channel overlap transmission by using orthogonal polarization. By use of orthogonal polarization transmission, the frequency band occupancy is doubled.

A platform utilizing this concept would have the following total traffic capability expressed in numbers of transponder channels.

· C-Band	24 channels
· K_{LO}-Band	24 channels
· K_{HI}-Band	168 channels
· Total Platform	216 channels

Other frequency reuse techniques on the platform could be used if necessary. One technique is to use time division multiple access (TDMA) combined with multiple beams and beam switching. This concept provides flexibility to account for peak needs in specific areas. It is particularly advantageous when the higher frequency (K_{LO} and K_{HI}) bands are used with narrow beams ($\sim$2 degrees).

Continental United States is a prime example where four 2-degree spot beams can be used, each to illuminate an area that roughly corresponds to the four U.S. time zones. By use of beam switching, the variable traffic density distribution with time of day and night can be accommodated.

The major frequency reuse technique utilizes orbitally spaced platforms. Spacing is sufficient to allow ground station antenna discrimination. This spacing can be a minimum of 4.6 degrees for 60-foot antennas and 3 degrees for 97-foot antennas. These data are expressed for C-band, 24-transponder systems, the limiting frequency band on a multiband platform system.

All of these frequency reuse techniques are necessary platform system requirements to meet the new model traffic needs.

Multiple K_{HI} platforms each with 168 available transponder channels could meet the traffic requirements of most world regions. C-band systems are, however, considered necessary to provide wide geographical coverage with feasible on-board RF power levels. Wide area coverage is necessary for point-to-area broadcast-type service. At C-band, all of the U.S. can be covered with a shaped beam antenna with a four-watt RF power output transmitter. A TV program, for instance, originating in New York, can be broadcast on a single C-band transponder channel and picked up by any or all ground stations in the continental United States. If a higher frequency (K_{LO} or K_{HI}) were used, where the 2-degree spot beams are maximum, it would be necessary to use four channels for each spot beam. C-band serves a useful purpose in efficiency of spectrum use for this type of broadcast transmission.

K_{LO}- band systems are used in the same manner as K_{HI}-band systems; i.e., with 2-degree spot beams. K_{LO}-band adds 24 channels to a data relay platform. The Domsat-type function requires maximum data relay capacity. Intelsat data relay platforms can be postulated with 192 channels each and still support the traffic needs with a reasonable number of units. Thus, Intelsat platforms could operate with K_{HI}- and C-band only (168 and 24 channels, respectively).

Multiple platforms are advantageous for several reasons. One is to provide continuous, but reduced capacity, operation during solar outages. This was explained in detail in the baseline traffic model section. Another is the inherent redundancy provided by the use of more than one platform. Traffic can easily be directed to other platforms during down times associated with regular maintenance or with fault correction. It is also advantageous to support growth and the gradual traffic increase by using the capability to place platforms in orbit as they are needed.

The 1990 zonal distribution of all geosynchronous satellites was given for the new traffic model in Section 4.2. A set of five charts (Figures 4.2-2 through 4.2-6) defined the satellite distribution for the six zones. Examination of these zonal charts for the Domsat and Intelsat satellites resulted in a table of distribution by zone and by service area. Table 5.3-2 identifies the numbers of satellites for each service area support by zone and identifies the orbital position location limits for each service area. These data are used to develop the regional platform requirements. Domsat traffic was determined by analysis of service area traffic on the basis of numbers of equivalent C-band transponder channels (assuming 24 channels per C-band satellite). The four regions that were established for global coverage for the baseline traffic model are also applicable for the new traffic model. The area coverage and longitude positions of the regions are listed in Table 5.3-3.

Table 5.3-3. Regional Characteristics

Region	Longitude	Domsat	Intelsat
I	172°E	Eastern Asia/Australia	Trans-Pacific
II	68°E	India/China	Indian Ocean
III	6°W	Europe/Africa	Trans-Pacific
IV	110°W	North/South America	North/South America

The first step in the analysis was to assign the service areas to the regions compatible with regional platform coverage. Because of regional overlaps, certain service areas could be covered from either of two regions. In those cases, assignments were based on a combination of the most compatible coverage (highest ground antenna elevation angle or mask angle) and an attempt to equalize regional traffic. It was also important to ensure that any single country could be covered from one regional orbital location. This ground rule was used to preclude the requirement on ground stations for separate wide antenna pointing angles for its Domsat service access. Table 5.3-4 shows the results of this analysis. Each region is displayed with a tabulation of (1) regional service areas, (2) their associated traffic in terms of transponder channels, (3) the orbital limits for service area coverage, (4) regional total traffic, (5) regional number of platforms, and (6) resultant total regional platform capability.

Table 5.3-2. Geosynchronous Data Relay Satellites Distribution (New Traffic Model - 1990)

NO.	SATELLITE SERVICE AREA	ZONE 1 0-45E (DEGREES)	ZONE 2 45E-165E (DEGREES)	ZONE 3 165E-165W (DEGREES)	ZONE 5 165W-140W (DEGREES)	ZONE 5 140W-45W (DEGREES)	ZONE 6 45W-0 (DEGREES)	ALLOWABLE RANGE (DEGREES)
	DOMSAT							
23	EUROPE	10	X	X	X	X	13	30W TO 55E
11	AFRICA	11	X	X	X	X	X	15W TO 57E
13	SOUTH AMERICA	X	X	X	X	12	1	110W TO 10W
21	NORTH AMERICA	X	X	X	X	21	X	138W TO 53W
8	USSR (WEST)	5	3	X	X	X	X	0 TO 85E
21	INDIA	3	18	X	X	X	X	16E TO 138E
37	CHINA	X	37	X	X	X	X	60E TO 148E
8	JAPAN	X	6	2	X	X	X	75E TO 170E
4	USSR (EAST)	X	4	X	X	X	X	90E TO 120E
146	TOTAL	29	68	2	0	33	14	
	INTELSAT							
11	ATLANTIC OCEAN	X	X	X	X	X	11	45W TO 0
18	INDIAN OCEAN	X	18	X	X	X	X	90E TO 105E
15	PACIFIC OCEAN	X	X	10	5	X	X	170E TO 205E
44	TOTAL	0	18	10	5	0	11	

Table 5.3-4. Regional Data Relay Platform Requirements (New Traffic Model - Domsats - 1990)

Platform Center (degrees)	Service Area	Orbital Limits (degrees)	(A) Number of C-Band Satellites	(B) Number of Channels (A) x 24	Required Number of Platforms (B) ÷ 216	Total Region Platform Capability
REGION I 172E	Japan	75 to 170E	7			
	Australia		1			
	USSR (East)	90 to 120E	4			
	Indochina		2			
	East Indies					
			18	432	2	432
REGION II 68E	India	16 to 138E	17			
	China	60 to 148E	35			
			52	1248	6	1296
REGION III 6W	Europe	30W to 55E	23			
	USSR (West)	0 to 85E	8			
	Africa	15W to 57E	11			
			42	1008	5	1080
REGION IV 110W	USA (Canada)	138W to 53W	21			
	South America	110 to 10W	13			
			34	816	4	864

The regional number of platforms (5) is calculated by dividing the regional total traffic in terms of transponders (4) by 216 (the capability in transponder channels of a three-band platform). This results in the following number of Domsat platforms in the four global regions for 1990:

	Region			
	I	II	III	IV
Number of platforms	2	6	5	4

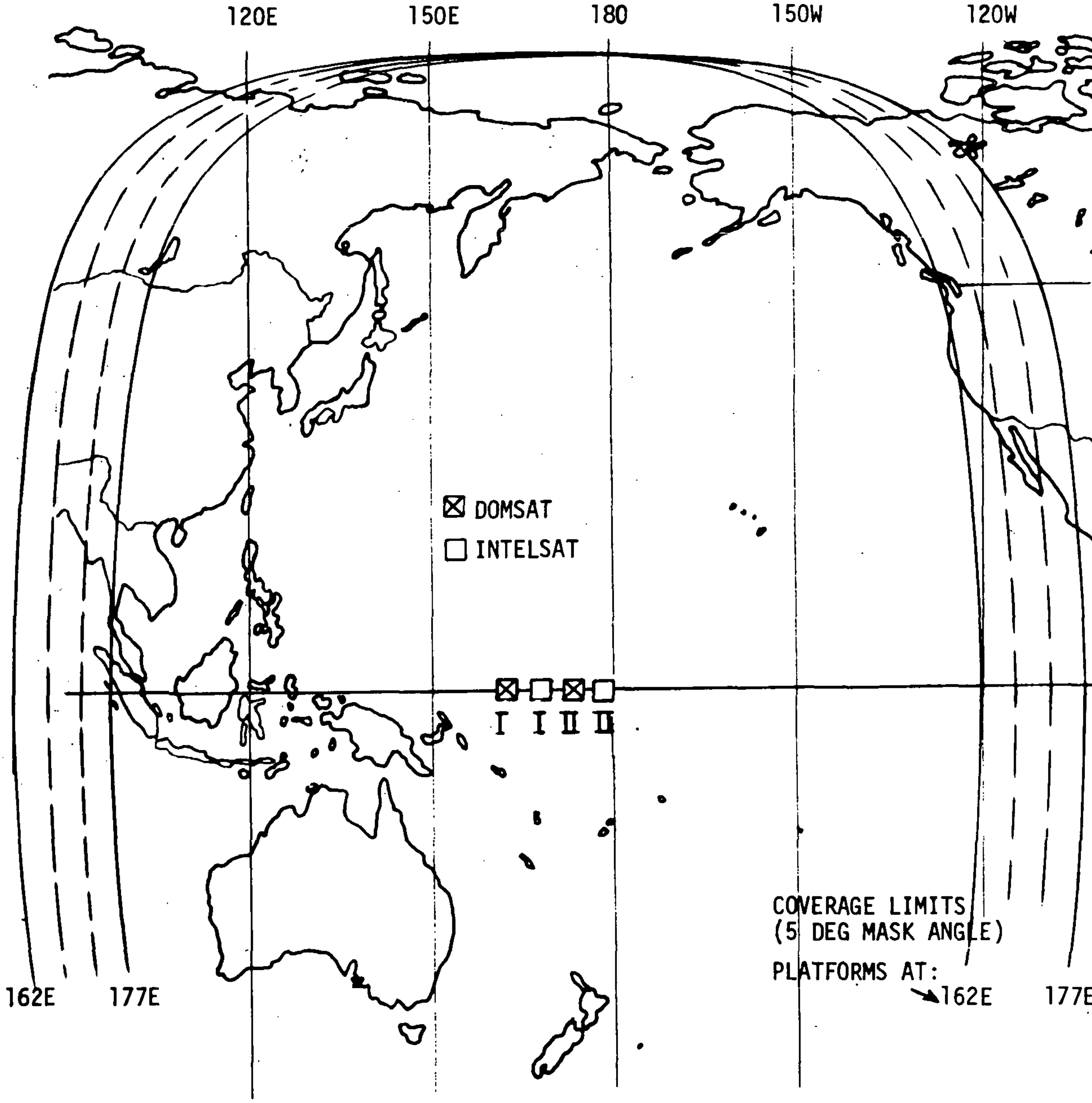
Orbital position placement of these platforms is predicated on a spacing of 5 degrees with a mixture of Domsat and Intelsat platforms. Compatibility with service area coverage is strictly observed. Five-degree spacing was chosen to ensure interference levels within allowable limits. Except for Region I, there are sufficient platforms to preclude solar outages of more than two links simultaneously. Platforms spaced 10 degrees will provide protection from this event. Actual Domsat locations were not chosen until after the Intelsat analysis was completed and the number of its platforms defined.

A similar analysis was made of the Intelsat platform requirements. The Intelsat problem is considerably simpler. Only three regions require Intelsat coverage, i.e., Regions I, II, and III. Intelsat requirements for Region IV for North/South America can be serviced from either Region IV Domsats (excess capacity exists) or partially from Region III Intelsats. Examination of the Intelsat traffic discloses the following regional traffic distribution (1990):

Region	Area	C-Band 24-Channel Reference	Number of Channels	Equivalent Platforms	Capability
I	Pacific Ocean	15	360	2	384
II	Indian Ocean	18	432	2	384
III	Atlantic Ocean	11	264	2	300

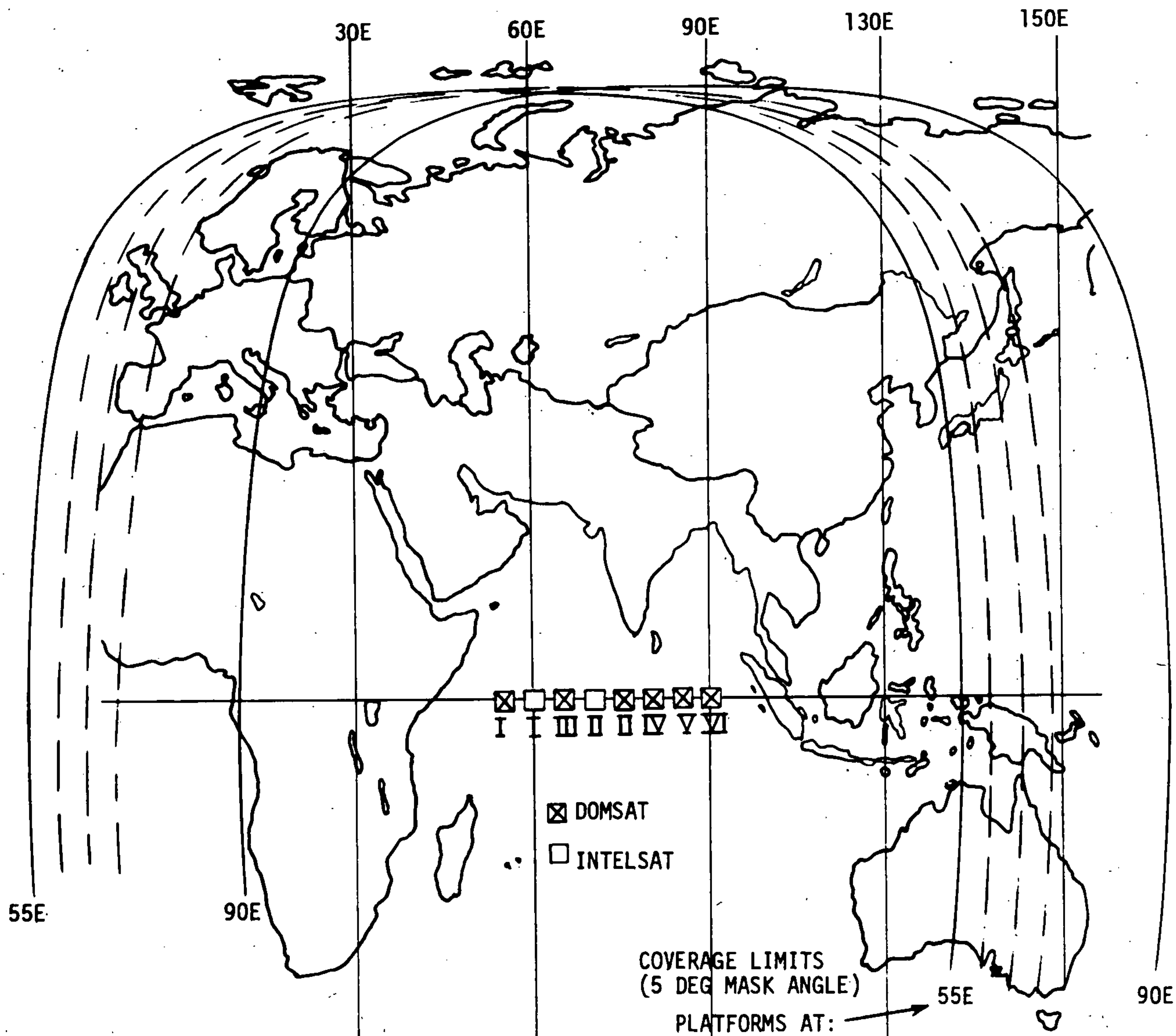
The capacities of Intelsat platforms are based on the use of C- and K_{HI}-band systems only. These two bands provide the capability for 192 transponder channels. C-band is used to provide area coverage so that low traffic density locations may be included. K_{HI} is used to provide spot beam illumination to high traffic density locations. K_{LO}-band was not proposed for use because of its low additional capacity (24 channels) and the problem of providing wide area coverage. In the case of Region II, additional capacity can be obtained from frequency reuse on K_{HI}-band widely separated beams. Region III requires one full Intelsat platform (24 C-band, 168 K_{HI}-band) and one Intelsat with 24 C-band channels and 84 (no dual polarization) K_{HI}-band channels.

Platform position locations were developed by combining regional Domsat and Intelsat platforms adjacent to each regional position identified and interspersed to ensure optimum area coverage. Figures 5.3-1 through 5.3-4 define orbital positions of these platforms and their service areas.



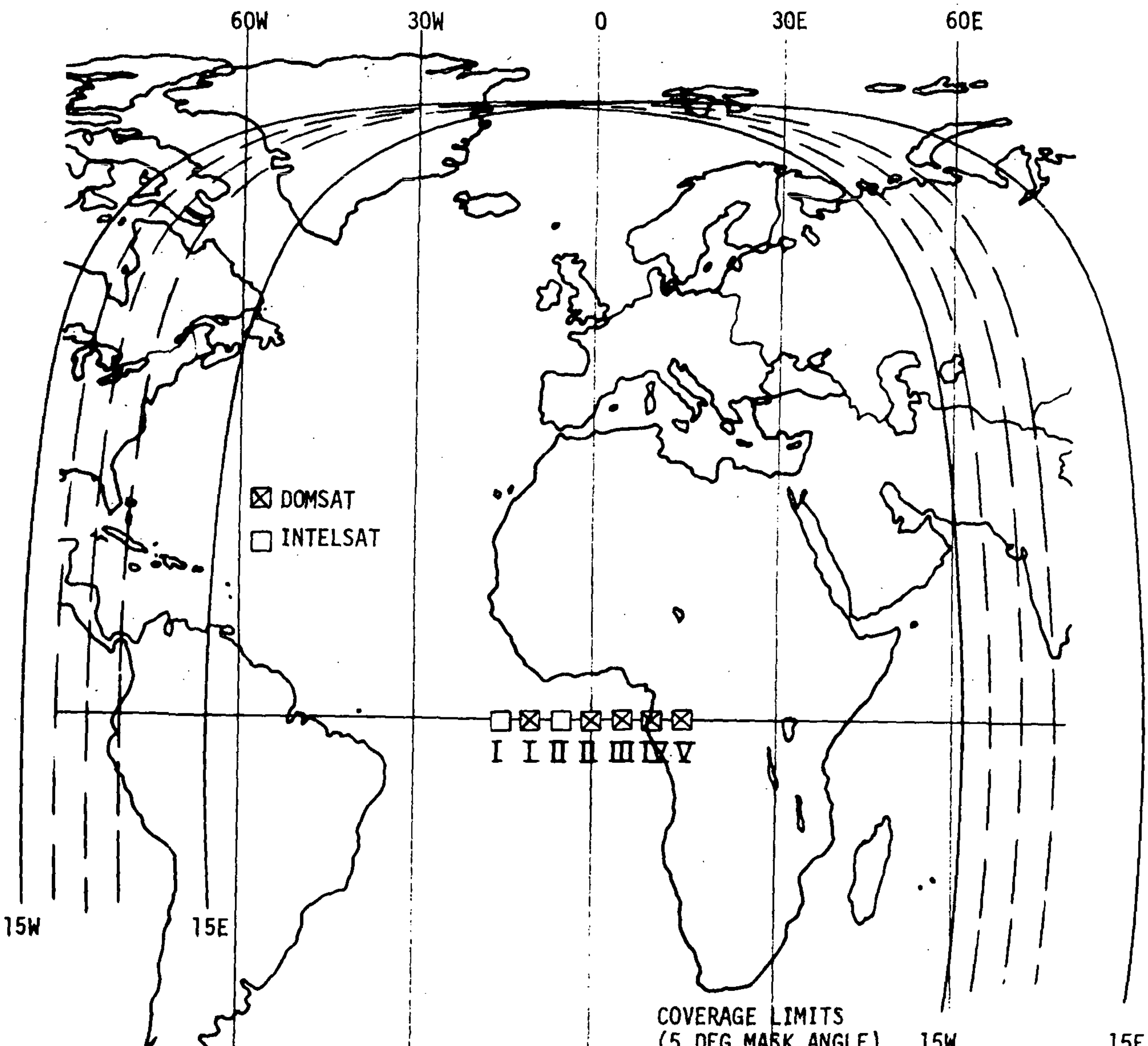
Platform	Location (degrees)	Service Area	Platform Capability, Channels	Region Capability, Channels
Domsat I	162E	Japan, USSR (East) Australia, New Zealand	216	432
Domsat II	172E	Indochina, East Indies Phillipines	216	
Intelsat I	167E	Japan/China/USSR (East) East Indies/Australia/ New Zealand	192	384
Intelsat II	177E	and U.S./Canada/Mexico	192	

Figure 5.3-1. Region I - Data Relay Platform Locations



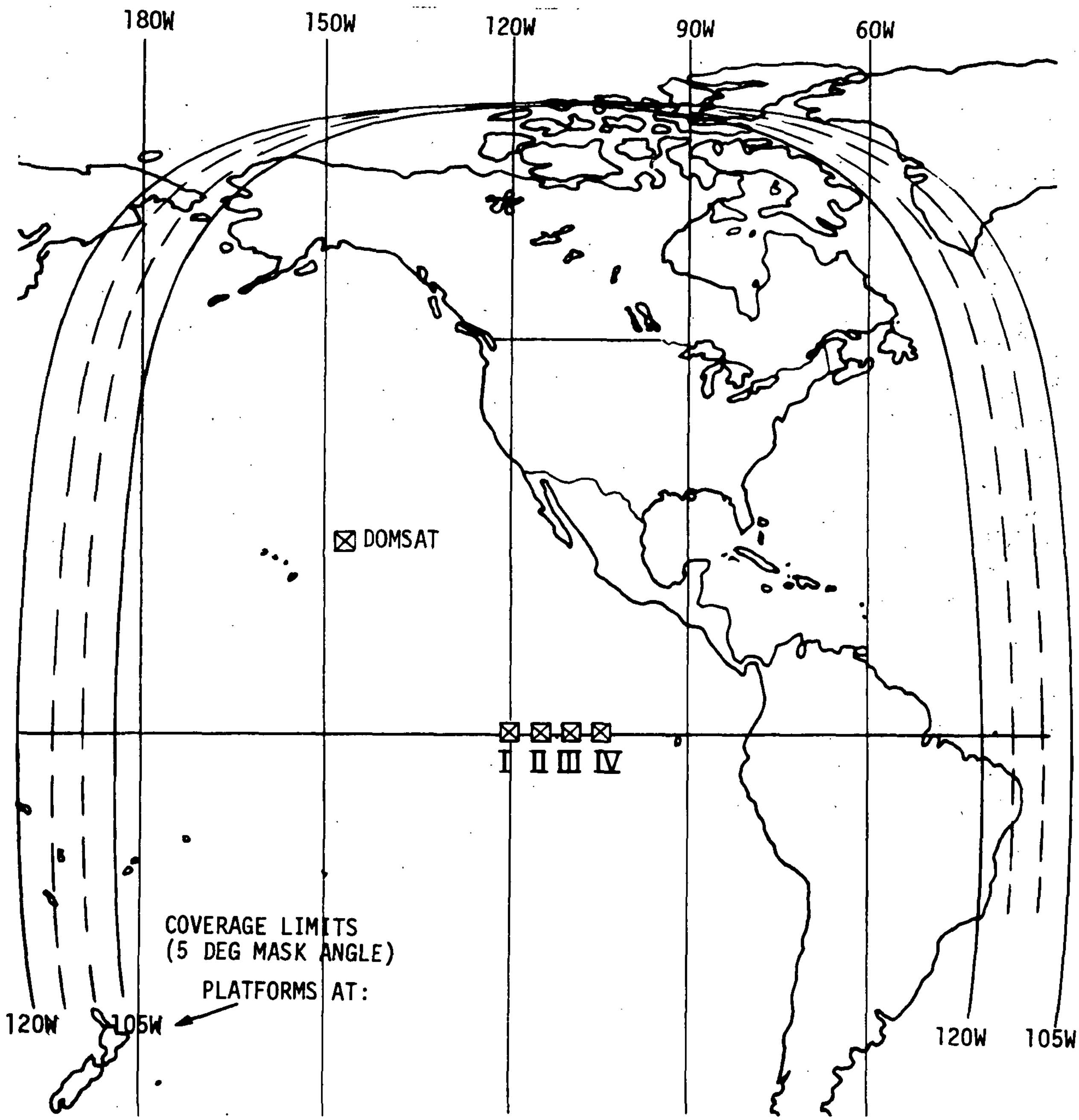
Platform	Location (degrees)	Service Area	Platform Capability, Channels	Region Capability, Channels
Domsat I Domsat II	55E 75E	India	216 216	
Domsat III Domsat IV Domsat V Domsat VI	65E 80E 85E 90E	China	216 216 216 216	1296
Intelsat I Intelsat II	60E 70E	China/India/Arabia Africa/Europe/ Indochina/Australia/ East Indies	192 192	384

Figure 5.3-2. Region II - Data Relay Platform Locations



Platform	Location (degrees)	Service Area	Platform Capability, Channels	Region Capability, Channels
Domsat I	10W	Europe	216	
Domsat II	0	Europe, Africa	216	
Domsat III	5E	Europe Africa USSR (West)	216	1080
Domsat IV	10E		216	
Domsat V	15E		216	
Intelsat I	15W	Canada/Europe/ Africa/U.S.A. South America	108*	300
Intelsat II	5W		192	
*K_{III}-band 84-channel single polarization only				

Figure 5.3-3. Region III - Data Relay Platform Locations



Platform	Location (degrees)	Service Area	Platform Capability, Channels	Region Capability, Channels
Domsat I	120W	U.S.A.	216	864
Domsat II	115W	Canada	216	
Domsat III	110W	Mexico	216	
Domsat IV	105W	South America	216	

Figure 5.3-4. Region IV - Data Relay Platform Locations

In all cases, care was taken to locate Intelsat and Domsat platforms so that any Intelsat coverage and, where possible, single country coverages by Domsat were protected from solar outages. This was accomplished by alternate positioning so that a minimum of 10-degree spacing between these platforms results. As previously mentioned, 10-degree spacing will preclude simultaneous solar outages. Region II is an ideal example. For example, figure 5.3-2 shows the 10-degree Intelsat platform spacing, the 20-degree India Domsat platform spacing, nominal 5-degree spacing for three China Domsat platforms, and 15-degree spacing for a fourth China Domsat platform. All of this was accomplished while still maintaining ground locations for the required functions within the 5-degree mask angle. Volume V, Section 4.4, defines the development of the platform hardware and the concepts for coverage of the desired service areas.

TRACKING AND DATA RELAY PLATFORMS

The baseline traffic model proposed a single tracking and data relay satellite (TDRS) system for the U.S. only. The new traffic model expands the use of geosynchronous satellites for the relaying of data from low earth orbit satellites both for the U.S. space program and foreign space programs. The only difference between the two traffic models is the number of satellites; neither the type nor functions are different. Therefore, the system requirements are the same as those of the baseline traffic model TDRS.

Operationally the foreign TDRS concept will obviously be different. Longitudinal positions will be dependent upon the single national ground station selected. The longitudinal separation and zones of exclusion will be numerically the same but obviously geographically different. None of these differences will affect the platform synthesis.

The system level requirements for the TDRS platform are the same as for the satellites of both the baseline and the new traffic models. They are as follows:

Low data rate relay -	10 kbps simultaneously from 20 low earth orbit space elements
Medium/high data rate relay -	50 Mbps simultaneously to/from 2 low earth orbit space elements
Low data rate uplink -	10 kbps to one low earth orbit space element

Low data rates are accomplished via VHF (136 to 138 MHz) for the downlink and UHF (400.5 to 401.5 MHz) for the uplink. Medium/high data transfer between the TDRS and the space elements utilizes S-band (2.025 to 2.1 GHz uplink; 2.22 to 2.28 GHz downlink) or Ku-band (14.81 to 14.91 GHz uplink; 13.85 to 14.0 GHz downlink). All TDRS to/from ground data relay is accomplished at Ku-band (13.4 to 13.64 GHz uplink; 14.6 to 15.2 GHz downlink).

OBSERVATIONAL PLATFORM REQUIREMENTS

The observational satellite characteristics assumed for the new traffic model reflect the observational platforms that were synthesized for the baseline traffic model. It was pointed out in Section 5.3 of Part 1 of Volume IV, that there was an inadequate definition of U.S. geosynchronous observational satellites. Therefore, as part of this study a representative model was developed. The new traffic model considers both U.S. and foreign observational satellites. Obviously, if adequate definition of the U.S. space elements is unavailable, definition of foreign satellites will be even less definitive. For purposes of this study it is assumed that the foreign observational platforms are identical to those synthesized as part of the baseline traffic model.

As a result of the analyses associated with the baseline traffic model, the four major discipline classes that lend themselves to multifunctional grouping are:

Earth observations
Solar astronomy
Stellar astronomy
Plasma and magnetospheric physics
High energy physics

The composite system requirements which are the same for both traffic models are reiterated in Table 5.3-5.

Table 5.3-5. Observational Platform Requirements

Function	Requirement	Driver
Orientation	Scanning local vertical	Earth observations
	Inertial	All except earth observations
Power	2 kw	Earth observations
Pointing	10 arc seconds	Stellar/solar astronomy
Stability	1 arc second/second	Stellar/solar astronomy
Data handling	50 Mbps	Earth observations
Impulse/propulsion	70 pounds hydrazine	Earth observations

NAVIGATION AND TRAFFIC CONTROL PLATFORMS

The system defined for the baseline traffic model utilized a single geostationary satellite in each region and was patterned after the Aerosat concept. Its purpose was to provide a communications link between aircraft and ground for traffic control and general communications. The system conceived for the new traffic model is considerably more complex. By utilizing a constellation of satellites, in geostationary and inclined geosynchronous orbits, navigation and surveillance functions are also provided to the user.

Both DoD and FAA are presently studying constellation type systems for operational use in the 1980 time period. Constellations range from the DoD concept of a five-satellite system with one geostationary and four-inclined geosynchronous orbit spacecraft to an FAA concept of two geostationary and nine inclined orbit satellites. Four such constellations would be needed for global coverage with the DoD concept; three would be required with the FAA concept.

Constellation type systems are necessary to provide the navigation and surveillance functions with sufficient precision and time continuity at any point in the regional coverage areas. Use of several inclined orbit satellites provides this capability by allowing aircraft and/or ships to "see" several spacecraft at any given time. Multi-point navigation and surveillance information is used to generate accurate position information.

For the new traffic model a five-satellite constellation system similar to the DoD system is defined. This system was chosen because of its better adaptability to global service. The FAA concept, with 11 satellites for CONUS and four more geostationary satellites for the oceanic areas, was more specifically defined for air navigation and traffic control of aircraft flights associated with U.S. traffic. Four constellations located approximately at 0°, 90°E, 180° and 90°W provide global coverage. This system would enable properly equipped users, at any global position, to determine position at any time of day. Figure 5.2-1 illustrates these constellations and the earth pattern track traced by the inclined orbit spacecraft. With this type global system, six satellites would be in view of users more than 80 percent of the time. Fifty percent of the time, at any specific latitude, eight satellites would be in line of sight. For navigation purposes, only four satellites need be in view of the user.

Each of the satellites generate a PN (pseudo random noise) code that would be received by the user for comparison with his own on-board generated signal. This determines range to the specific satellite by the amount of time delay. Repetition to the measurement three times yields three dimensional position information of the user. Velocity data could be acquired in a similar manner by tracking Doppler information. A signal from the geo-stationary satellite is used to correct the user's clock. User position accuracy will be in the order of 100 feet or less, less than one foot per second velocity, and within nanoseconds of time. Navigation information can be acquired in less than one minute.

User navigation is the primary requirement for the Nacsat platform. Surveillance--for traffic control--and two-way user/ground communications (both voice and data) must also be accommodated. Each satellite must, therefore, provide the necessary subsystems to effectively perform these functions.

In summary the functional requirements of a Nacsat platform system are:

1. Navigation: The platform must provide information signals to aircraft/ships to enable the user to calculate a position fix. The information consists of range data between the platforms and the user, and the precise ephemeris data of the platforms as originated from the ground stations.

2. Surveillance: Platforms must be capable of relaying ground control initiated interrogation signals to each user individually. Measurement of elapsed time until a response from each user is received is the primary data utilized. Elapsed time measurement is performed by the ground station. The platform provides the space link.

3. Communications: This function is essentially the same as in the baseline traffic model. The platforms must relay both voice and digital data between users and a ground control center.

Functional Parameters

The platform parametric requirements for the navigation, surveillance, and communications functions are listed in Table 5.3-6.

Table 5.3-6. Nacsat Platform Requirements

Function	Link	No. of Channels	Bandwidth (MHz)	
			Per Channel	Total
Navigation	Platform/aircraft	1	20	20
Surveillance	Platform/aircraft	1	20	20
Surveillance	Platform/ground	1	20	20
Communications (digital data)	Platform/aircraft	1	5	5
Communications (digital data)	Platform/ground	1	15	15
Communications (voice)	Platform/ground	25	0.025	0.625
Communications (voice)	Platform/aircraft	25	0.025	0.625

These requirements stem from the data relay loads imposed by the traffic control system. Two mass functions size the required parameters: (1) surveillance samples per unit time to be processed, and (2) message/bit rate required for air-to-ground communications.

These requirements and their frequency band allocations are shown on the pictorial chart, Figure 5.3-5.

Summary

A five-platform constellation type system was selected for the navigation and traffic control system. It is similar to a system presently being considered by DOD. This system provides global coverage with a total of 20 platforms. It provides the necessary continuity of contact with users in any region for the navigation, surveillance, and communications functions. Since each constellation consists of one geostationary and four inclined orbit geosynchronous platforms, it was decided to make a separate Nacsat platform usable for any of the constellation units. For the proper global coverage, it is also necessary that these platforms be placed at 0°, 90°E, 180° and 90°W, or as closely thereto as possible.

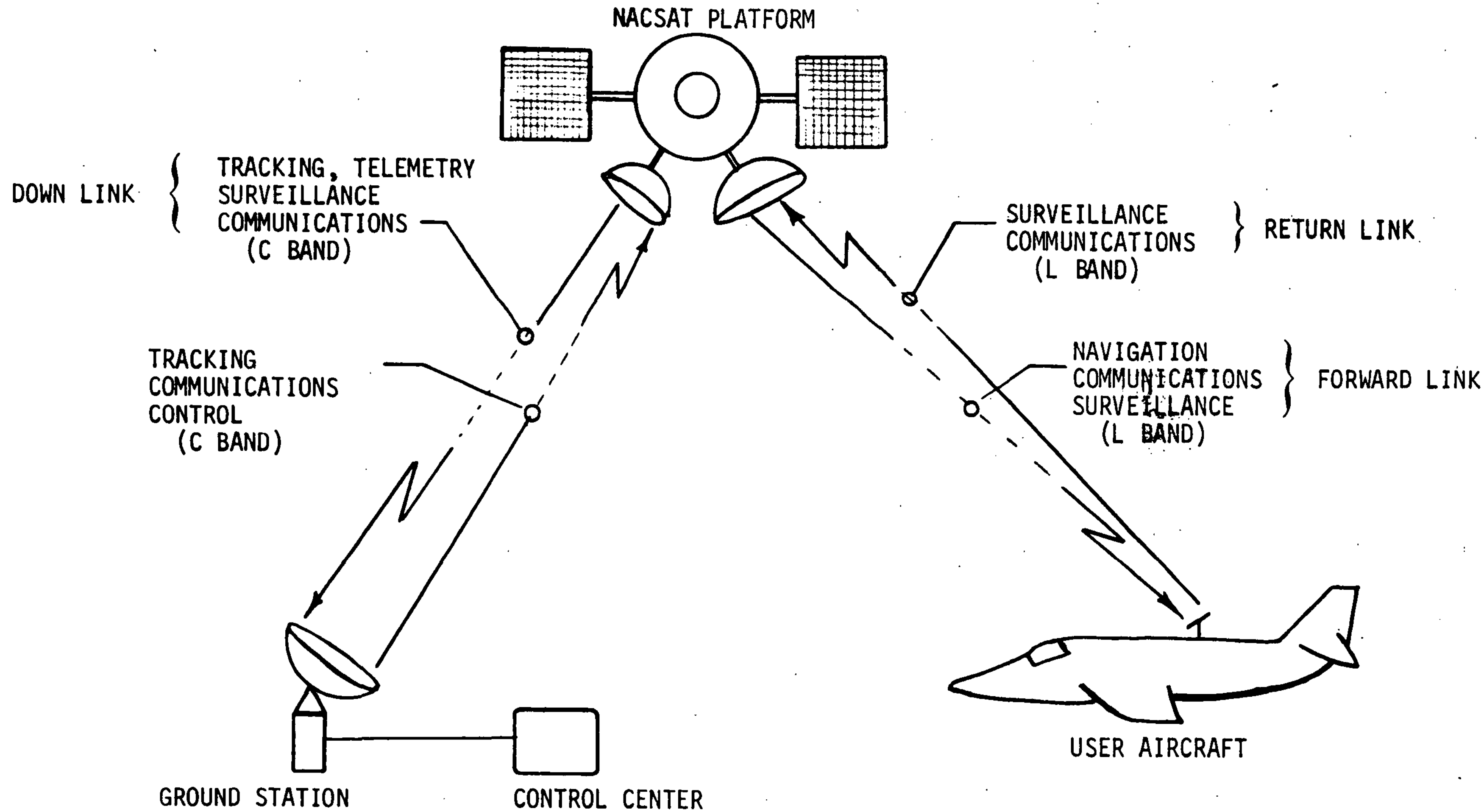


Figure 5.3-5. Nacsat Data and Communications Links

5.4 ON-ORBIT SERVICING CRITERIA

The servicing modes for the platforms associated with the new traffic model are the same modes as for the baseline traffic model equivalanet platforms; auto-remote and both pressure suited and shirtsleeve manned attendance. No unique requirements on the platform design were defined as a result of the expanded satellite inventory of the new traffic model. All functions are the same.

The platform requirements and rationale are developed in Section 5.4, Part 1 of Volume IV. A condensed summary of these requirements is presented herein.

CONFIGURATIONAL REQUIREMENTS

Overall size, shape, and arrangement of the platform must provide for servicing access by the selected system. In the unmanned case, this means that the platform must allow a manipulative device to grasp, remove, and withdraw any replaceable unit and, subsequently, to insert and install its replacement. This could be accomplished by either removal external to the surface of the platform or through an annular structure (docking ring) which provides adequate clearance for the largest package and articulation motions of the manipulative device. Clearances must also consider possible use of portable (manipulator-mounted) lights and TV for remote operations. This concept also implies a manipulator end effector, which has sufficient accuracy and rigidity to grasp special latching mechanism for module interchange and actuation of electrical and plumbing quick disconnects.

For the manned approaches, clearance requirements for internal access must consider the man in a suited envelope, and his movement through passageways and docking ring with replaceable units, tools, etc. Package installation can be conventional ground-type, latches or disconnects, but with allowances for additional clearance and loss of dexterity due to a gloved hand.

SUBSYSTEMS REQUIREMENTS

The various requirements imposed on the subsystems differ with the servicing approach. Shirtsleeve servicing requires the greatest number of provisions including a pressurizable compartment, atmospheric control (or man-module interface), lighting, voice communication, crew aids, and protective provisions. EVA/IVA requires similar but fewer provisions in that life support and environmental protection are furnished by the pressure garment assemblies. All concepts require a form of docking for rigid attachment, interface connections to the service unit, data links for trouble analysis and checkout, and a capability to deadface or shut down systems or equipments undergoing replacement. For the manned modes, the latter could consist of manual switches and valves. For the remote mode, ground commands could be input via the service unit or directly to the platform.

Various schemes could be employed for diagnostics, test, and checkout. Status data to the level of the replaceable unit are required at the ground station prior to the servicing mission to ensure adequate delivery of spares. It would seem feasible that the ground station would periodically checkout systems for trend data and confidence checks. The platform must, at a minimum, be compatible with these requirements with higher levels of built-in test capability optional for operational needs.

EVOLUTIONARY CONSIDERATIONS

It appears that an evolutionary servicing concept is appropriate for a platform program. Initial module replacement can be achieved by the auto-remote concept. As the platform program progresses, repairs and refurbishment will probably be required and more complex and intricate operations will be necessary. This type of activity is more amenable to man attendance. The projected development of the tug supports the evolutionary concept. Initial IOC of the shuttle and unmanned tug supports the early phase of on-orbit servicing of platforms at the modular interchange level. Approximately five years after initiation of platform operations, a man-rated tug is planned. This timing would support potential refurbishment of platforms.

In order to minimize total program development effort, it is recommended that the platform be designed to an integrated set of servicing requirements; a single concept that will accommodate remote, EVA, and shirtsleeve servicing. In this approach, the servicing mode evolves, not the platform design.

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