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COMSAT Laboratories

VOLUME II - TECHNICAL

FINAL REPORT

GEOSTATIONARY PLATFORMS MISSION

AND

PAYLOAD REQUIREMENTS STUDY

TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

George C. Marshall Space Flight Center

George C. Marshall Space Flight Center, Alabama 35812

UNDER CONTRACT NAS8-33226 TASKS 1,2, AND 3

OCTOBER 30, 1979

COMMUNICATIONS SATELLITE CORPORATION
COMSAT Laboratories, Clarksburg, Maryland 20734

(NASA-CR-161808) GEOSTATIONARY PLATFORMS MISSION AND PAYLOAD REQUIREMENTS STUDY. VOLUME 2: TECHNICAL Final Report, 12 Oct. 1978 - 18 Oct. 1979 (Communications Satellite Corp.) 151 p HC A08/MF A01 N81-26165 Unclas G3/15 26738

Volume II—Technical

Final Report

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Submitted to

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October 30, 1979

By

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Foreword

This is the final report for the "Geostationary Platforms Mission and Payload Requirements Study" conducted by the Communications Satellite Corporation from October 12, 1978, to October 18, 1979, under National Aeronautics and Space Administration (NASA) Contract No. NAS8-33226. The NASA study director was W. T. Carey, Jr. of the NASA George C. Marshall Space Flight Center at Huntsville, Alabama.

Volume I is the Executive Summary, and Volume II describes the work performed. During the contracting period, monthly letter-type reports and two extensive midterm reports were filed.

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1. INTRODUCTION

1.1 WHY A LARGE SPACE PLATFORM?

Large space stations (geostationary platforms or orbital antenna farms) offer the potential of lowering communications costs through the economy of scale that results from combining multiple satellite missions onto a single large satellite or platform. These platforms, which are placed into geostationary orbit, are characterized by their large aperture antennas interconnected by a switch or switches, diversity of missions (communications and other), and the possibility of adding or replacing portions to incrementally modify or update the payload on platforms in orbit. By their very nature, these are characteristic of a new shuttle-launched class of satellites.

1.2 PLATFORM TRANSPONDERS

Through the use of advanced technolcgy, large antennas are able to transmit multiple narrowbeams to the earth. This permits frequency reuse (thus multiplying the available RF spectrum to meet future needs) and the use of low-power satellite transmitters. The multiplicity of beams and services are connected by an onboard switch matrix.* Placing the switch in orbit (rather than on the ground) will permit telephone calls and data with a network to be routed along optimized routes. The impact of this approach (coupled with onboard regeneration and remodulation) may influence

*A companion study by the Aerospace Corporation has specified a switch matrix.

the design of TDMA earth stations, their costs, and overall network operations.

1.3 CONTRACT OBJECTIVES

The contract specified that the following tasks be performed:

a. Determine the optimum locations for geostationary platforms.
b. Determine potential missions and their characteristics.
c. Contact potential users for their comments.
d. Determine the interface requirements between the missions and the geostationary platform.
e. Prepare a payload data book.
f. Conduct antenna tradeoff studies.

1.4 PAYLOAD AND HOUSEKEEPING REQUIREMENTS

This particular study identified potential generic missions, their time-phasing, and the payload characteristics. From these, the payload demands upon the housekeeping functions were determined. Payload is defined to include those functions unique to a particular service (e.g., educational television). The payload includes the antennas (or sensors) and transponders dedicated (in whole or in part) to a service. Conversely, housekeeping incorporates all the non-payload unique elements such as structure; power generation and storage; gross power control; attitude control (but not necessarily antenna beam pointing); stationkeeping; gross thermal; and telemetry, command, and control.

From this study, detailed data are now available on the payload and housekeeping requirements of the selected communications missions (see Appendix A). In addition, there is one typical non-communications mission based on government-furnished data. "These typical payloads are defined in terms of frequency, power, beam patterns, interconnecting and support requirements and other characteristics that can be used to synthesize the design specifications for platforms" (from the Statement of Work).

1.5 ANTENNAS

A variety of antenna types have been evaluated for each application. Frequently, the choice is sufficiently broad to permit several options which may be narrowed by other (housekeeping and mission) constraints. In numerous cases a single reflector surface can be utilized simultaneously for several missions (e.g., ATS-6). Although a single large reflector was studied, it was not utilized because of feed-space conflicts.

1.6 PLATFORM LOC ONS

"The contractor will study the choice of locations for three geostationary platforms that may serve the United States, North, Central and South America, and Europe" (from Task 1.1 of the Statement of Work). The results are given in Sections 3 and 4 and Table 1-1. For each location there is a back-up (geosynchronous orbit position). Since this platform study was based on an 1989 launch, occupants of the orbit cannot be predicted as several generations of satellites will have passed and at least one Regional and one General World Administrative Radio Conference (GWARC) will have transpired. Also, there will be other contenders (and not just U.S. entities) for geostationary orbit locations.

Table 1-1. Principal and Alternate Platform Locations

Selected Locations		
Regional Coverage	Longitude	
	Prime	Alternate
North America	120°W	116°W
South America (North & South America)	80°W (100°W)	60°W (97°W)
Western Europe	0°E	5°E

1.7 MISSIONS AND PLATFORMS

A list of 31 generic "potential missions for each of the geostationary platforms identified" was prepared. These included "international, domestic, aeronautical, maritime, and regional commercial communications satellite applications and other applications" (excerpts from Task 1.2 of the Statement of Work). As a result of extensive user contacts and NASA direction, these were consolidated into twelve missions (with instruction to use three missions from a parallel Aerospace Corporation contract). The resulting list of missions and the particular platforms are shown in Table 1-2.

Table 1-2. Geographic Distribution of Services

Mission	South America	North America	Western Europe
1. Direct-to-User	—[a]	—[a,b]	—[a,b]
2. High Volume Trunking	—[a]	—[a,b]	—[a,b]
3. Broadcast & Video Distribution	—[a]	—[a,b]	—[a,b]
4. Tracking and Data Relay	yes	yes	yes
5. Educational Television	yes	yes	no
6. Direct Television Broadcast	—[c]	yes	—[c]
7. Mobile, Air	yes	yes	no
8. Mobile, Sea	yes	—[d]	—[d]
9. Mobile, Land	—[e]	maybe	yes
10. International	yes	yes	no
11. Inter-Platform Links	yes	yes	yes
12. Data Collection	yes	yes	no
13. Severe Storms Research	yes	yes	no

[a]Adopted from the Aerospace Corporation Study.
[b]Coverage of this region would require extrapolations from the Aerospace Corporation Study.
[c]Commercial service is currently under study.
[d]International maritime services will be provided by INMARSAT.
[e]Depends on GWARC-79 outcome.

1.8 INDUSTRIAL CONTACTS

Potential customers of the geostationary platform were contacted "to survey the needs of each user and carrier contacted for service in the time frame of the late 1980's and 1990's to develop the following types of information for communications missions:

a. Type of communications (present and emerging).
b. Traffic sources and destination locations.
c. Private (corporate or government) communications networks and satellite services.
d. Means of using the existing investment in earth stations, terrestrial switching centers, etc.
e. The mixture of voice, video, data and record communications.
f. Replacement plans for the present satellite systems (time and type of satellite).
g. Interconnection requirements among several missions.
h. The coverage pattern requirements of antennas.
i. Reliability and diverse routing.
j. Frequency bands to be used" (excerpt from Task 1.3 of the Statement of Work).

1.9 PLATFORM INTERFACE REQUIREMENTS

Under Task 2, the platform support (housekeeping) requirements were identified. These requirements and results are contained in Table 1-3 for the antenna parameters and the beam pointing. The overall requirements are summarized in Table 1-4.

Table 1-3. Antenna Requirements (Communications)

Mission	Beams	Beamwidth (°)	Diameter (m)	Frequency (GHz)	Polarization	Transponder RF	Power (W) DC	Point (°)	Antenna Type[a]
1. Direct-to-User[b]	60	0.35±	3 @ 5	14/12	2	0.7 (ea.)	3700	0.03	FA/CP
2. High-Volume Trunking[b]	20	0.106/0.165	1 @ 30	6/4	2	0.05	940	0.01	FA/CP
3. Broadcast & Video Distribution[b]	7	Time Zone	1.5	17/13	2	10	2910	0.10	FA/OFP
4. Tracking & Data Relay	Many	0.3 to 4.5	2 to 5	2 to 15 2 to 13	2	1.6 to 50	444	0.10	FFP & PA
5. Educational TV	4	3 x 4	2 x 2.8	14/2.5	2	3	368	0.10	RA/CP
6. Direct TV Broadcast	4	3 x 4	7.5 x 10	14/0.7	2	100	2064	0.10	RA/FFP, MY
7. Mobile, Air	4	0.6, 17	0.8, 7	1.6 to 6/ 1.5 to 5	2	50 to 200	869	0.10	HA/FFP, HO
8. Mobile, Sea	4	1, 17	uses 30 m	1.6 to 6/ 1.5 to 4	2	2.0 to 60	437	0.10	HA,HO, FFP
9. Mobile, Land	10-19	1	uses 30 m	0.9/0.9	2	60 to 560	2080 to 7920	0.10	MY, HA
10. International	12	1	1.1 to 5.3	6 to 29/ 4 to 18	2	0.01 to 50	123 to 598	0.10	FFP, OFP
11. Inter-platform links	2	0.13	3	55/55	1	65 or 300	308 or 1208	0.03	FFP
12. Data Collection	1	5	11	0.4/DTU	1	0.05	18	0.10	MY/FFP

[a]FA = Feed array
FFP = Front-fed parabola
CP = Cassegrain parabola
OFP = Offset fed parabola
HO = Horn

PA = Phased array
RA = Reconfigurable array
MY = Multi-yagi type array
HA = Helix array

[b]Per NAS8-33281.

Table 1-4. Platform Interface Requirements

Power Requirements (Approx.)	20 kW
Thermal Dissipation (Approx.)	16 kW (th)
Attitude Control (Gross*)	±0.1°
(Fine RF)	±0.03° and ±0.07°
Reflector Surface Structure (stability)	0.018 to 5.5 cm rms
Stationkeeping (East-West)	±0.1°
(North-South)	±0.1°

*Measured at antenna roots.

1.10 ANTENNA TYPES

Four different types of antennas were considered: a single reflector with multiple feeds; multiple independent reflectors, each illuminated with a single feed to define the axis of one beam; a single reflector illuminated with a phased array feed system; and a phased array antenna.

Both assymetric and offset fed reflectors were considered. Although it is too early to limit the choice to one antenna per mission, missions employing many beams (for example mobile, land) will require low sidelobe antennas. Therefore, an offset fed reflector is probably the best.

During the support effort which was provided to the Aerospace Corporation study, nonideal beam shapes, the crowding in the Northeast, and finally the potentially low C/Is were identified. However, only typical cluster beams were studied.

The antenna configuration options are listed on a mission by mission basis in Appendix A.

1.11 NON-COMMUNICATIONS MISSIONS

A severe storms research mission was selected by the study director and provided to the contractor in the form of raw reports and data. This mission (from Stormsat-85 or System-85) involved gathering data on the mechanisms of tornadoes, thunderstorms, hurricanes, etc. The choice of this mission involved the spectrum from infrared down to 118- and 183-GHz.

The sensing beamwidths were relatively narrow and, when combined with resolution (4.4 m), produced small beam pointing requirements. In these cases a subplatform may be required.

1.12 PLATFORM PAYLOAD DATA BOOK

The final aspect of Task 3 was to produce a detailed and internally consistent Platform Payload Data Book using an agreed upon format. The results of this extensive study are provided in Appendix A.

1.13 STUDY LIMITATIONS

The underlying purpose of this study was to identify time-phased missions and payloads for potential accommodation on geostationary platforms and to identify the engineering requirements placed upon the platform housekeeping elements by selected payloads. Subsequently an investigation contract for structural studies would be awarded. The "Geostationary Platforms Mission and Payload Requirements Study" contract did not examine non-payload aspects such as structural design or propulsion stages, and non-engineering factors such as flight operations or regulatory, statuatory, and institutional aspects.

2. PURPOSE OF THE STUDY

This study examined the possibility of using a few platforms in place of many small satellites to provide communications and other services. It is based on the original "Orbital Antenna Farm" conceived by W. L. Morgan and B. I. Edelson of the Communications Satellite Corporation [1] in 1975 and subsequent NASA studies [2].

The purpose of this study was to identify and define time-phased missions and payload that may be accommodated by several geostationary platforms placed at high-traffic locations around the globe (defined as covering the United States; North, Central, and South America; and Western Europe). However, it was not the intent to determine the economics, mechanical feasibility, institutional propriety, assembly techniques, or overall satellite configuration of geostationary platforms. NASA intended to subsequently use the data developed under this contract to perform tradeoff studies and analyses of potential geostationary platform approaches and concepts to determine an optimum geostationary platform concept.

2.1 PLATFORM CONCEPTS

Platforms will be transported to low orbit by Shuttle. One or more launches will contain the basic geostationary platform. Deployment and assembly of sections of the platform, as well as some tests, will be performed in low earth orbit. Upper stage vehicles (e.g., Centaur, I.U.S., or the NASA-MSFC-OTV) will be used to transfer the contents to the geostationary orbit. The platforms may have an open-ended lifetime through periodic replacement of life-limited components (e.g., fuel and flywheels) and retrofit of technology-limited devices (e.g., transponders). The basic platform will provide electric power, telemetry, stationkeeping, coarse pointing, and thermal control, for the individual mission payloads.

2.2 END USE

Typical payload missions have been defined in terms of frequencies, power, beam patterns, interconnections, support requirements, and other characteristics. This study reviewed a number of potential missions, consulted with leaders in industry, determined the platform interface requirements, and coordinated with various NASA centers and headquarters.

2.3 USER SURVEY

The user survey, which employed a novel card system, resulted in data on individual satellite system requirements of the future. The data included information on the earth station figure-of-merit, the satellite antenna coverage, the amount of traffic, and the date of substantial service via satellite for 31 service categories. The participants were asked to consider individual missions. Each organization was given a copy of an article by Jaffe, Fordyce, and Hamilton entitled, "A Switchboard in the Sky Concept for Domestic Satellite Communications" [2].

Subsequently, the 31 possible missions were consolidated (with NASA-MSFC's guidance) into 12 missions, of which three were considered duplicates of the study conducted in parallel with the Aerospace Corporation [3] under Contract NAS8-32281. In these three cases, COMSAT was directed to use the Aerospace Corporation models.

2.4 TASK 3

As an additional task, COMSAT was asked to study various forms of antennas and to conduct a tradeoff analysis of single vs multiple antennas. A government-furnished, non-communications mission (severe storms) was added. Also, the conceptual definition of platform payloads was to be compiled into a "Payload Data Book" (see Appendix A of this report). The results of these tasks, which have been reported in the two midterm reviews and one final briefing, are summarized in this final report for Contract NAS8-33226.

3. APPROACH

3.1 MISSIONS

Table 3-1 shows the three lists of missions considered in this study. Column 1 contains the service categories given in the Statement of Work as potential subjects for investigation. The list of categories for the user survey is in column 2. The final list is a combination of columns 1 and 2.

Although all of the suggested services were included, several have been combined into a more generic form to increase manageability. Only one, standard time and frequency, was dismissed because of lack of interest. The deletion of this small mission [4] affected the total geostationary platform mass and power budgets by less than one percent.

3.2 INDUSTRIAL PARTICIPATION

For the user survey (Task 1.3), a list of 31 potential missions (compiled under Task 1.2 was presented personally to the vice presidents of the leading telecommunications suppliers (carriers, programmers, users, and manufacturers). An attempt was made to select both advocates and antagonists of the mission to provide an appropriate cross section of the industry. The results of the survey were used to configure missions, subject to NASA direction in Task 1.2a (see Figure 3-1). It was then possible to synthesize the platform interface requirements (Task 2a).

Table 3-1. List of Missions

Initial List (from Statement of Work)	User Survey List	Final Model List
Communications		
Trunking Systems and Fixed Networks	Trunk Telephony	High-Volume Trunking*
	International	International
	Private Line	
Mobile Systems		
Maritime-Mobile	Maritime	Mobile, Sea
	Search & Rescue	Mobile, Sea
Aeronautical-Mobile	Aeronautical	Mobile, Air
	Search & Rescue	Mobile, Air
Land-Mobile	Land-Mobile	Mobile, Land
	Bush Voice	Mobile, Land
Distribution Systems	CATV	Broadcast*
	Educational TV	Educational TV
	Data	Direct to User*
	Electronic Funds Transfer	Direct to User*
	Electronic Mail	Direct to User*
	Electronic Office	Direct to User*
	Telelibrary	Direct to User*
	Paging	Direct to User*
	Personal Communications	Direct to User*
	Public Safety	Direct to User*
	Remote Printing	Direct to User*
	Telehealth	Direct to User*

*Adopted from the Aerospace Corporation Study.

Table 3-1. List of Missions (continued)

Initial List (from Statement of Work)	User Survey List	Final Model List
Data Collection	Data Collection	Data Collection
Broadcast Services	Direct TV Broadcast Network TV Teleconference	Direct TV Broadcast Broadcast* Broadcast*
Intersatellite Communications		
Geostationary	Intersatellite Link	Inter-platform Links
Deep Space	Intersatellite Link	TDRS
Other Applications		
Navigation	Navigation	(intergrated into mobile)
Disaster Warnings	Public Safety	Direct to User*
Earth Resources	Earth Exploration	Data Collection & TDRS
Meteorology	Weather	Severe Storm Research
Standard Time & Frequency	Time & Frequency Standards	(dropped)
Space Tracking	Low Orbit Relay	TDRS

*Adopted from the Aerospace Corporation Study.

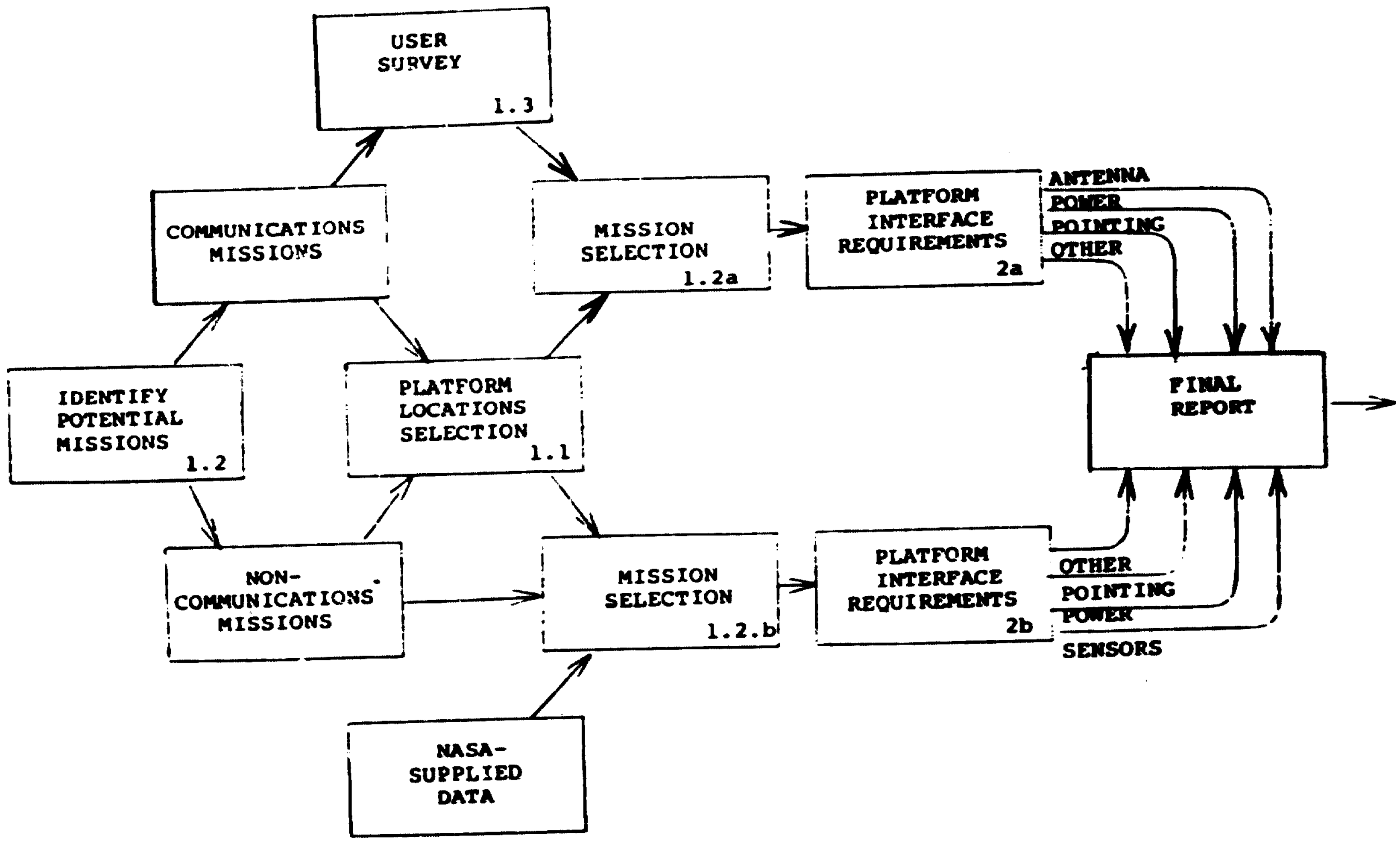


Figure 3-1. Study Work Flow (Tasks 1 and 2 only)

The formal user survey, which was personally conducted, involved over 25 participants. In addition, informal contacts were conducted with both U.S. and European contacts.

The survey covered all 31 mission categories. The users were informed that the intent was to identify potential services which could be provided by a large communications platform. They were informed that the purpose of this study being conducted for NASA was to determine the technical requirements their needs would impose upon a platform. The survey was conducted using sets of cards which contained choices of values for each parameter or the name of a mission.

3.3 MISSION TIMING

Thirty-one category cards were distributed along with four date cards (1979, 1984, 1989, and "unknown"). The user was asked to sort the cards by the inception date of substantial commercial service and to place them in each data deck by priority. In this manner, the more vital categories were separated from the less interesting.

3.4 SPACE-TO-EARTH LINK REQUIREMENTS

Next the type of earth station envisioned to provide each service in the 1980's (the NASA-provided time frame of the initial platform) was identified. With knowledge of the earth station's figure-of-merit (G/T_s), the service's bandwidth, the signal-to-noise requirements, and the modulation method, the satellite's equivalent isotropically radiated power (e.i.r.p.) can be determined.

3.5 COVERAGE FROM THE GEOSTATIONARY ORBIT

Knowledge of the e.i.r.p. is not sufficient to define the transponder adequately to determine the platform interfaces. Therefore, the users were offered a wide choice of satellite antenna coverage patterns ranging from global to cluster beams. Each category card was matched with a coverage pattern.

3.6 TRANSPONDER RF POWER OUTPUT REQUIREMENTS

The transponder power requirement at the antenna input may be determined when the e.i.r.p. and antenna pattern (which translates to satellite antenna gain) are known.

3.7 EARTH-TO-SATELLITE LINK CAPABILITIES

In a similar manner, the up-link G/T_s may be determined, since the antenna gain, G, is now known and a typical satellite, T_s, can be selected based on experience. With knowledge of the up-link G/T_s, the earth station transmitter may be specified for a given margin and bandwidth.

3.8 TRANSPONDER CHARACTERISTICS

Identification of the characteristics of the platform's transponder, its antenna, its beamwidth (hence, the antenna pointing accuracy), and the DC power (using the DC to RF conversion efficiency) is now possible for an individual mission's transponder. Knowing the DC and RF losses permits computation of the thermal load.

3.9 TRAFFIC

The next question concerning the number of transponders was not asked directly. (Many users admitted they had no idea how many will be needed; others would not reveal corporate plans.) However, users were asked what portion of the total communications marketplace (for each of the categories) will be served by satellites in 1984. Other studies [5] have identified total markets, and this survey then provided estimates of the submarket share provided by satellites.

3.10 USER SURVEY CONTROLS

This survey included a number of control questions which were successfully used for verification and quality control. The collected data have the expected diversity of opinion and appear internally consistent. Because of the high caliber of users contacted (all senior members of engineering management concerned with the provision of satellite related services), the survey was very beneficial.

3.11 STUDY LIMITATIONS

The principal bounds on this study were the resources available in terms of radio spectrum, existing usage of frequencies, current antenna and attitude control technology, and the I.T.U. power flux density limitations. This study was conducted prior to the conclusions of the GWARC-79. It is anticipated that this world radio conference will have a far-reaching impact upon follow-on studies.

Precise traffic requirements were not determined, as this would duplicate NASA work at the Aerospace Corporation [3], Western Union and U.S. Telephone & Telegraph [5], and Future System, Inc. [6,7] Throughout the study, attempts were made to make these results consistent with prior [2] and current [3,8] NASA studies.

4. PRINCIPAL RESULTS

4.1 PAYLOADS SELECTED

Based on the user survey, existing frequency allocations, the Aerospace Corporation study [3], and NASA-MSFC direction [9], certain payloads (shown on the left column in Figure 4-1) were selected for further study under a follow-on contract (NAS8-33527) [8]. Details on the individual payloads are given in Appendix A. Table 1-2 lists the missions by platform location.

4.2 EARTH STATIONS

The results of the earth station requirement survey are given in Table 4-1. In some instances, several choices were made depending upon the perspective of the user and his particular need. The alternate antenna is given in the final column. This variation was generally between adjoining sizes, which may imply a need for an intermediate size.

4.3 PLATFORM ANTENNA SELECTIONS

The user was asked to sort the mission category cards by down-link coverage; the results are shown in Figure 4-2. The vertical scale represents the number of respondents that selected each of the eight patterns. Since in some cases (e.g., earth exploration) individual users disqualified themselves on the basis of no interest or knowledge, the total number of participants varies

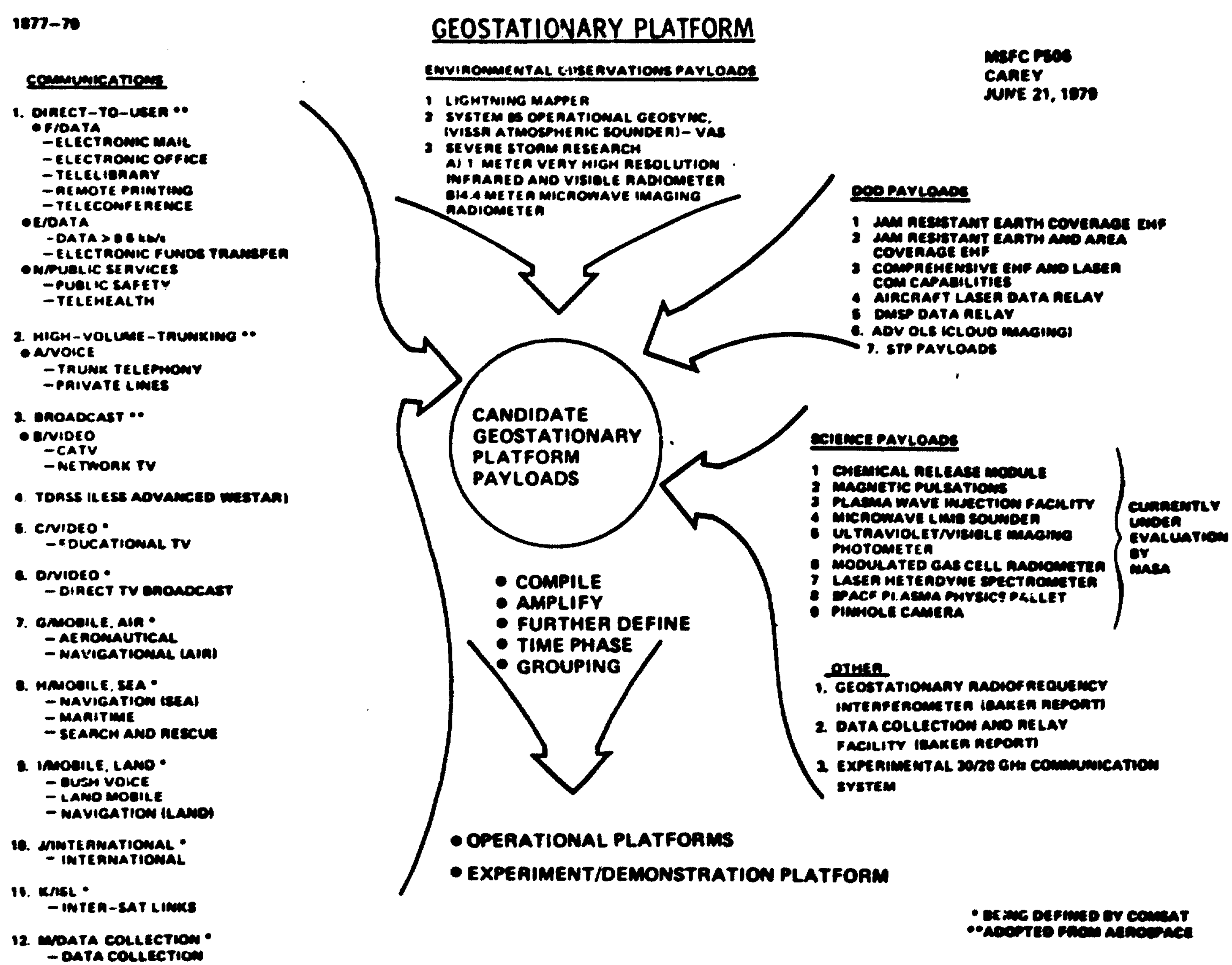


Figure 4-1. Payloads Selected

Table 4-1. Earth Stations Chosen for Various Missions

CODE	ANT.	DIA.	G/Ts	MISSION	ALTERNATE
A40	30m	100'	40	15. INT'L COMMUNICATIONS	A30
A30	10m	32'	30	8. TRUNK TELEPHONE	
				9. EARTH EXPLORATION	
				15. INT'L COMMUNICATIONS	A40
				18. LOW ORBIT RELAY (EARTH STATION)	
				20. NETWORK TV	A25
				26. REMOTE PRINTING	A25
				31. WEATHER (MAJOR READOUT STATION)	
				24. PRIVATE LINES	A20
A25	4.5m	15'	25	3. CATV	A20
				4. DATA 9.6 kbit/s	A20
				12. ELECTRONIC MAIL	A20
				13. ELECTRONIC OFFICE	A20
				20. NETWORK TV	A30
				26. REMOTE PRINTING	A30
				28. TELECONFERENCING	

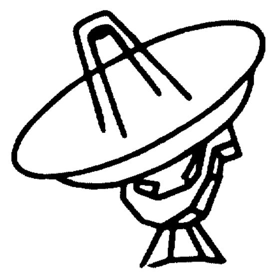


Table 4-1. Earth Stations Chosen for Various Missions (cont.)

CODE	ANT.	DIA.	G/Ts	MISSION	ALTERNATE
A20	3m	10'	20	3. CATV	A25
				4. DATA 9.6 kbit/s	A25
				10. EDUCATIONAL TV	
				11. ELECTRONIC FUNDS TRANSFER	
				12. ELECTRONIC MAIL	A25
				13. ELECTRONIC OFFICE	A25
				14. TELELIBRARY	
				24. PRIVATE LINES	A30
				25. PUBLIC SAFETY	
				29. TELEHEALTH	A10
A10	1.2m	4'	10	2. BUSH VOICE	
				5. DATA COLLECTION	
				7. DIRECT TV BROADCAST	AW
				21. MARITIME	
				29. TELEHEALTH	A20
				30. TIME STANDARD	

Table 4-1. Earth Stations Chosen for Various Missions (cont.)

CODE	ANT.	DIA.	G/Ts	MISSION	ALTERNATE
AW	WIRE-TYPE ANTENNA			1. AERONAUTICAL	A0
				7. DIRECT TV BROADCAST	A10
				17. LAND MOBILE	A0
				19. NAVIGATION	
				23. PERSONAL COMM.	A0
				27. SEARCH & RESCUE	
				31. WEATHER (SIMPLE READOUT)	
A0	OMNIDIRECTIONAL			1. AERONAUTICAL	AW
				17. LAND MOBILE	AW
				22. PAYING	
				23. PERSONAL COMM.	AW
				6. DEFENSE	(MANY)
				16. INTERSATELLITE	(N.A.)

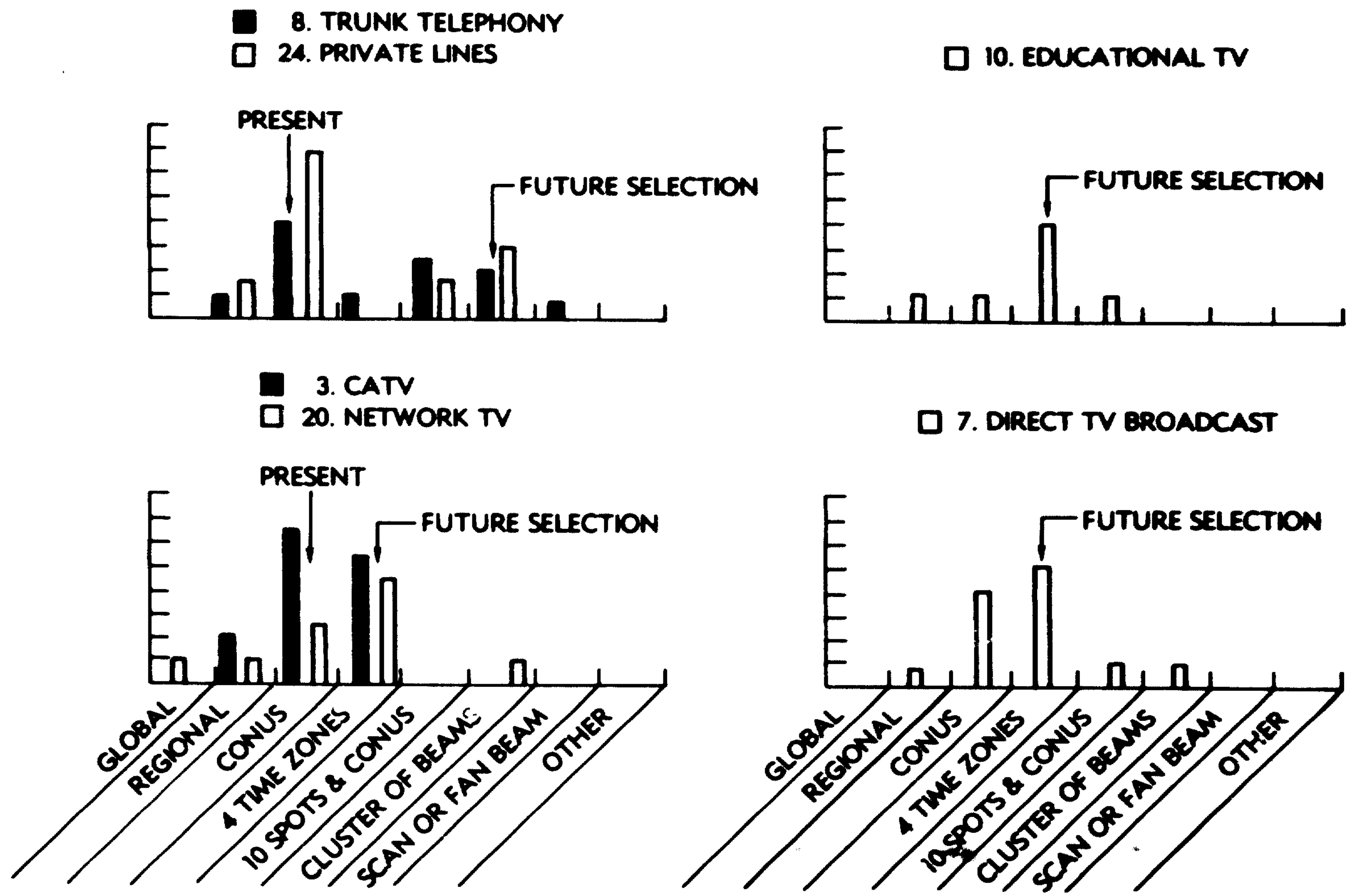


Figure 4-2. Antenna Coverage

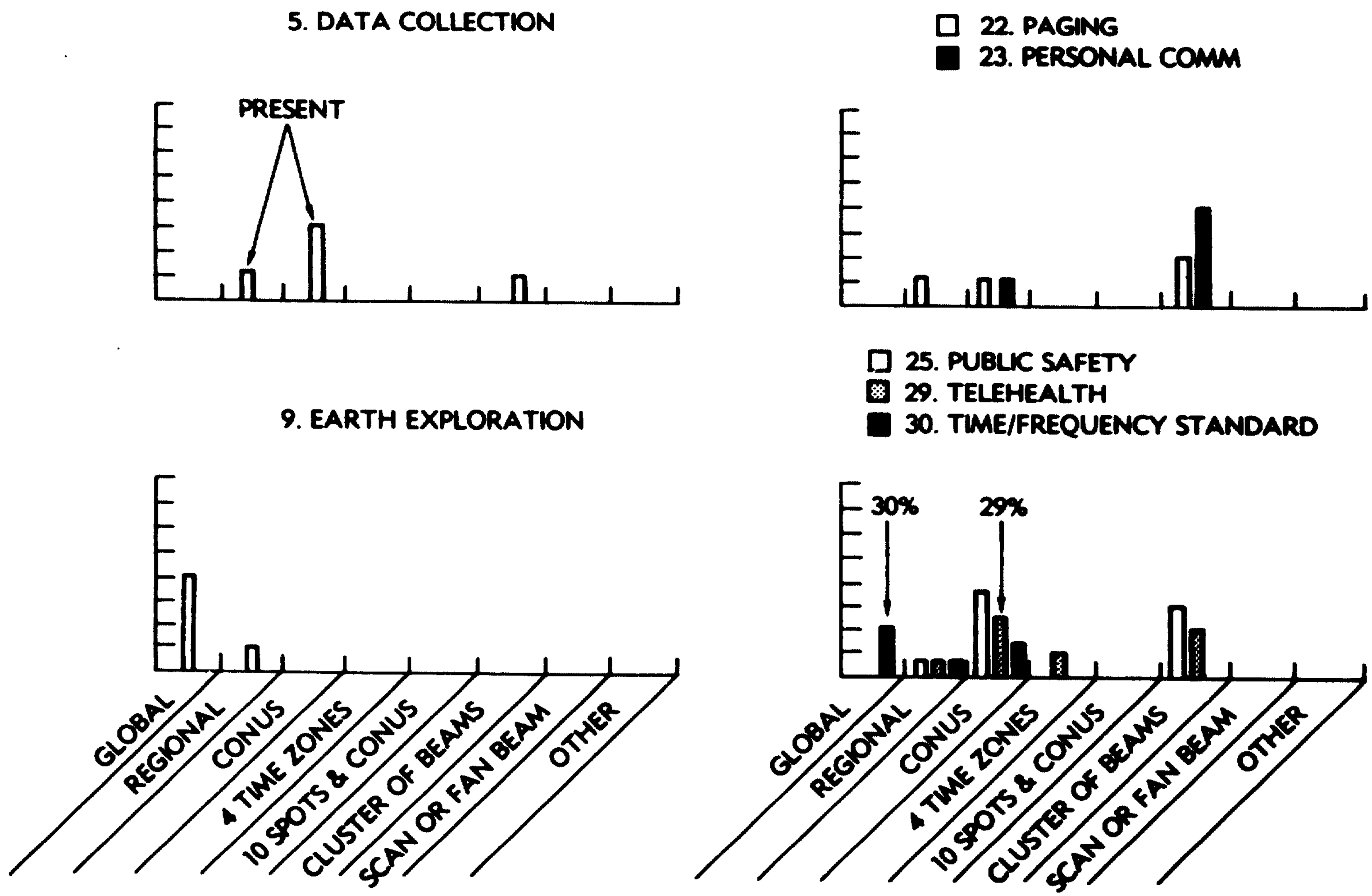


Figure 4-2. Antenna Coverage (cont.)

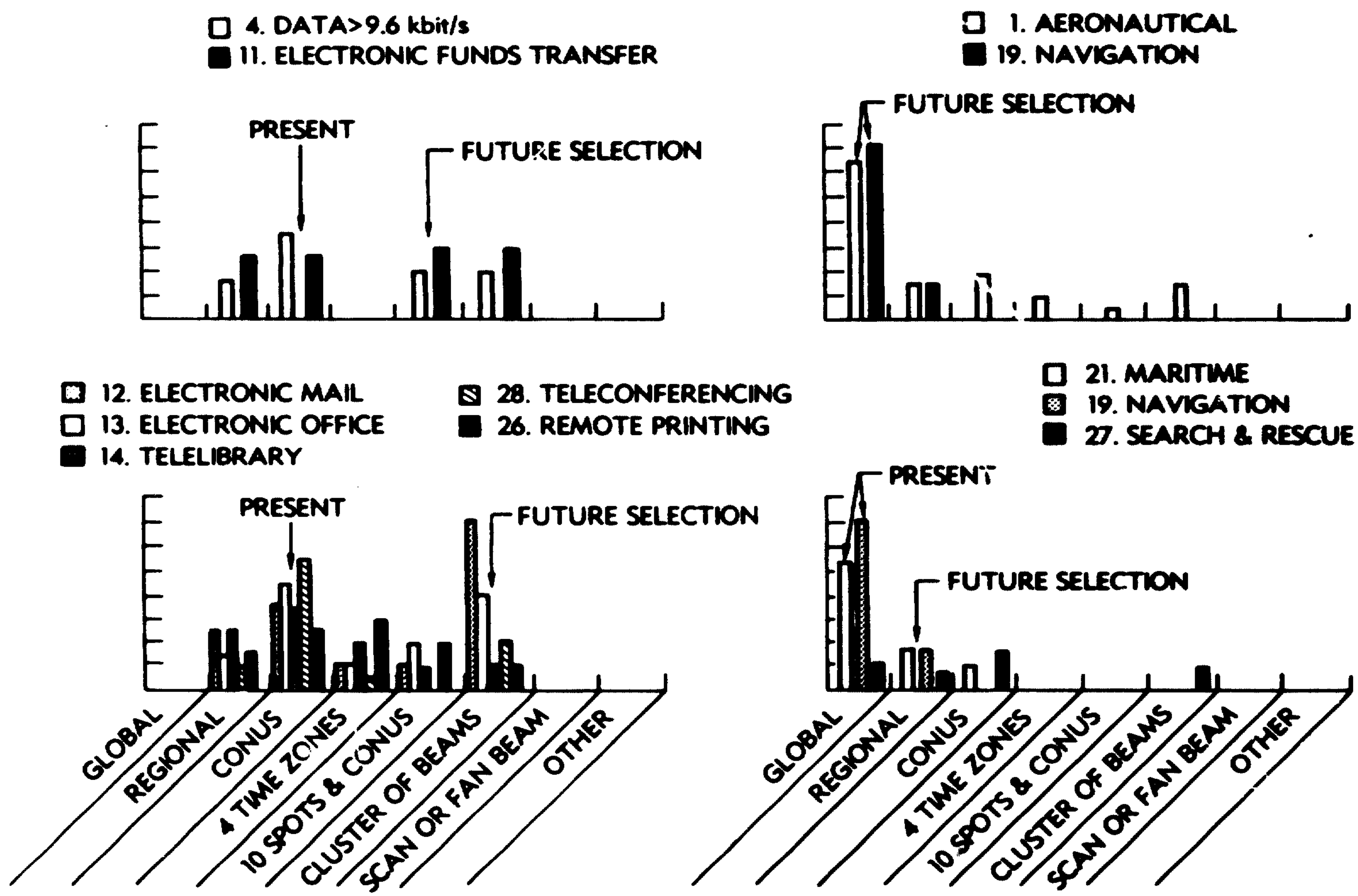


Figure 4-2. Antenna Coverage (cont.)

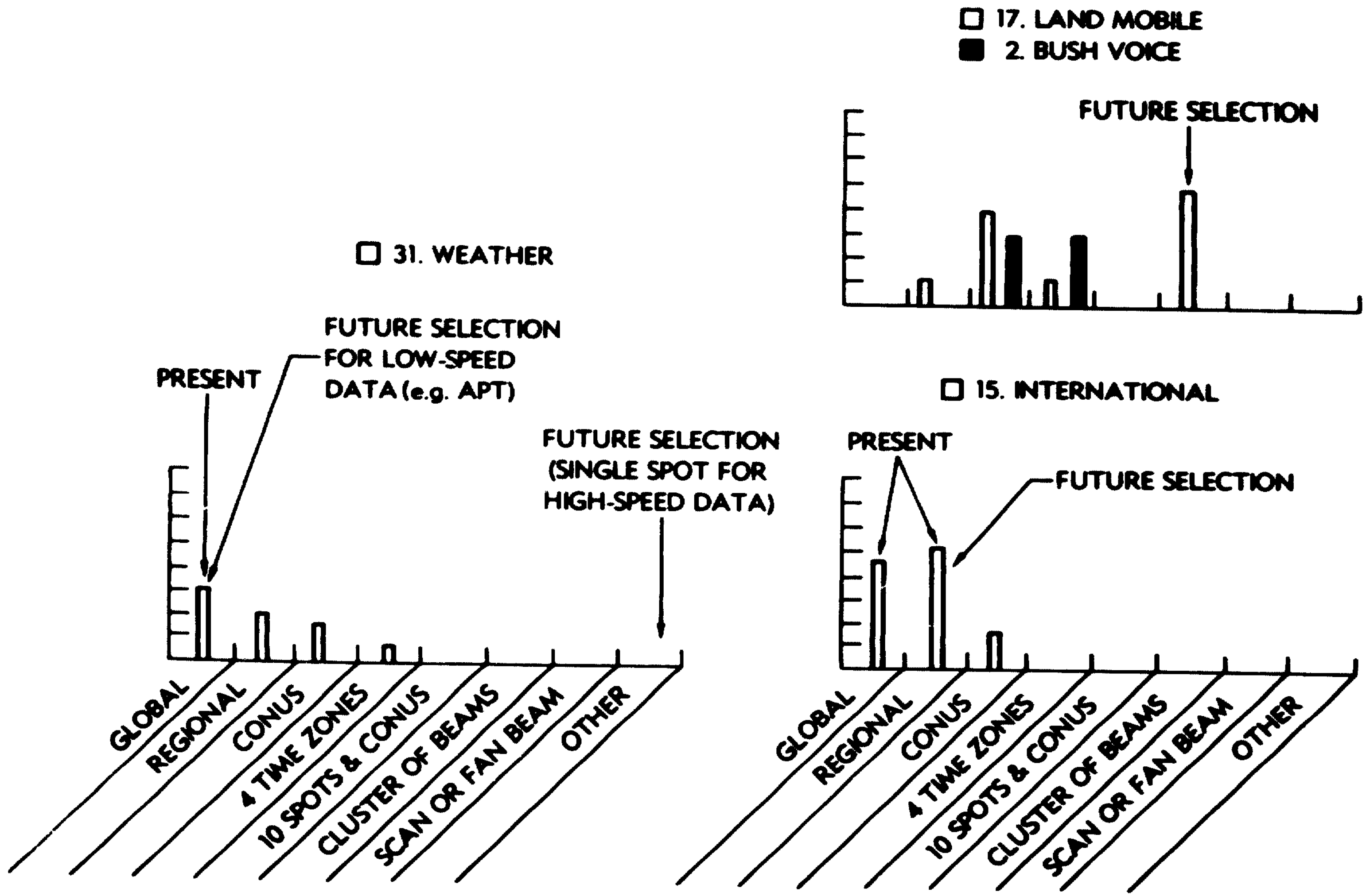


Figure 4-2. Antenna Coverage (cont.)

with the mission. Many users believed that multibeam configurations will eventually be needed to obtain additional frequency reuse, but these complex patterns will be used only when needed.

Figure 4-3 shows the corresponding platform antenna sizes based on selected mission models of Appendix A plotted on a graph prepared by NASA-JPL [10] showing the existing state-of-the-art for large-antenna performance. This figure indicates that either solid or mesh antennas may be used for all of the selected missions. The horizontal scale shows the antenna diameters, and the vertical scale gives the surface accuracy for each mission.

As part of Task 3, various types of antenna patterns have also been studied. An overview of several methods for covering an area is given in Table 4-2. In the survey, the most popular methods were the continental U.S. (CONUS) and the multi-beam cluster. The least popular was the scan or fan beam because of concerns about its utility in an operating network or because of the high-burst rates required. Table 4-2 uses a standard 6-m, 300-K, 12-GHz earth station for comparison. The 14-GHz up-links use 250, 0.20, and 0.25 W HPAs, respectively.

Figures 4-4 and 4-5 illustrate a basic dilemma of beam clustering. If the 0.35° patterns of the Aerospace Corporation Study [3] and the Western Union traffic distribution [5] are used, then a few beams (e.g., those covering New York/Pennsylvania/New Jersey) carry a disproportionate share of the total U.S. traffic. (The numbers denote the percent of the U.S. traffic devoted to voice, data, and video services in each geographic district). Other 0.35° beams covering the Rocky Mountains and the deserts have very little traffic. Traffic from the heaviest node (New York City and environs) was divided among three beams so that much of the short haul traffic (New York to Philadelphia, New York to Boston, and New York to Pittsburgh) could be contained

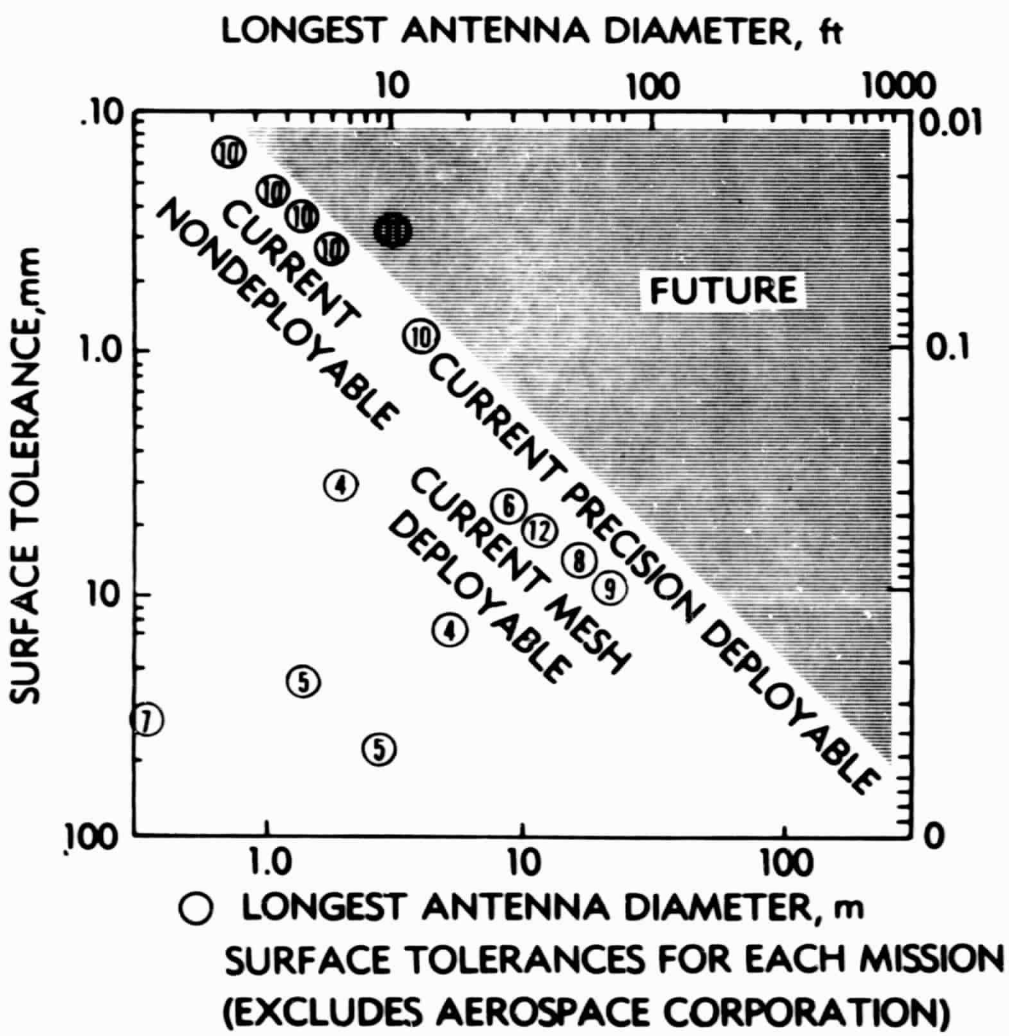


Figure 4-3. Antenna Capabilities

Table 4-2. Satellite Antenna Pattern Types

Antenna Type	Beams	Frequency Uses	Intra Beam Connection	Antenna Gain (Typical)	Limitations	Prior Use	Satellite Antenna Type
Conus Coverage	1	1-2 (Dual Pol.)	Direct	Low 30 dBi (30 dBi)	Power & Spectrum	DOMSATs	Single Reflector
Multibeam Cluster	Many (N)	(N or 2N) (3 or 4)	Switch	High (53 dBi)	Interference	Advanced Westar	Multifeed or Phased Array
Scanning Beam	Few (N)	Few (N)	Direct for N = 2	Highest (60 dBi)	Interference and Speed of Beam Hopping	Beam Hopping on DSCS-III	Active Phased Array

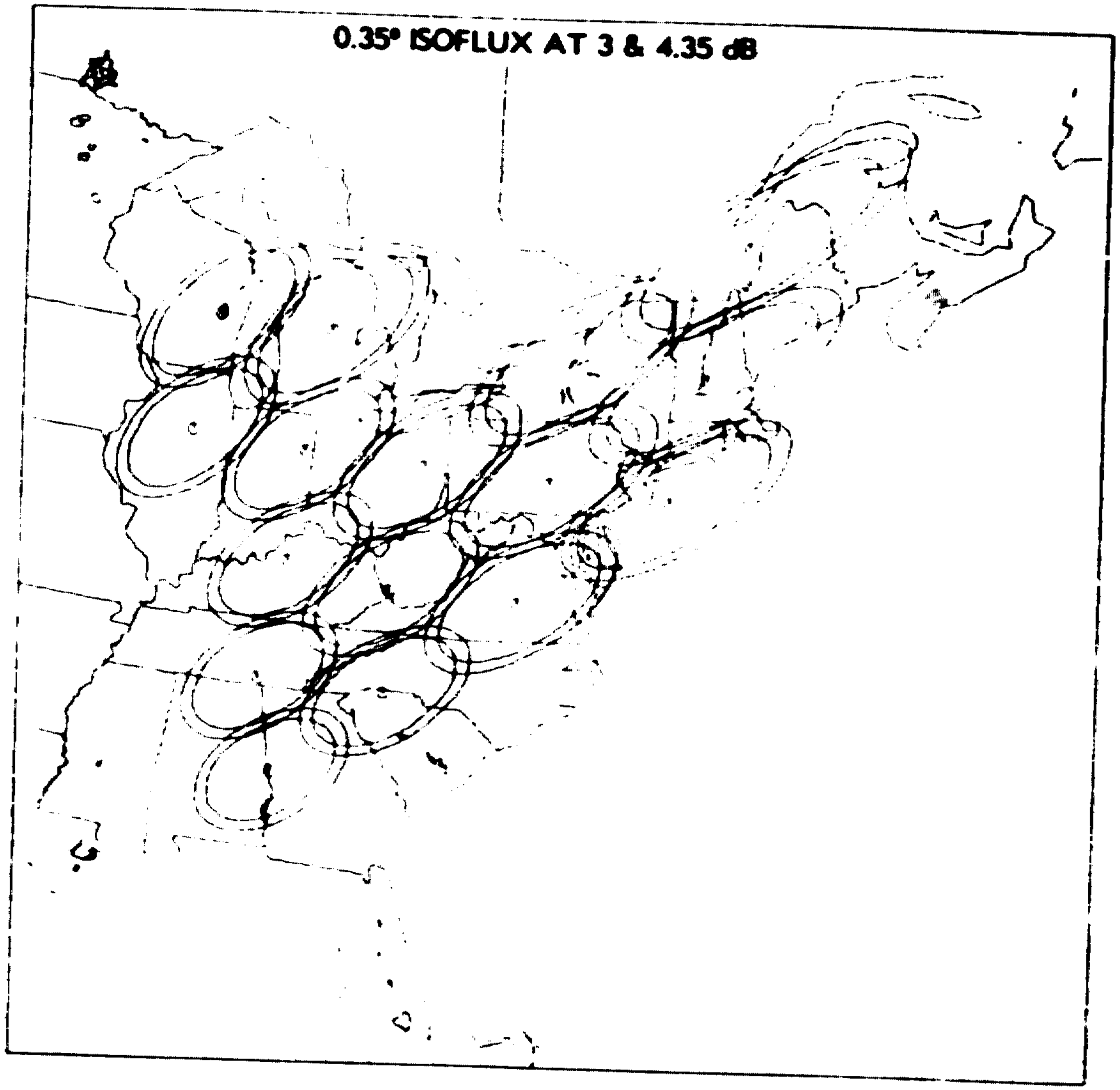


Figure 4-4. Eastern U.S. Coverage

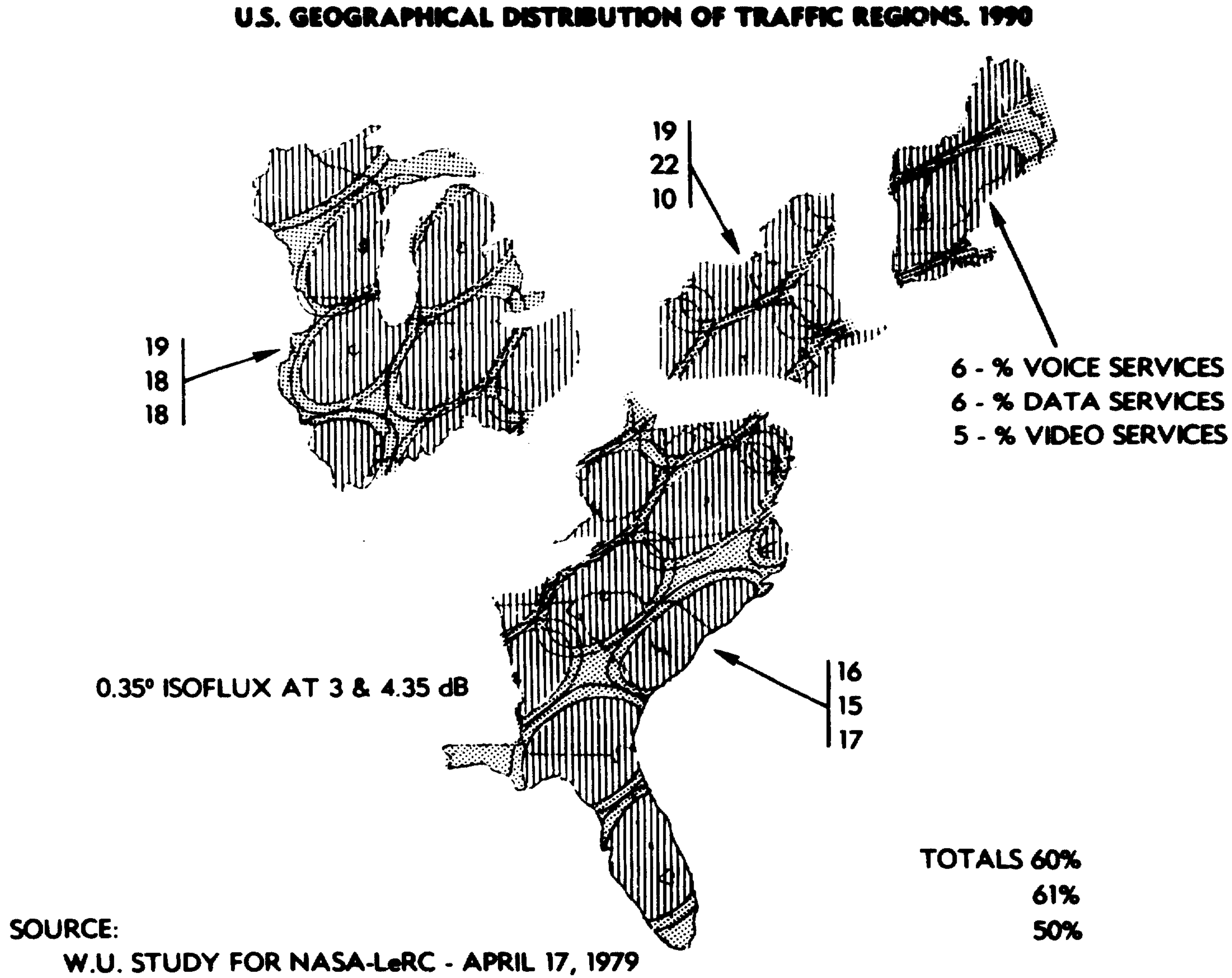


Figure 4-5. Traffic Per Beam

within a single beam to avoid the need for onboard beam-to-beam switching of at least some of this heavy traffic.

4.4 LINK SUMMARY

Table 4-3 is the transmissions link summary for each of the major missions studied by COMSAT. The format uses the successful NASA ATS-F data book technique [11] which permits each up-, down-, and cross-link to be fully specified and compared. Improvements to this format allow the presentation of even more extensive data. Further details will be found in Appendix A.

Column one gives the name of the mission; the second column gives the direction of the link. The bandwidth (BW) of each transmission path occupied by a single carrier is given in column three. In single-carrier per transponder (SCPT) cases (e.g., FM/TV and TDMA), this represents the transponder bandwidth. In single-channel per carrier (SCPC) cases, this is the width of a single information channel. The up- and down-link bandwidths may differ. Up-link traffic may arrive at the satellite in the form of many narrowband channels and be transmitted as a wideband signal that must be processed at an earth station.

The transmitter power requirement (nameplate, not the backed-off output) is also included. For up-links this is the HPA, and for down-links (and cross-links) this is the satellite RF requirement in the specified bandwidth (see Figure 4-6).

The actual e.i.r.p. is derived by subtracting the feed line losses from the transmitter power reduced by backoff and adding the worst case field of view antenna gain. Thus the e.i.r.p. shown is for the most remote earth station in the intended field of view for a down-link, and for the worst earth station antenna pointing error in an up-link.

Table 4-3. Transmission Link Data Summary

Mission	Link	Nominal Frequency (GHz)	RF Beamwidth (MHz)	Transmit Power (W)	Actual e.i.r.p. (dBW)	Antenna – Transmit – Diameter	Antenna – Transmit – Field of View (deg)	Antenna – Transmit – Peak Gain (dBi)	Antenna – Transmit – Field of View Gain (dBi)	Antenna – Receive – Diameter	Antenna – Receive – Field of View (deg)	Antenna – Receive – Peak Gain (dBi)	Antenna – Receive – Field of View Gain (dBi)	G/T (dBi/K)	No. of Beams	Output Backoff (dB)	C/N + M(dB)	Remarks	T_e (K)
Tracking and Data Relay[a]	Down	13.775	25	1.6	54.7	5	0.30	54.5	53.3	1.5	1.0	44.0	41.0	+14	2	0	16	KSA	450
	Down	2.050	20	26	50.1	5	2.0	44.8	44.6	1.5	6.8	27.5	24.5	-2	2	0	13	SSA	450
	Down	13.70	20	30	57.3	2	0.77	46.4	46.2	18	0.08	66.2	63.2	+36	1	2	38	-	450
	Down	2.10641	50 (kHz)	50	28.7	20 el[b]	14.5	~24	~21	1.5	6.8	27.5	24.5	-2	many	5	17	MA	450
	Up	15.0034	25	0.72	41.4	1.5	0.93	44.8	44.7	5	0.28	55.3	53.8	+27	2	0	15	KSA	450
	Up	2.25	12	20	35.8	1.5	6.2	28.4	25.4	5	1.9	38.8	38.7	+12	2	0	15	SSA	450
	Up	14.7	1000	5.0	68.6	18	0.08	66.3	63.3	2.0	0.7	47.2	47.0	+21	1		20	-	450
	Up	2.2875	50 (kHz)	20	31.1	1.5	0.1	28.5	25.5	20 el[b]	14.5	~24	~21	-6	many	5	15	MA	450
Educational Television (C)	Down	2.517	17.5	3	35.9	2 x 2.8	3 x 4	33.5	30.1	3	2.8	35.3	35.0	+15	4	0	14.5		100
	Up	14.45	17.5	2.0	56.1	5	0.28	54.8	54.7	1.5	1.0	44.3	44.2	+17	2	0	21.5		525
Direct TV Broadcast (D)	Up	14.25	40	15	61.5	4.5	0.33	53.9	52.4	1.5	1.0	44.3	44.3	+18.5	3	0	25		371
	Down	0.7	40	100	51.3	7.5 x 10	3 x 4	33.5	33.1	2.5	11.5	23.0	23.0	-7	4	0	15		1000
International (J)	Down	3.950	40	0.01	16.2	5.3	1.0	44.3	44.2	30.0	0.18	59.4	59.0	+40.7	2	5	13		90
	Down	11.325	80	1.5	44.0	1.9	1.0	44.3	44.2	5.0	0.35	55.3	55.1	+30.0	8	0	18		320
	Down	18.950	100	50.0	59.5	1.1	1.0	44.3	44.2	3.0	0.39	55.3	55.1	+30.0	2	0	28		320
	Up	6.175	5	0.01	41.2	30.0	0.11	63.5	63.0	3.5	1.00	44.3	44.2	+14.5	2	0	17		920
	Up	14.250	80	15.00	64.5	5.0	0.30	54.8	54.6	1.5	1.00	44.3	44.2	+18.5	8	0	22		371
	Up	28.750	100	700.00	83.0	3.0	0.25	56.5	56.3	0.75	1.00	44.3	44.2	+15.0	2	0	33		920
Meteorological (L)	Up	0.150	50 (kHz)	2	27.4	--[c]	8	26.1	26.1	3	47	6	6	-21	1	0	20	Command	500
	Down	0.137	20 (kHz)	20 mW	-3.4	--[d]	--[e]	19.0	14.7	--[d]	8	26.1	23.1	0	1	0	15	APT	200
	Down	17	6	1.25	43.3	1.25	1.0	44.2	42.8	6	0.20	58.0	56.0	30	1	0	25		400

[a] Similar to TDRS's.
[b] Phased array.
[c] Yagi.
[d] Helix.
[e] Global.

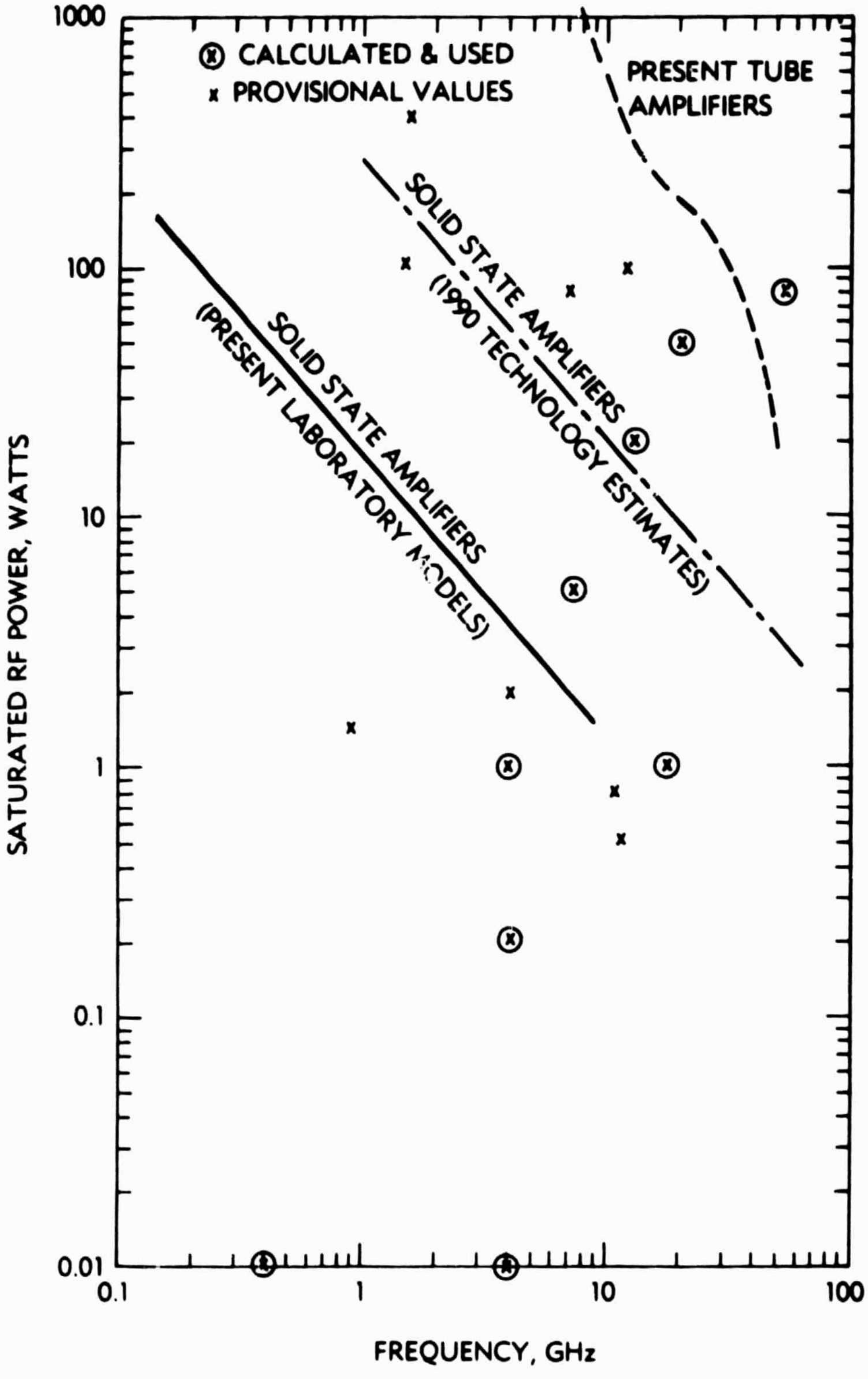


Figure 4-6. Down-Link Transmitter Requirements

Columns seven through fourteen deal with antenna performance. The first four columns characterize the transmit antenna and the last four the receive antenna. The location of a transmit antenna depends upon the link direction.

Columns seven and eleven state the actual reflector diameter. When a large number of beams are involved, each beam may illuminate only part of the reflector (see Figure 4-7); therefore, the actual reflector has been oversized. If this had not been done, the extreme coverage beams would over scan ("spill over") the reflector's surface and produce distorted, lower gain beams with uncontrolled sidelobes.

The field of view (defined as the half-power beamwidth) is also given in Table 4-3. In conformance with usual engineering practice (and to meet typical needs of a future satellite switch), the up- and down-link satellite coverages are made identical.

Antenna gain is specified in two manners. The first, on-axis or peak gain, is the value specified by earth station antenna manufacturers and others. The second is the practical or useful gain at the extreme limit of performance. The difference between these two values includes the antenna pointing error (either due to satellite attitude control or earth station tracking) and the location of the receiver within the antenna beam. For satellite antennas in the single point service (one earth station located at the nominal on-axis position), the difference is primarily the 0.1° platform pointing accuracy (unless otherwise specified in Appendix A). Satellites providing multipoint services (e.g., television) or services involving more than one earth station per beam must account for the gain loss to the worst station location. In these cases, it was assumed that the station was located at the one-half or one-εth power contour.

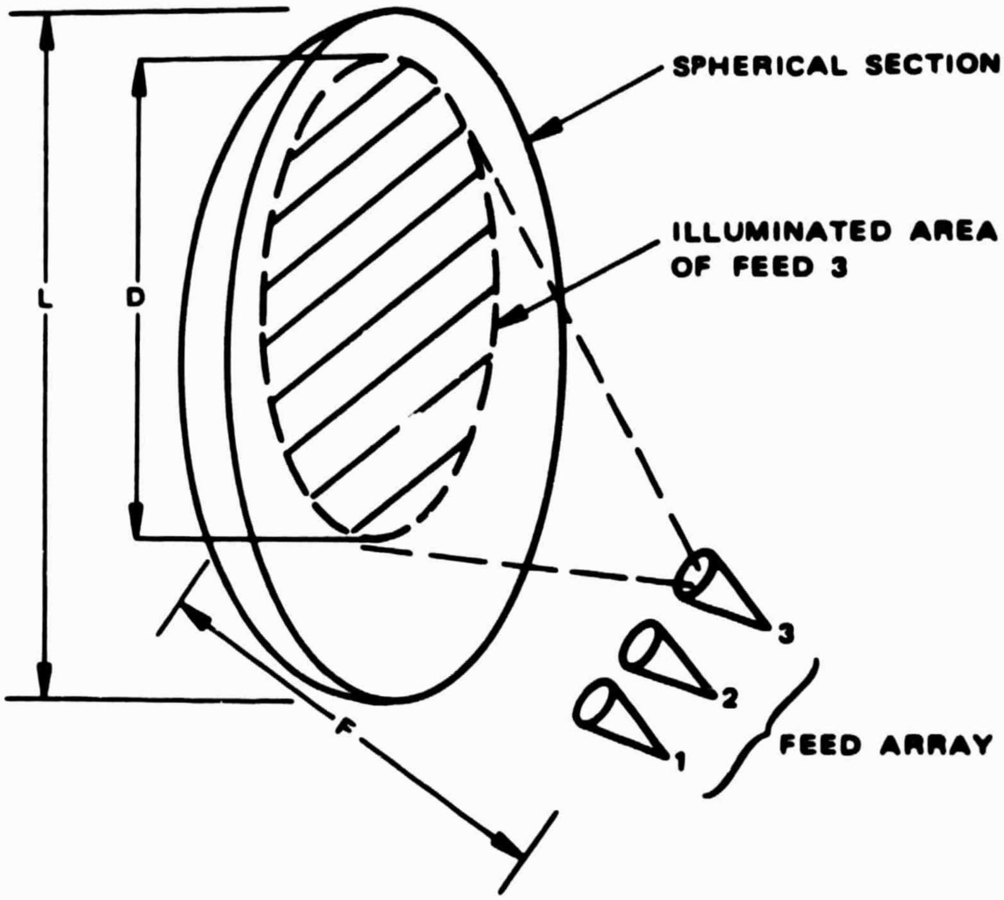


Figure 4-7. Multibeam Antenna Illumination

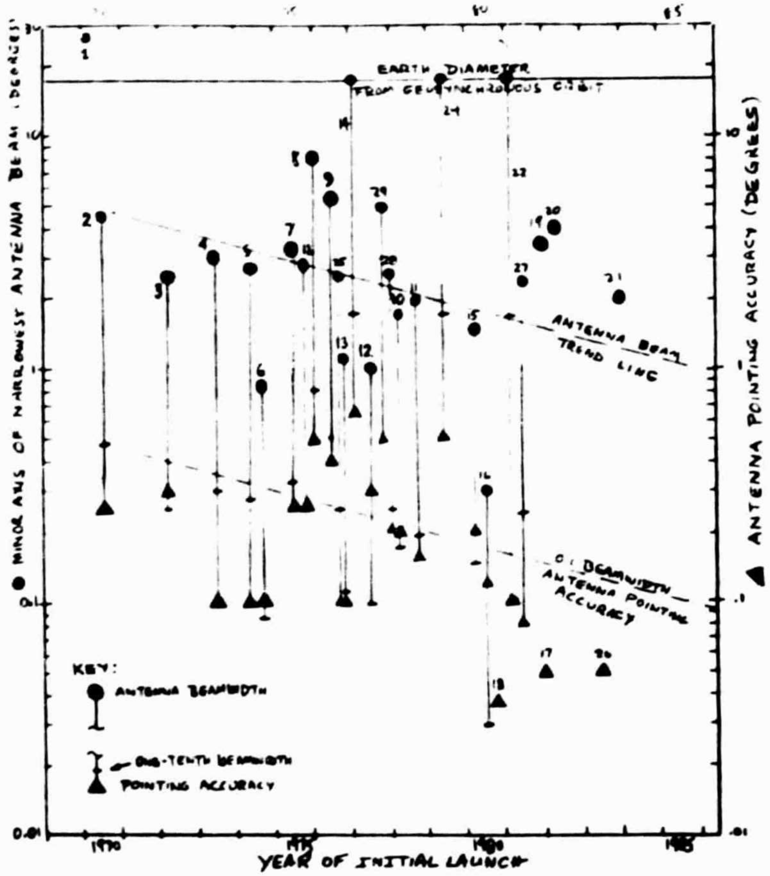
Column 15 gives the figure-of-merit (G/T_s) for the link. This is the satellite field of view receive gain minus the system noise temperature (shown in the last column). For down-links the earth station G/T_s was established by the user survey. From this, the earth station antenna diameter was determined. In general the same antenna diameter was used for the up-link. The e.i.r.p. and the HPA size were then selected. These, in turn, influenced the platform equipment.

Column 16 identifies the number of beams involved at a single platform location. When multiple beams or frequencies were used, a line item is given for each type. The output back-off relates to the power amplifier. In FDMA multichannel operation, it is common to backoff the transmitter output power to reduce intermodulation distortion. In general, this does not apply to single-channel per transmitter (SCPT) operation.

Column 18 shows the sum of the link's carrier-to-noise ratio (C/N) and margin (over the detector threshold). The threshold varied as a function of the earth station size from 7.8 dB (threshold extension demodulator) to 12 dB. This column is used to provide margins for rainfall, equipment degradation, etc.

4.5 POINTING REQUIREMENTS

The antenna beam pointing losses are included in Table 4-2 based upon the type of service (point-to-point or multipoint) and a 0.1° platform pointing capability. This value was derived based on current satellite technology for small rigid satellites (see Figure 4-8) and the antenna beam requirements. Although these data may not apply to a large flexible structure, they should be attainable for the rigid structures originally envisioned by NASA [2]. Several missions required subplatform



1- DCSC-I
2- INTELSAT IV
3- DSCS-II
4- ANIK-A
5- WESTAR
6- ATS-6
7- COMSTAR
8- SYMPHONIE
9- NATO III
10- BSE (YURI)
11- ANIK-B
12- SATCOM
13- LES-8 & -9
14- MARISAT
15- INTELSAT V
16- TDRS/AW
17- LO-4 (H-SAT)
18- SBS
19- ECS (ESA)
20- INSAT
21- SATCOL
22- MAROTS
23- CS (SAKURA)
24- FLTSATCOM
25- CTS (HERMES)
26- TVBS (Germany)
27- DSCS-III
28- OTS
29- SIRIO

Figure 4-8. Pointing Accuracies of Contemporary Satellites stabilization of less than 0.1° for pointing narrowbeam antennas or radiometers. Tradeoffs between platform and antenna pointing requirements will be studied in subsequent contracts. Basically, mass and power may be traded. If the platform pointing accuracy is poor, the field of view antenna gain drops and more transponder power is needed to maintain the link figure of quality. Traffic routing problems may also be encountered if it is uncertain which beam is covering Atlanta at any given time. Conversely, a tight platform specification may require excessive flywheel power and structural rigidity.

4.6 STATIONKEEPING

A study of the platform stationkeeping requirements concluded that large non-tracking earth stations impose the most severe requirements on the platform. A continuation of the achieved ±0.01° to +0.1° stationkeeping is justified until smaller earth station antennas (made possible by the higher satellite antenna gain) are used.

4.7 PLATFORM LOCATIONS

The U.S. coverage is shown in Figure 4-9. The scale at the bottom of the figure shows the longitude (degrees West) for 10° elevation angles for the limit cities shown. The overall limit to satisfy the 10° minimum for all these sites is 100° to 131°W. Figure 4-10 provides this information for angles between 0° and 20° for various North American sites. The selected locations are 120°W (prime) and 116°W (alternate). Figure 4-11 shows the orbit arc coverages for Western Europe. Table 1-1 lists the selected prime and alternate platform locations, which will need to be coordinated with other users. The early 1979

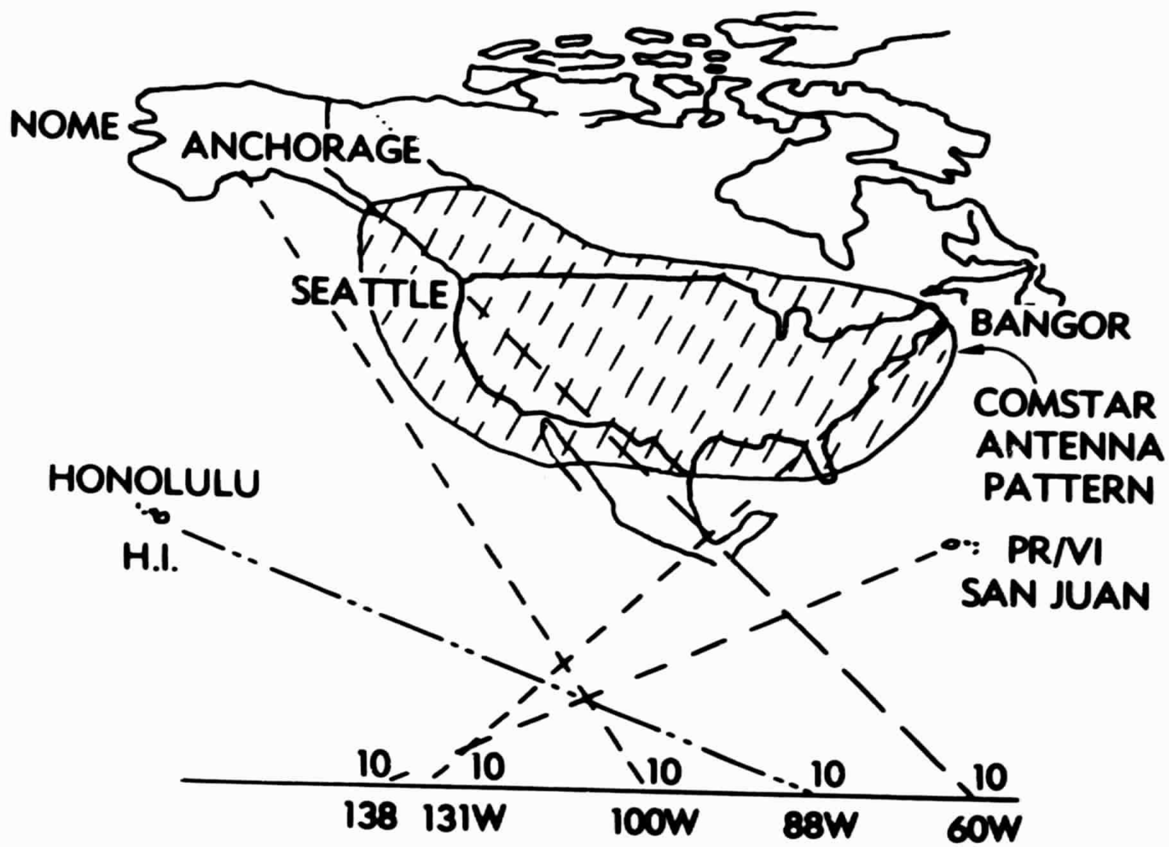


Figure 4-9. Coverage of the USA

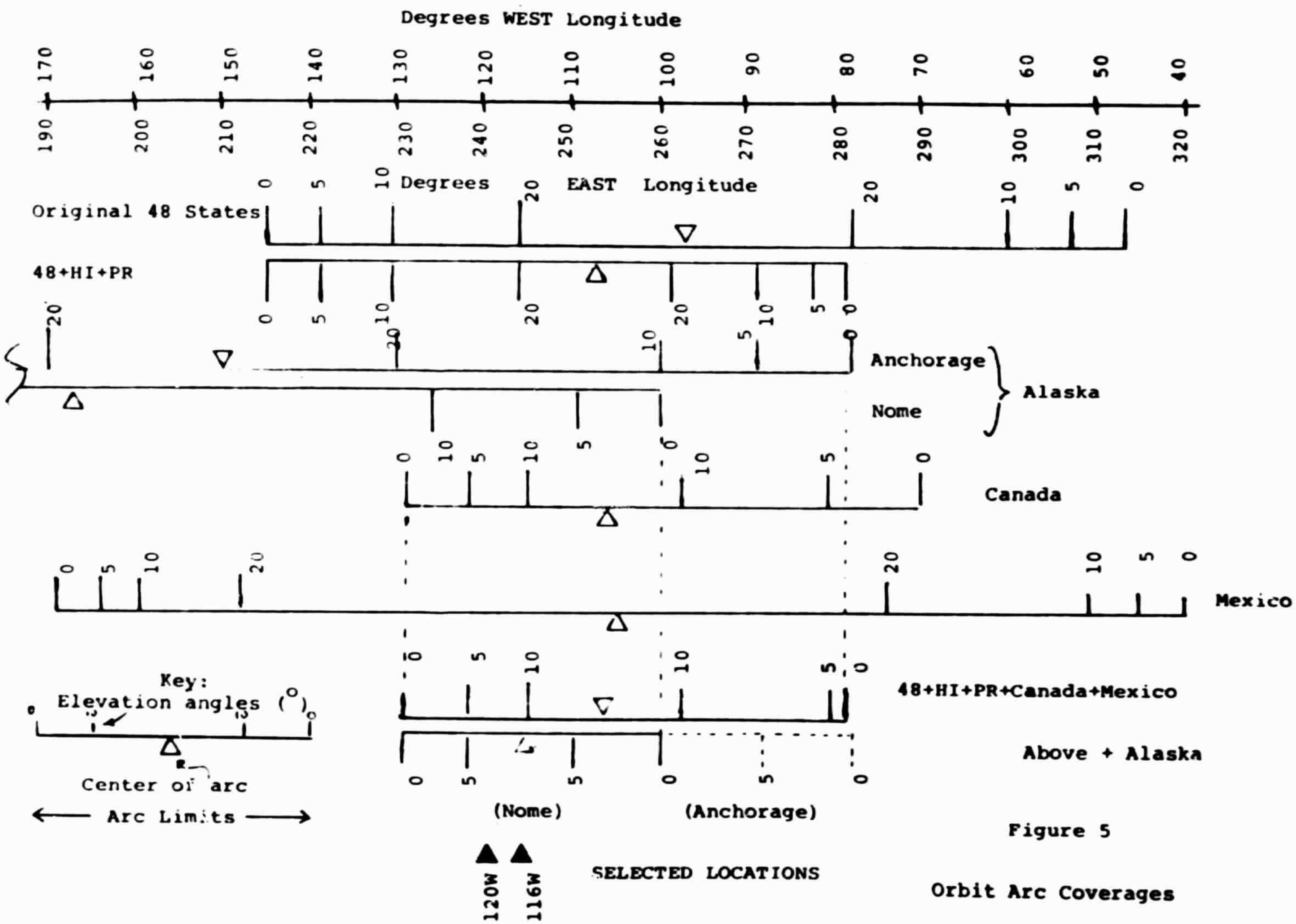


Figure 4-10. Elevation Angle vs Location (North America)

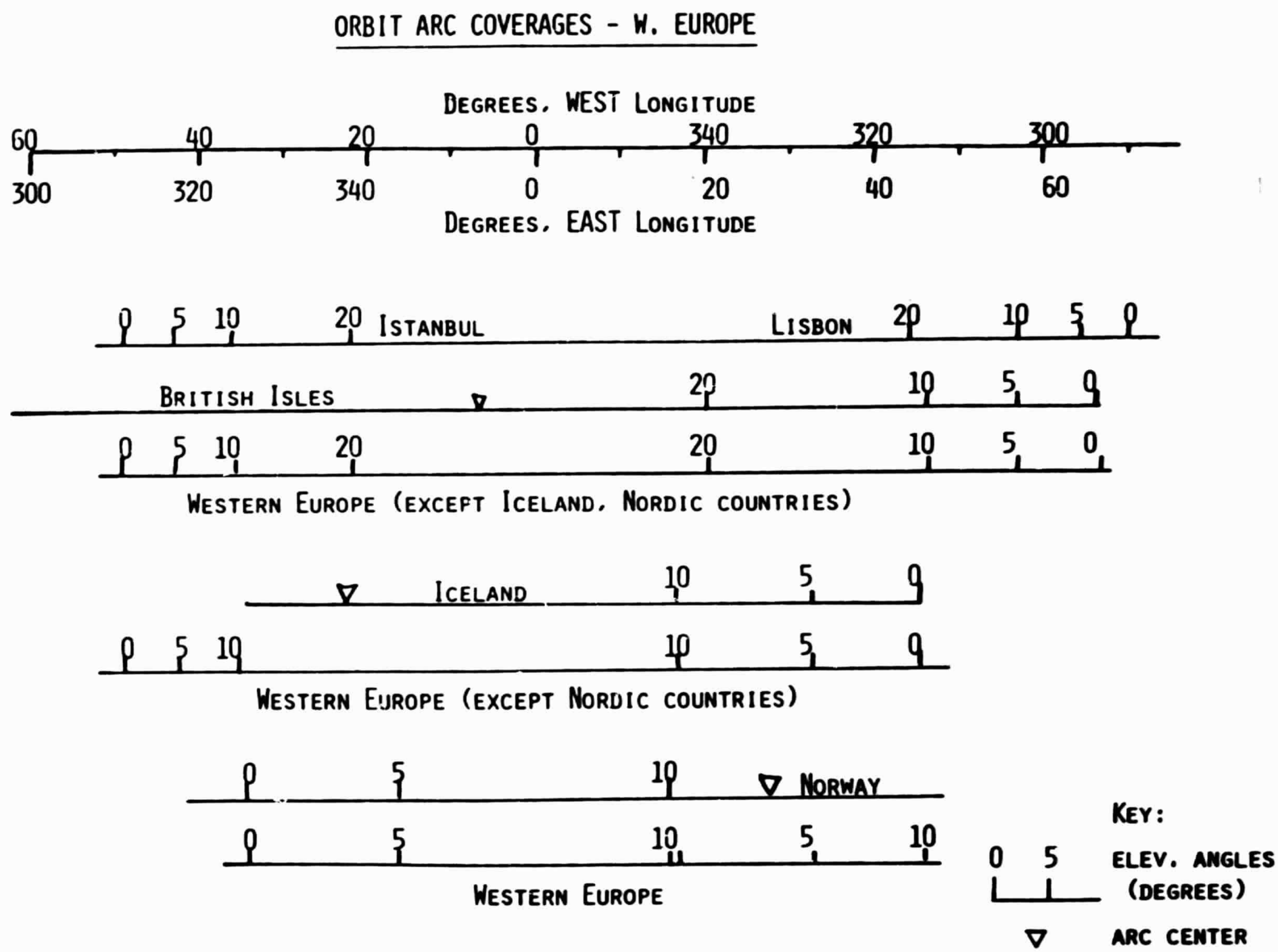


Figure 4-11. Coverage of Western Europe

satellite occupancy of the geostationary orbit is shown in Figure 4-12 [12].

4.8 MARKET SHARES

The market shares captured by satellites in 1984 are shown in Figure 4-13. The polygons give a weighted (by proximity of the person surveyed to a particular marketplace) estimate of the traffic portions. The bar graphs are unweighted.

4.9 MISSION INTERCONNECTION

The mission payloads are connected through ports in the interconnect switch, which was studied as part of the Aerospace Corporation contract [3]. However, not every mission needs to be interconnected as shown in Figure 4-14.

4.10 MULTIBEAM ANTENNAS

Section 4.3 and Figures 4-4 and 4-5 indicate limitations on spectrum reuse. A series of studies that were conducted using computer simulation under near perfect conditions examined individual beams and limited subsets of a national coverage using clustered beams. Figure 4-15 is modified from the Aerospace Corporation report [3]. The A, B, and C cells each fully utilize one-third of the spectrum in each of the two polarizations. If there are 54 beams each with one-third of the spectrum (500 MHz/ 3 = 166.7 MHz) and two polarizations, the total spectrum is

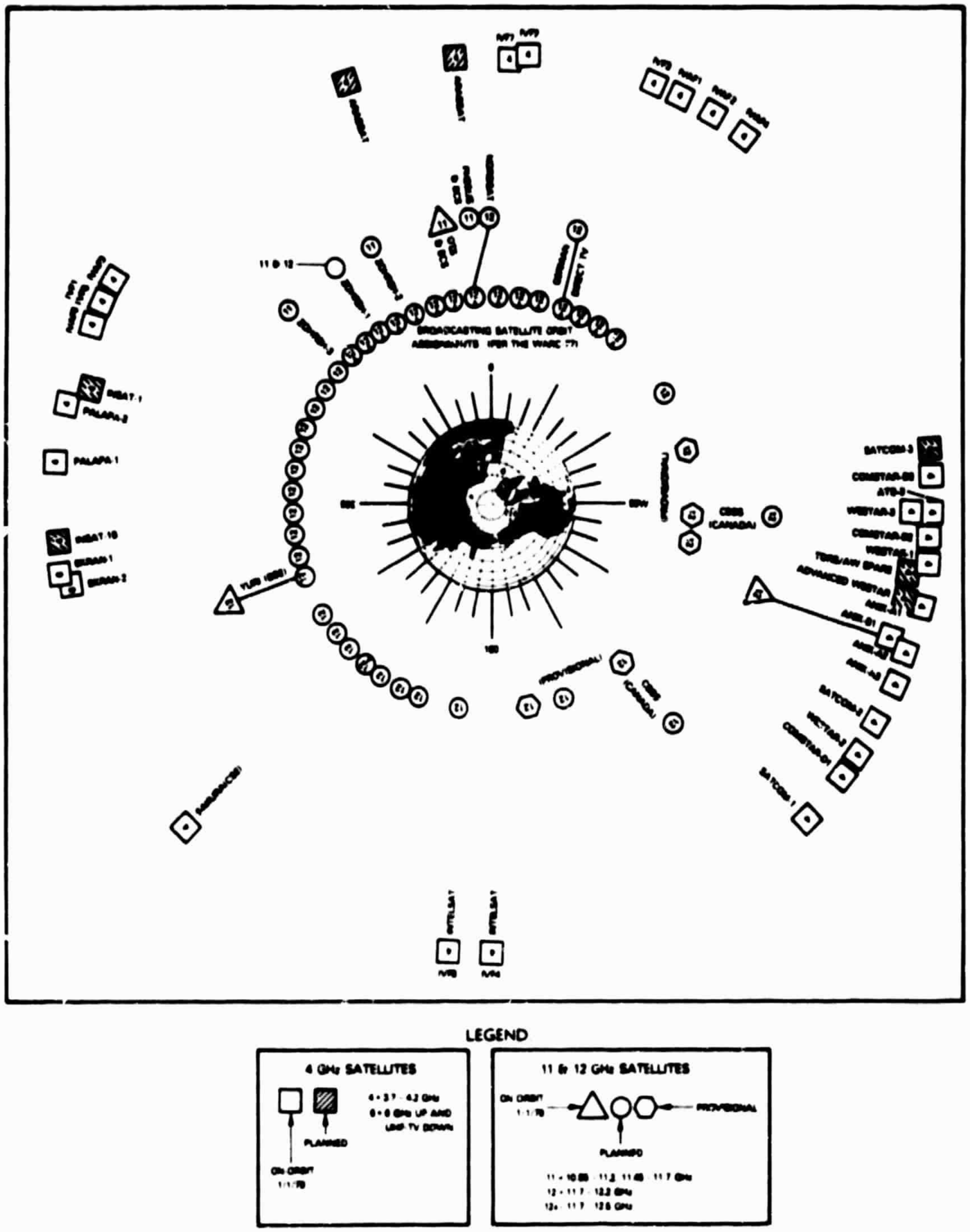


Figure 4-12. Orbit Occupancy

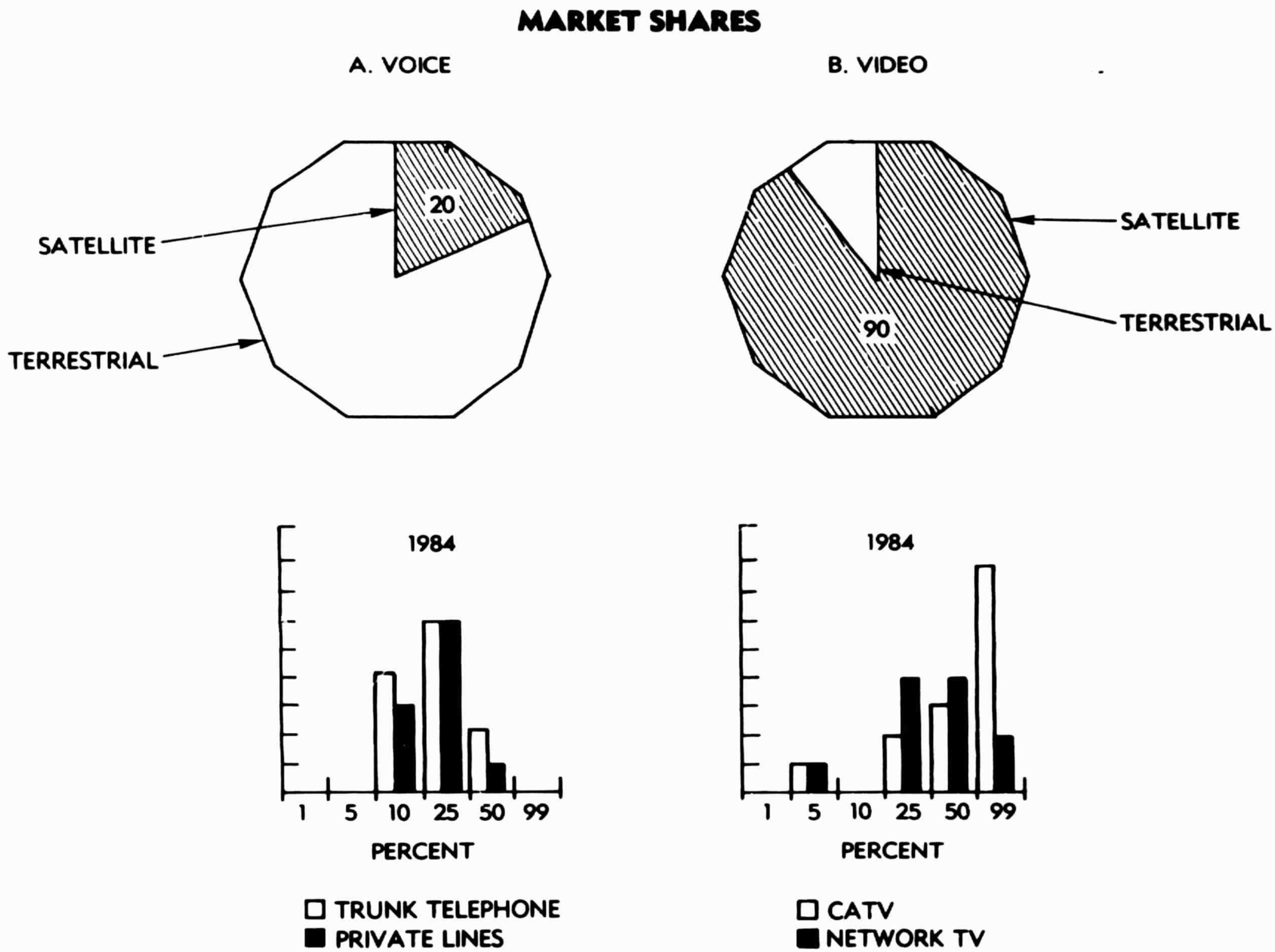


Figure 4-13. Traffic Projections

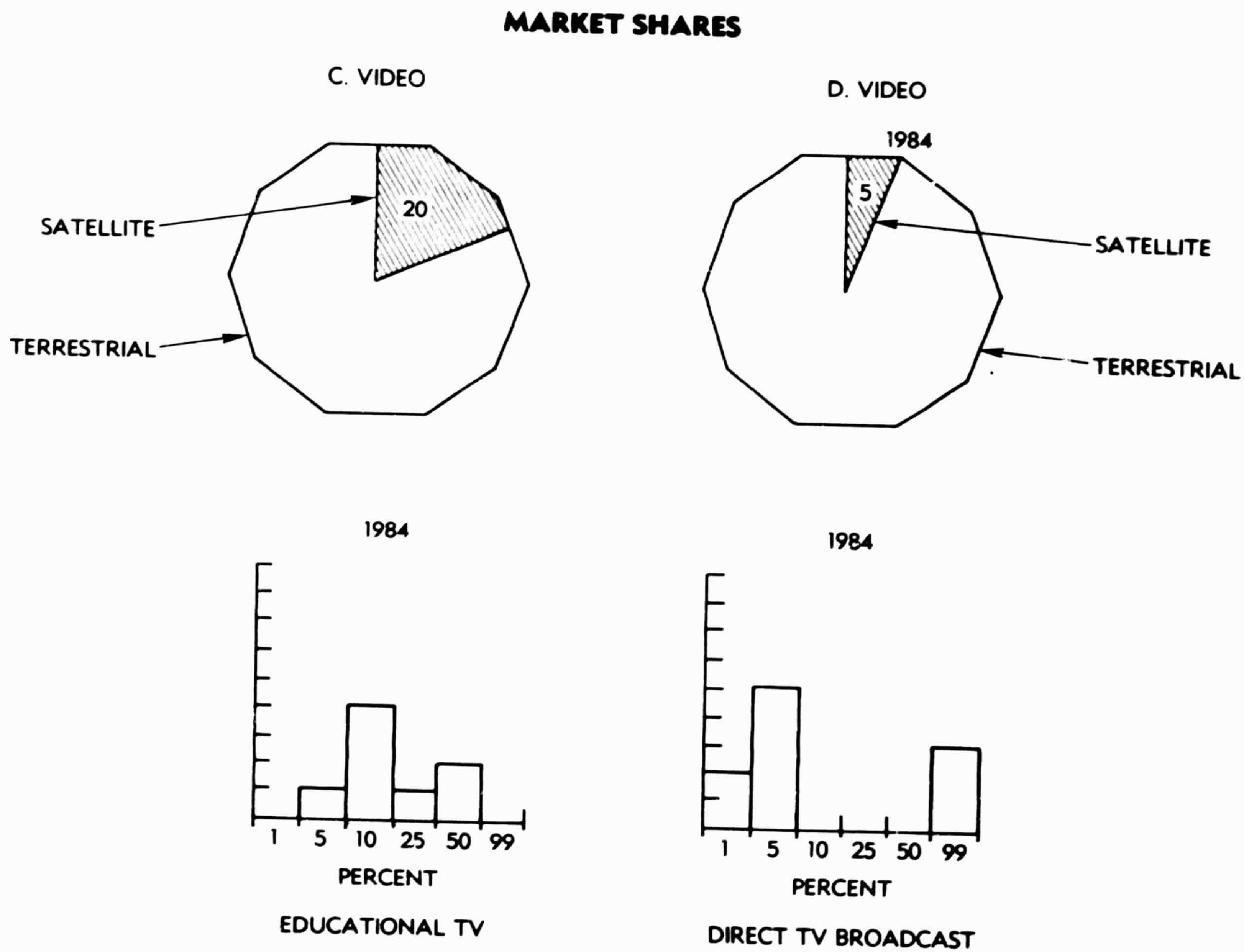


Figure 4-13. Traffic Projection (cont.)

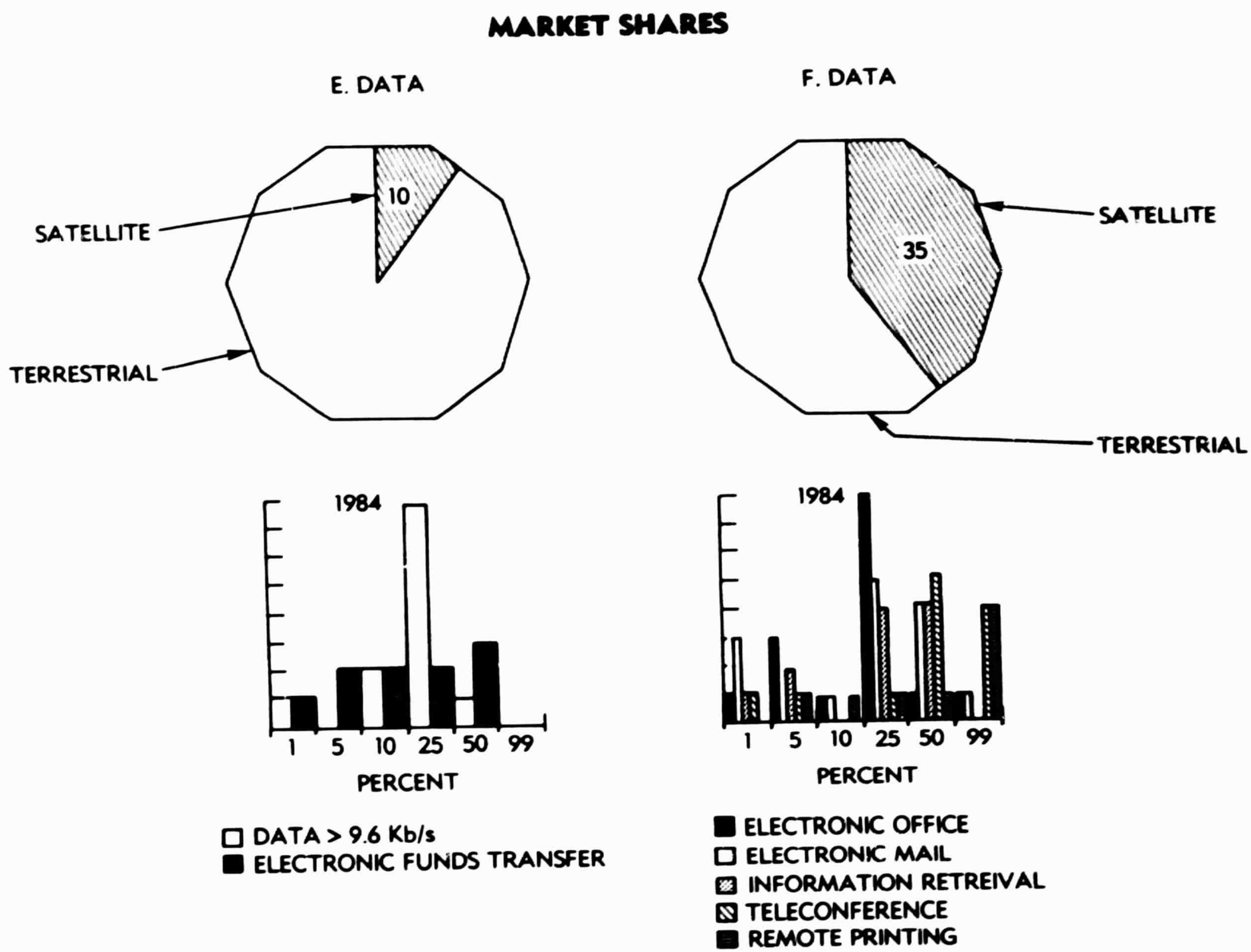


Figure 4-13. Traffic Projections (cont.)

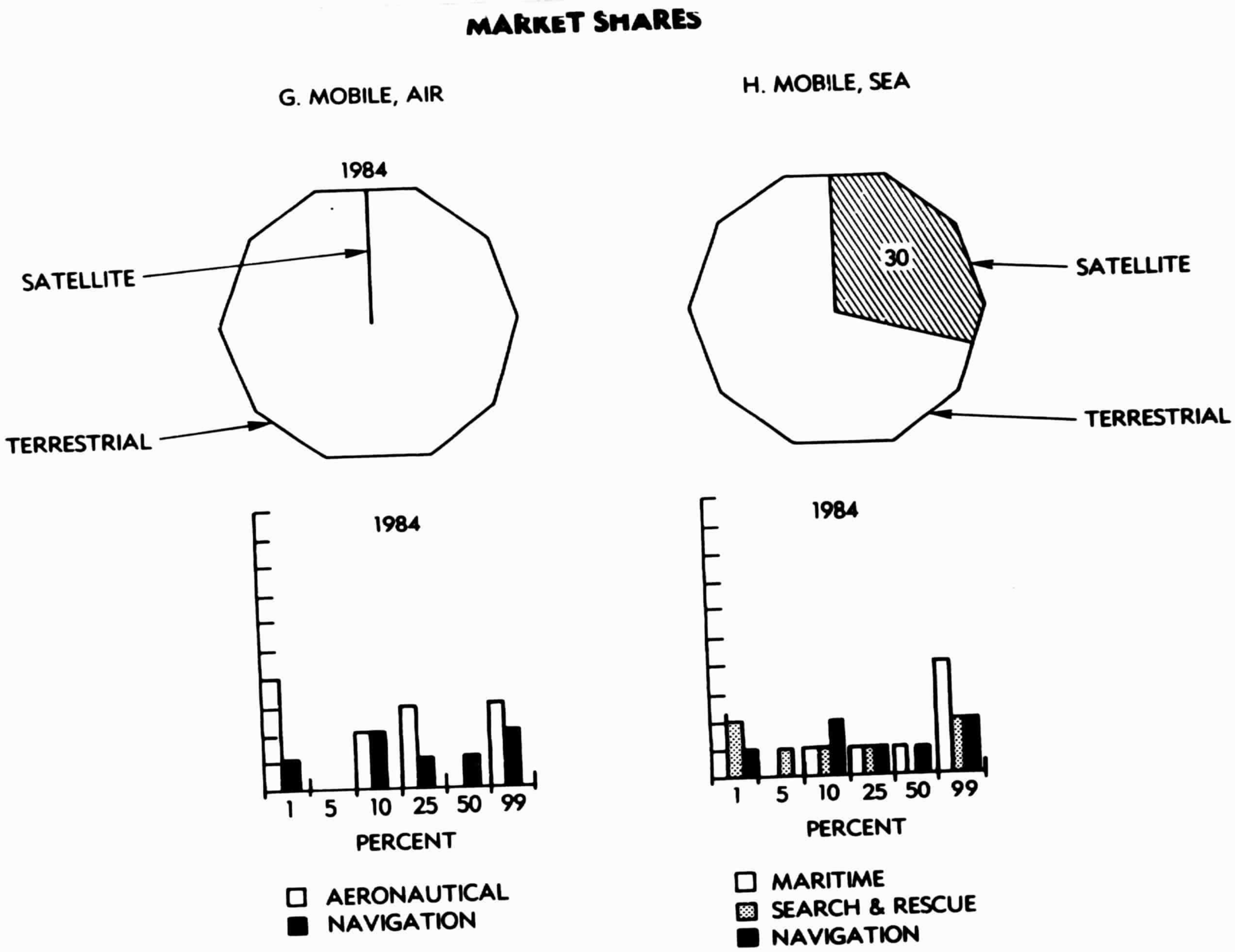


Figure 4-13. Traffic Projections (cont.)

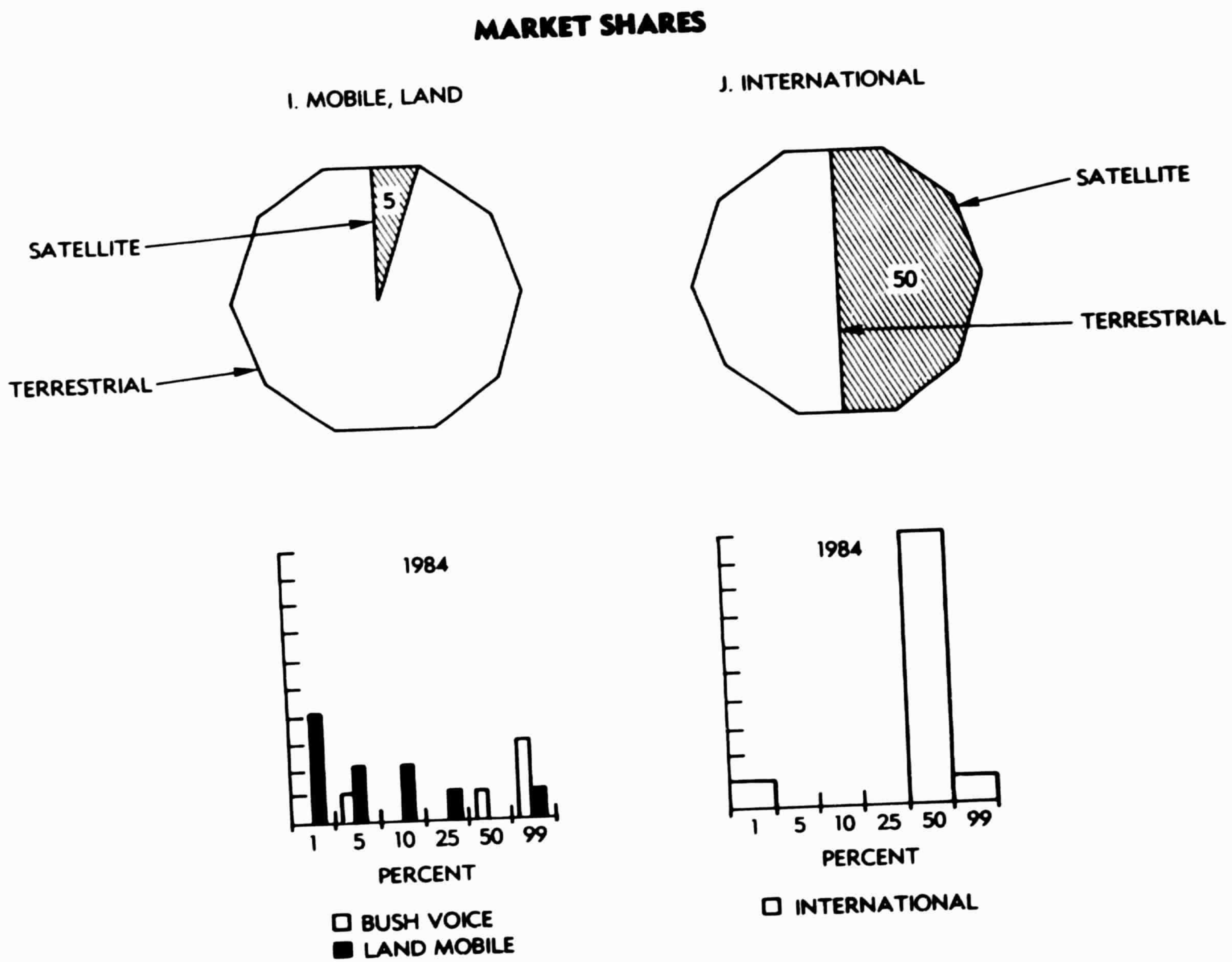


Figure 4-13. Traffic Projections (cont.)

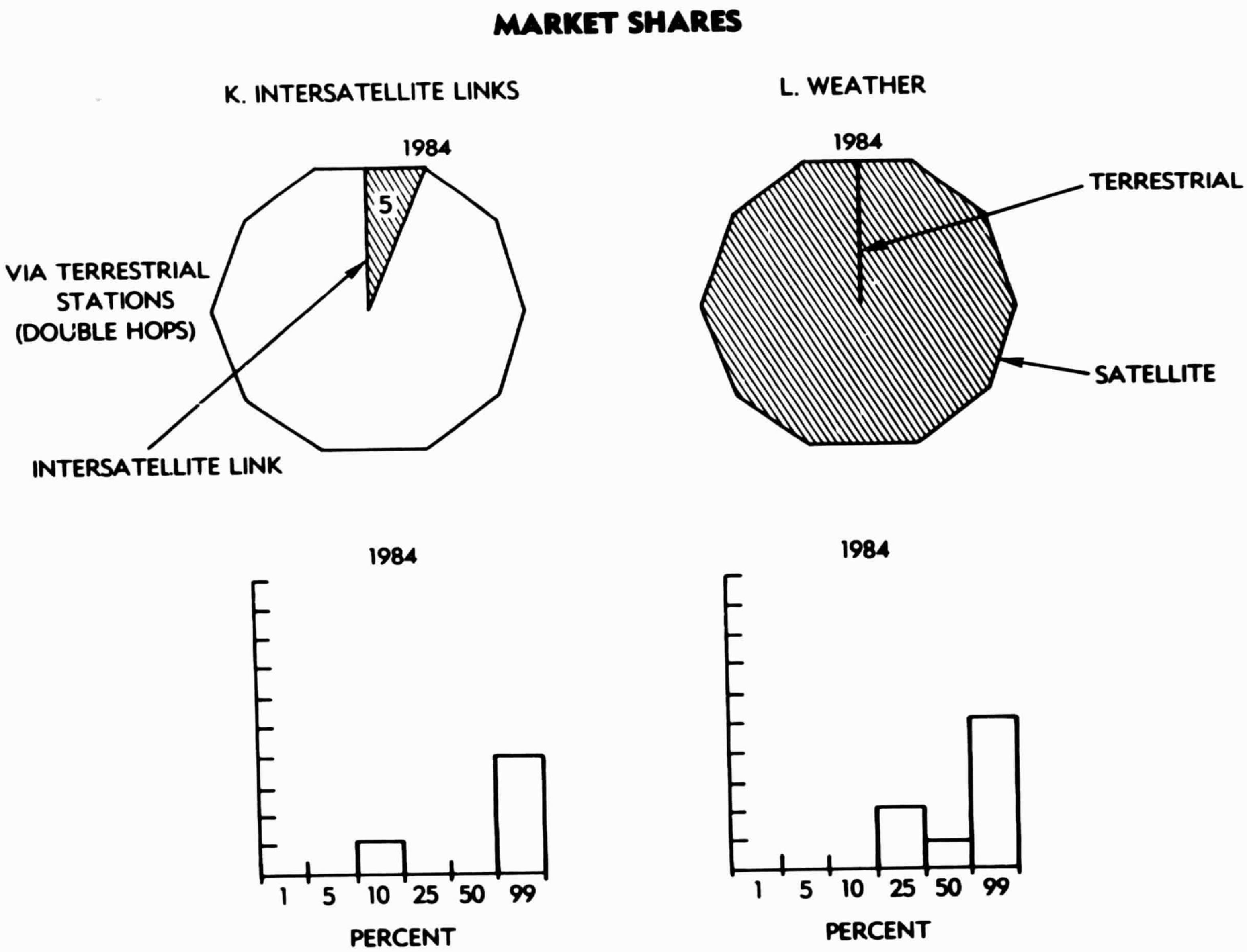


Figure 4-13. Traffic Projections (cont.)

MISSION CATEGORY

FROM

TO	1	2	3	4	5	6	7	8	9	10	11	12
1	*	*	*				x	x	x			
2	*	*	*				x	x	x	x	x	
3	*	*	*									
4												
5												
6												
7	x	x										
8	x	x										
9	x	x										
10		x									x	
11		x								x		
12												

☐ NO MISSION CATEGORY INTERCONNECTION

☒ MISSION INTERCONNECTION

* SEE AEROSPACE CORPORATION REPORT

Figure 4-14. Interconnection Between Mission Payloads

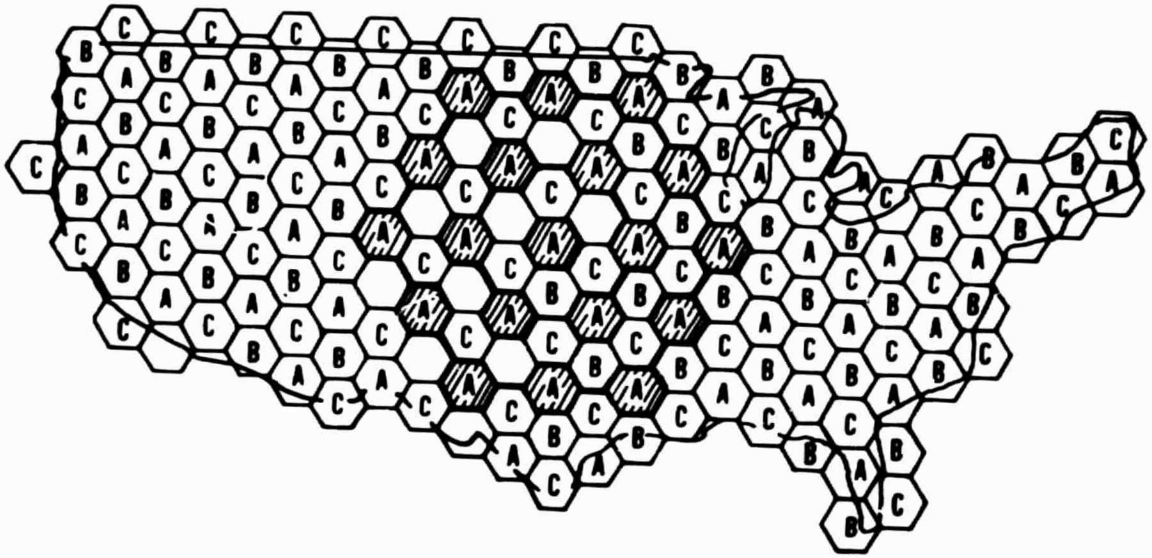


Figure 4-15. Three-Frequency Plan

$$B_A = 54 \times (500/3) \times 2 = 18{,}034 \text{ MHz}$$
$$B_B = 58 \times (500/3) \times 2 = 19{,}329 \text{ MHz}$$
$$B_C = 61 \times (500/3) \times 2 = \underline{20{,}341} \text{ MHz}$$
$$B_{TOTAL} = 57{,}704 \text{ MHz}$$

(57.7 GHz)

(1442 transponders @ 40 MHz)

The number of C beams exceeds A and B only because of the geometry selected by the Aerospace Corporation. The total numbers, which are the most important, are based on uniform traffic loading. In reality, traffic is not uniform in either the spatial or temporal sense and, therefore, B_{TOTAL} is only a reference value.

If one feed horn per beam is used with a long focal length and an oversized reflector (see Figure 4-7), the sidelobe interference of the single beam located two beamwidths away is 24 dB into the most susceptible part of the desired beam (the + in Figure 4-16). Since there are six beams at two beamwidths (Figures 4-15 and 4-16) in the first ring, the actual level is approximately 24 - 10 log n, where n is the number of beams in the ring. The second ring (actually two rings) has an interference level of 30 dB, but n is twice as large. As shown in Figure 4-15, there are additional rings but the per beam interference level continues to fall. The actual carrier-to-interference ratio (C/I) is computed on the noise power sum of the interference.

A C/I goal of 35- to 38-dB per beam from the worst beam should be considered in future studies. This will require a combination of techniques; the first is further beam spacing. Figure 4-17 shows a four beamwidth spacing which yields 14 uses of A. The use of seven beamwidths as the minimum reuse spacing has also been suggested. The next technique is to use a network of power dividers, phase shifters, and multiple feeds to form the beams and,

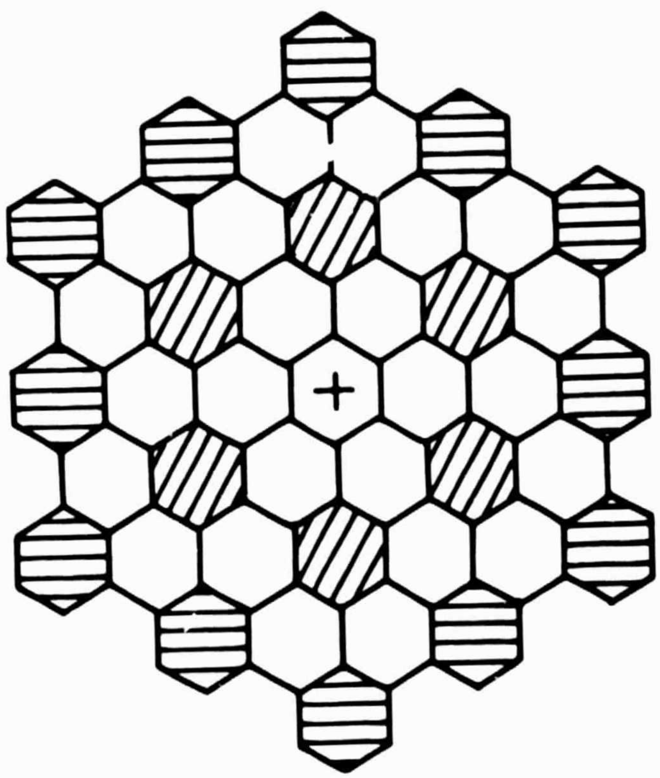


Figure 4-16. Beam Locations

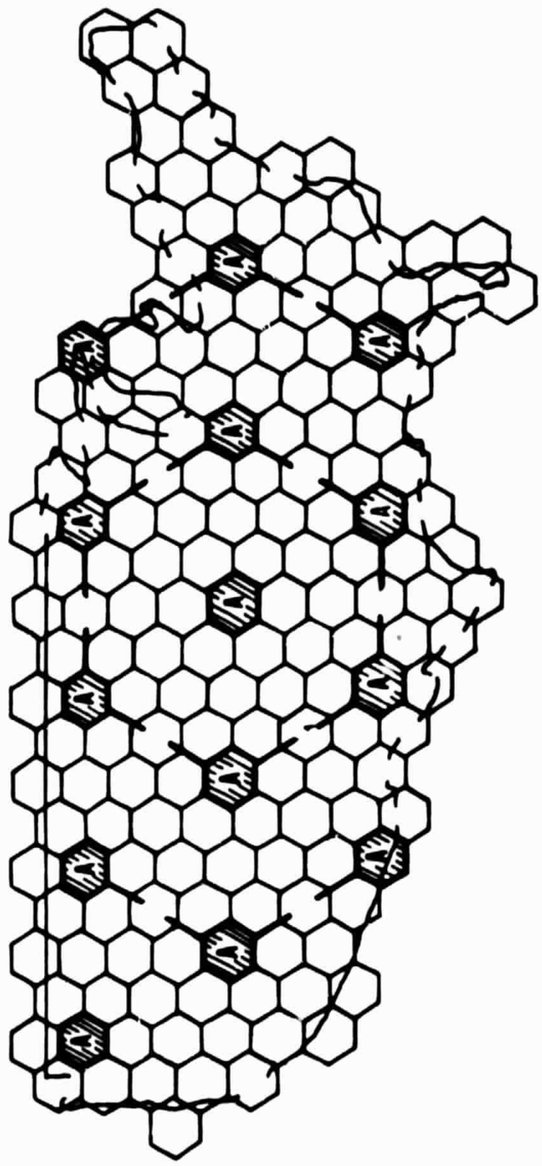


Figure 4-17. Twelve Frequency Plan

thereby, control the sidelobe levels. Feed-sharing may be possible between beams. Another method involves avoiding the influence of any object in the field of view of the beam. This includes subreflector supports, booms, and nearby structural elements that either block (reflect) the beam or act as parasitic re-radiators [13].

Because of the regular location of the beams, it may be desirable to form beams with heximetric sidelobes if the Aerospace Corporation concept is utilized. All of these techniques are sensitive to the feed network and the environmental effects of time and age. Substantial improvements are required in the techniques of measurements using far-field test ranges [14].

After an antenna is depolyed in low earth orbit, it should be possible to repeat the earth tests to verify performance. A third test would be performed on the geostationary orbit [15] to determine the effects of the ascent, of lunar/solar/stationkeeping/subplatform torques, and of age on the antenna's performance.

New diagnostic tools to simulate interbeam interference (first on a co-polarized basis, and then for cross-polarized components) will be necessary to make possible the extensive spectral reuse envisioned in the Aerospace Corporation study (see Appendix A, direct-to-user system with 480 transponders). Another alternative is to utilize interference resistant modulation techniques to accommodate the decreased C/I. These have been studied for military applications which require jam resistance; however this may be counter productive, since more bandwidth is normally necessary.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 PLATFORM INTERFACE REQUIREMENTS

Table 1-4 summarizes the platform interface requirements derived from the detailed analysis summaries of Section 4 and Appendix A of the Technical Volume of the Final Report. Table 5-1a and b details individual mission performances.

5.2 ADVANCED ANTENNA DESIGNS

Studies in the antenna area have indicated that additional work is needed on multibeam antennas using wide scan angles. The shape of the individual beam patterns varies over the area to be covered (contrary to simplistic hexagonal presentations), and interference from the summation of the individual sidelobe levels can be significant. These studies suggest that, by breaking the area to be covered into different parts (e.g., a nation into several regional markets using various independent reflectors), the scan angle may be restricted to maintain pattern shape and to reduce sidelobe levels. Since these topics are being addressed in other studies [16,17], these results should be integrated into any follow-on work.

Table 5-1a. Summary of Payload Configurations[a]

Parameters	Direct-to-User System	High-Volume Trunking System	Broadcast
Transponders			
Frequency Band	Ku	C	Ku
No.	480	200	54
Burst Rate (Mbit/s QPSK)	64	256	64
P.A. RF Power (W)	1	0.05	10
NF (FET preamp) dB	5.5	3.4	5.5
kg[c]	1130	340	275
DC Power (W)	3700	940	2910
Antennas			
Type	Center Fed Cassegrain	Center Fed Cassegrain	Offset Fed[d] Feed Plane
Diam of Refl. (m)	5 (3 reflectors)	30	1.5
Gain (dB)	54.5 (up-link) 53 (down-link)	59 (up-link) 56 (down-link)	~34
Sidelobe Objective (dB)	28	28	Not Critical
Required Accuracy Pointing	0.03°	0.01°	0.01°
kg	96	250	9
Switch-Fast Matrix			
Size	630 x 630	240 x 240	50 x 50
Matrix			
kg[c]	240	36	4.8
DC Power (W)	4000	400	40
Total Wt kg	1666	626	289
Total DC Power Watts	7700	1340	2950

[a] Source Aerospace Corporation.
[b] 40 transponders operated at 512 Mbit/s using higher level PSK.
[c] Includes 20 percent additional for redundancy and on-orbit servicing.
[d] Using polarizaiton-sensitive sub-reflector.

Table 5-1b. Summary of Additional Communications Payloads

Parameters	Tracking & Data Relay 4	Educa-tional TV 5	Direct TV Broadcast 6	Air 7	Sea 8	Land 9	Inter-national 10	Inter-Platform Links 11	Data Collection 12
Transponders									
Frequency Band[a] (GHz)	2.0-15.0	2.5-14.5	0.7-14	1.5-5	1.5	0.9	4-30	55	0.4
Number (active)	6	32	8	3	4	19	12	1	1
Bandwidth (MHz)	110	17.5	40	400.4	0.2-0.6	2-17	40-100	500[b]	1
RF Power (rated W)	1.6-50	6	100	5-90	2-70	60-560	to 50	65-300[b]	0.3
T_S (K)	450	525	371	354	1000	200	377-920	600	1000
Mass (kg)	70.3	424	362	128.9	52	1644[c]	123[c]	48[b]	17.5
Power (W)	444	368	2064	869	437	7920[c]	425[c]	308[b]	18
Antennas									
Type	TDRS[d]	Offset	Centerfed	Helical	Helical	—[e]	Several	Special	—[e]
Diameter (m)[f]	0.7-18	2x2.8	7.5x10	Array	14 m	—[e]	0.75-5.3	3	11
Gain (dBi)[f]	24-55	44.3	44.3	19	44.3	44.3	44.3	—[b]	30
Sidelobe Objective (dB)	TDRS[d]	30	30	30	30	30	30	—[b]	n.a.
Pointing Accuracy (deg)	TDRS[d]	0.1	0.1	0.1	0.1	0.1	0.1	b	0.1
Mass (deg)	31	54.8	7.3[e]	23.6	[illegible]	45[e]	53	40	25[e]
Totals									
Mass (kg)	101.3	478.8	369.3	152.5	59	1689[c]	178[c]	88[b]	42.5
Power (W)	444	368	2064	869	437	7920[c]	425[c]	308[b]	18

[a] Subject to revision as the result of GWARC-79.
[b] See Technical Volume.
[c] North America.
[d] Tracking & data relay satellite model.
[e] Uses HVT reflector
[f] Largest.

5.3 ATTITUDE CONTROL AND STRUCTURAL RIGIDITY

Occasionally, the antenna and radiometer beam pointing requirements necessitate subplatforms even if an overall platform pointing accuracy of 0.1° can be maintained. The use of light rather than hexagonally rigid structures |2| will increase flexibility; therefore, the platform pointing errors may be greater. Also, under thermal stress conditions, the long booms may warp. This study has successfully identified individual antenna beam pointing requirements; subsequent studies (already under contract) have been tasked to consider these tradeoffs which involve platform structure vs subplatform mass, power, and reliability.

5.4 SATELLITE SWITCHING

Onboard satellite switching was studied under the companion Aerospace Corporation contract and will be the topic of three subsequent NASA-Lewis contracts |18|. Switch complexity increases with the square of the number of beams, and the mass increases substantially (as indicated in the Aerospace studies). The removal of the internal switch heat will be an important aspect for future study.

5.5 PLATFORM SIZING

The dates of substantial service introduction (as envisioned by the users) vary substantially as shown in Table 5-2; therefore, the missions to be included or excluded from an initial platform should be determined. This list of missions depends upon the launch date selected for the geostationary platform.

Table 5-2. Approximate Date of Substantial Service Introduction

1.	Aeronautical Communications	1985
2.	Bush Voice	(Now)
3.	CATV	(Now)
4.	Data (>9600 b/s)	Some Now, Bulk by 1981
5.	Data Collection	Little Now, 1984
6.	Defense	(Now)
7.	Direct TV Broadcast (USA)	1987
8.	Trunk Telephone	(Now)
9.	Earth Exploration	(Now)
10.	Educational TV - PBS	(Now)
	- Dedicated Transponder	1980
	- Dedicated Satellite	1985 (?)
11.	Electronic Funds Transfer	Little Now, 1985
12.	Electronic Mail (USA)	(Depends on Congress)
13.	Electronic Office	1982
14.	Telelibrary	Little Now, 1984
15.	International	(Now)
16.	Inter Satellite Links	LES-8-9 Now, Commercial Service: 1988
17.	Land Mobile	1990
18.	Low Orbit Relay	1981
19.	Navigation	Low Orbit Now, Sync: 1985
20.	Network TV	PBS Now, Others: 1980
21.	Maritime	(Now)
22.	Paging (from Orbit)	1990+
23.	Personal Communication - Commercially Sponsored	1995+
	- NASA Sponsored	1987
24	Private Lines	(Now)
25.	Public Safety	1987
26.	Remote Printing	(Now)
27.	Search & Rescue	1983
28.	Teleconference	1982
29.	Telehealth	1982
30.	Time & Frequency Standards	1983
31.	Weather	(Now)

Subsequent studies should address the desire or need for on-orbit refurbishment. Should a satellite be launched with sufficient capability for twenty years? Should it be augmented every year, two years, or two months? The design philosophies are quite different.

5.6 GWARC-79

Frequency selections have been based on the now-existing allocations by the International Telecommunications Union and the Federal Communications Commission. After completion of this study, the General World Administrative Radio Conference (GWARC-79) met in Geneva, Switzerland, to make its once every twenty year determination on the use of the world's radio frequencies. At the time of writing this report, many often-conflicting national positions exist on the allocation of radio frequencies for space and orbit position for satellites; 14,000 proposals have been submitted on the reallocation of the RF spectrum [19]. In addition, there are satellites and frequencies already in use in the potential locations for the geostationary platform. As shown in Section 4, some flexibility in orbit location is possible. After the GWARC-79 has been completed, the frequency and orbit locations should be reviewed by subsequent contractors.

6. REFERENCES

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[18] NASA's Lewis Research Center has let satellite switching contracts with General Electric, MITRE, and Clarkson College.

[19] "1979 WARC Finally Gets Down to Business . . .", Telecommunications Reports, October 1, 1979.

Appendix A. PAYLOAD DATA BOOK

By

Communications Satellite Corporation
COMSAT Laboratories
22300 COMSAT Drive
Clarksburg, Maryland 20734

Under Contract NAS8-33226

October 30, 1979

APPENDIX A. PAYLOAD DATA BOOK

List of Missions

Number	Name
	Communications
1	Direct-to-User*
2	High-Volume Trunking*
3	Broadcast and Video Distribution*
4	Tracking and Data Relay
5	Educational Television
6	Direct Television Broadcast
7	Mobile, Air
8	Mobile, Sea
9	Mobile, Land
10	International
11	Inter-Platform Links
12	Data Collection
	Non-Commununications
E3	Severe Storms Research**

*This work was entirely performed by the Aerospace Corporation.
**This is a summary of NASA-furnished data.

Missions 1, 2, and 3

Mission Numbers: 1, 2, and 3

Mission Names: Direct-to-User

High-Volume Trunking

Broadcast and Video Distribution

Consult attached Aerospace Corporation material for full details.

DIRECT-TO-USER SYSTEM SUMMARY

193 CONTIGUOUS BEAMS @ 0.35° (174 OVER CONUS) — 3 CASSAGRAIN ANTENNAS - 5 m DIAM.

60 CLUSTERS — 1 TO 35 BEAMS PER CLUSTER *

480 "STANDARD" TRANSPONDERS

TRANSPONDERS   8 PER CLUSTER   FDMA   36 MHz EACH

MODULATION AND MULTIPLE ACCESS
- QPSK
- SSTDMA - 64 MBS PER TRANSPONDER
- FRAME RATE 800 PER SECOND
- 40 BURSTS PER FRAME (MAX)
- DATA RATES 64 KBS, 1.54, 3, 4.5, 6, 32, 64 MBS

SWITCH

- FAST MATRIX
- BASEBAND
- 480 x 480
- ~ 19,200 PATHS @ 1.5 MBS
- CROSSPOINTS SYNCHED TO TDMA BURSTS (NO STORAGE)
- CROSSPOINT OPERATING RATE 32,000/sec.

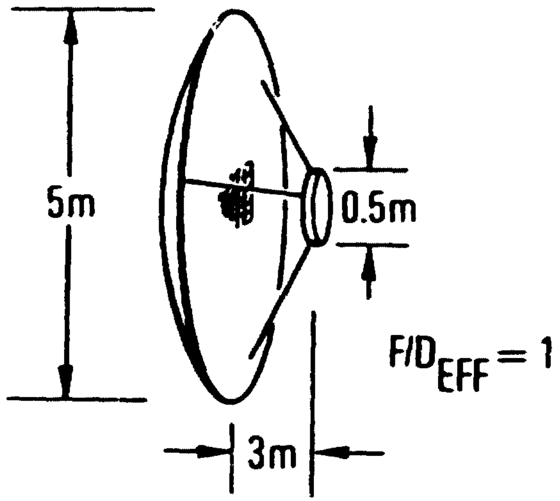
TERMINALS

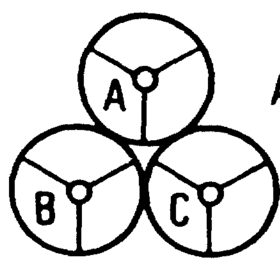
- 10,000; ~ 167/CLUSTER: ~20/TRANSPONDER
- ANTENNA 4.5 m K_u BAND
- RF POWER   5 WATTS/TRANSPONDER
- FET LNA 220° K NOISE TEMPERATURE

* SOME BEAM HOPPING EMPLOYED IN SPARSELY POPULATED AREAS

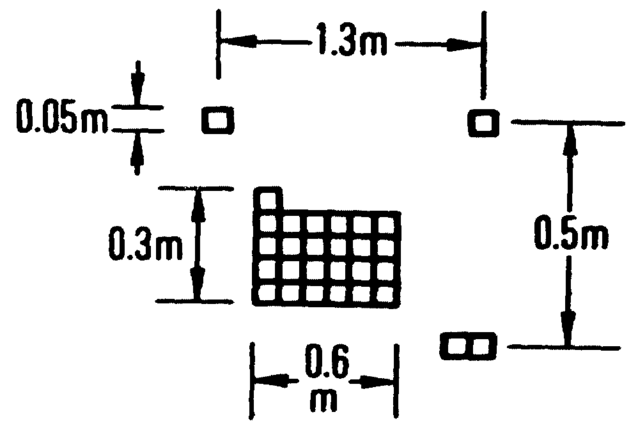
Source: **Aerospace Corporation**

Direct-to-User Antenna System





ARRANGEMENT OF THREE 5-meter REFLECTORS



FEED ARRAY FOR REFLECTOR A, LOOKING TOWARD REFLECTOR

	U/L	D/L
FREQUENCY, GHz	14.0-14.5	11.7-12.2
CENTER ELEMENT BEAM PEAK GAIN, dB	54.5	53
CENTER ELEMENT BEAM H.P. BEAMWIDTH, deg	0.27	0.33
ANTENNA SYSTEM WEIGHT, kg	— 96	—
NUMBER OF FEEDS	— 193	—

Source: Aerospace Corporation

HIGH VOLUME TRUNKING SYSTEM SUMMARY

20 BEAMS @ 0.16° * 30 m DIAM. CASSAGRAIN ANTENNA

10 "LARGE" TRANSPONDERS/BEAM ** TOTAL 200

FDMA 144 MHz EACH

MODULATION AND MULTIPLE ACCESS

- QPSK (16 LEVEL APSK ON BOSTON, N. Y., WASH., L. A. BEAMS)
- SSTDMA - 256 MBS (512) PER TRANSPONDER
- FRAME RATE 1000/SEC.
- 240 (MAX) BURSTS PER FRAME - ADJUSTABLE TO ACCOMMODATE INTERCITY TRAFF
- DATA RATES 1 TO 512 MBS

SWITCH

- FAST MATRIX
- BASEBAND
- 240 x 240
- 57,600 PATHS @ 1 MBS
- CROSSPOINTS SYNCHRONIZED TO TDMA (NO STORAGE)
- CROSSPOINT OPERATING RATE 240,000/SEC.

TERMINALS

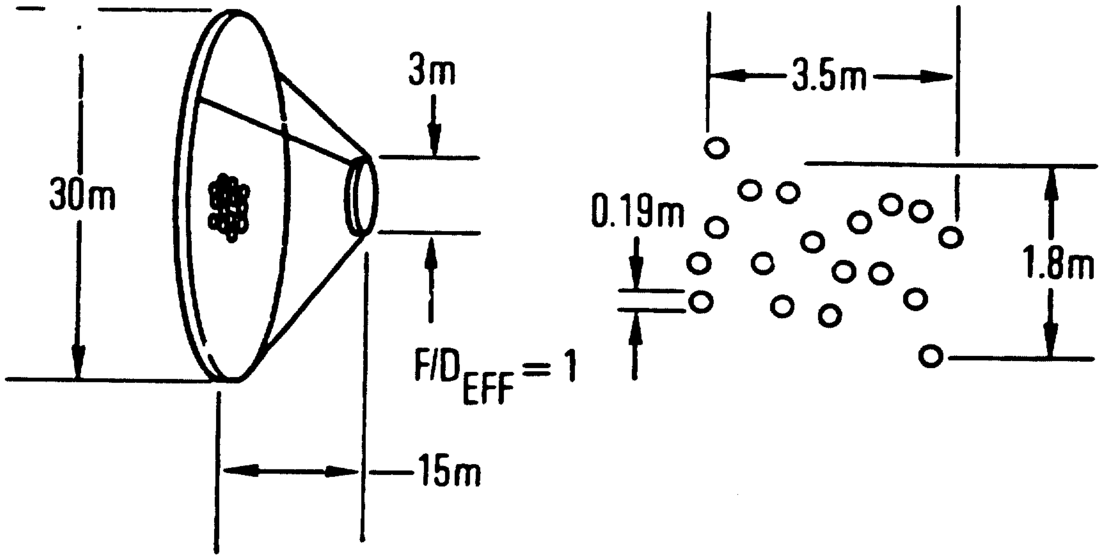
- ≥20 10 TRANSPONDERS/TERMINAL
- ANTENNA 4.5 m C BAND
- RF POWER 1.5 WATTS/TRANSPONDER
- FET LNA 130° K

* CAN COVER > 20 LOCATIONS USING BEAM HOPPING TO SMALL CITIES

** LARGE TRANSPONDER CAPACITY = 4 x STANDARD TRANSPONDER

Source: Aerospace Corporation

High-Volume Trunking Antenna



FEED LAYOUT, LOOKING TOWARD REFLECTOR

	U/L	D/L
FREQ, GHz	5.625-6.425	3.4-4.2
GAIN, dB	59	56
HALF POWER BEAMWIDTH, deg	0.106	0.165
ANTENNA SYSTEM WEIGHT kg (reflector, feeds, structure, control)	-250-	

Source: **Aerospace Corporation**

BROADCAST AND VIDEO DISTRIBUTION SYSTEM SUMMARY

4 TIME ZONE BEAM CLUSTERS FOR CONUS

3 SPOT BEAMS FOR ALASKA, HAWAII, PUERTO RICO

54 STANDARD TRANSPONDERS — 12 PER TIME ZONE FDMA 36 MHz EACH

2 PER SPOT BEAM

2 OR 3 VIDEO CHANNELS PER TRANSPONDER

MODULATION AND MULTIPLE ACCESS

- QPSK
- SSTDMA - 64 MBS PER TRANSPONDER
- FRAME RATE 4,000/SECOND
- 2 OR 3 BURSTS/FRAME
- DATA RATES 22, 32 MBS

SWITCH

- FAST MATRIX
- BASEBAND
- 50 x 50

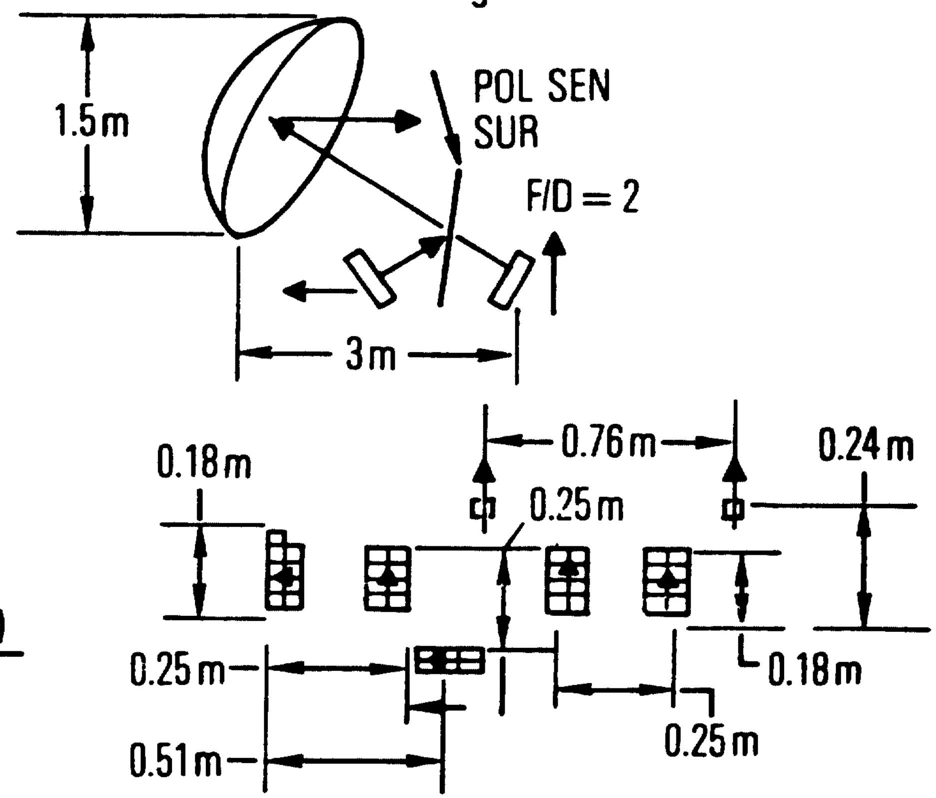
TERMINALS

- FEW TRANSMIT
- SEVERAL THOUSAND - RECEIVE ONLY
- ANTENNA 4.5 m K_u BAND
- RF POWER 60 WATTS
- FET LNA 220° K

Source: Aerospace Corporation

Broadcast and Video Distribution Antennas

ANTENNA SYSTEM WEIGHT = 9.0 kg



TIME ZONE	GAIN (dB)
WESTERN	36.5
MOUNTAIN	34.0
CENTRAL	34.0
EASTERN	33.5

Source: Aerospace Corporation

SUMMARY OF RECOMMENDED PAYLOAD CONFIGURATION

		D.T.U. SYSTEM	H.V.T. SYSTEM	BCAST
Transponders	Freq. Band	Ku	C	Ku
	No.	480	200	54
	Burst Rate	64 MBS QPSK	256 MBS QPSK ***	64 MBS QPSK
	P. A. RF Power	1 Watt	0.05 Watt	10 Watt
	NF (FET Preamp) dB	5.5	3.4	5.5
	WT* Kg	1130	340	275
	DC Power Watts	3700	940	2910
Antennas	Type	Center Fed Cassegrain	Center Fed Cassegrain	Offset Fed ** (℄ Feed Plane
	Diam of Refl. (m)	5 (3 Reflectors)	30	1.5
	Gain (dB)	54.5 ↑ 53 ↓	59 ↑ 56 ↓	~34
	Sidelobe Objective (dB)	28	28	Not Critical
	Required Accuracy Pointing	0.03^{o}	0.01^{o}	0.1^{o}
	WT Kg	96	250	9
Switch-Fast Matrix	Size	630 x 630	240 x 240	50 x 50
	WT* Kg	240	36	4.8
	DC Power Watts	4000	400	40
Total WT	Kg	1666	626	289
Total DC Power	Watts	7700	1340	2950

* Includes 20% additional for redundancy and on-orbit servicing

** Using polarization-sensitive sub-reflector

*** 40 transponders operate at 512 Mbps using higher level PSK

Source: Aerospace Corporation

Mission 4

Mission Number: 4

Mission Name: Tracking and Data Relay

Objective: Obtain real-time data from low-orbit satellites. These data are communicated from the low-orbit satellite directly to the geostationary platform. From the geostationary platform the data are transmitted to a central receiving earth station (e.g., White Sands, New Mexico), either directly or via another intersatellite link (see ISL service) and another geostationary platform.

Methodology: This mission is based on the current tracking and data relay satellite systems requirements. It includes both fixed (phased array) and moving (center fed) antennas to track one or more low-orbit satellites. Up- and down-links are in the NASA S- and K-bands.

If relay via a distant geostationary platform is needed (thus providing global coverage without "blind spots"), it is via another service (ISL) link.

User Community: NASA, Department of Defense, etc.

Mission Payload Description

Four basic links are involved in each direction:

a. K-band single access (KSA);

b. S-band single access (SSA);

c. Multiple access (MA); and

d. Trunk link to/from the White Sands facility.

The individual low-orbit satellite antennas have been set at 1.5 m with noise temperatures of 450 K and transmitters with power levels between 0.72 and 20 W (depending on the frequency and bandwidth).

The geostationary platform uses 2- and 5-m center-fed reflectors and a phased array. The system noise temperatures are 450 K, and the transmitters range from 1.6 to 50 W. The main station (at White Sands) uses 18-m antennas for the data streams. This equipment is compatible with the interim TDRS.

Space Segment Description

Antennas: 2- (rigid) and 5-m (deployable mesh) center-fed antennas plus a bidirectional phased array with 20 elements.

Receivers: Four dual chains of 450 K receivers at both K- and S-bands.

Transmitters
K-band: 1.6 and 30 W
S-band: 26 and 50 W

Two transmitters (and two spare TWTAs) are required at both K- and S-bands.

Frequency, Up-link (GHz)
K-band: 14.7 and 15.0034
S-band: 2.25 and 2.2875

Frequency, Down-link (GHz)
K-band: 13.7 and 13.775
S-band: 2.050 and 2.10641

Harmonics: S-band harmonics may present problems at 4 GHz (2nd), 6 GHz (3rd), 8 GHz (4th), 12 GHz (6th), and 14 GHz (7th). K-band harmonics may be difficult at 29 GHz (2nd) and 55 GHz (4th).

Antenna Surface Tolerances: A 1.6-mm rms tolerance on the 5-m mesh reflector results in an 0.06-dB loss at S-band and a 2.5-dB loss at K-band. A 0.38-mm rms tolerance on the 2-m rigid reflector results in a loss of 0.2 dB.

Candidate Antenna Types: Front-fed reflectors with motor drives and phased arrays.

e.i.r.p. (dBW)
K-band: 54.7 and 57.3
S-band: 28.7 and 50.1

G/Ts (dBi/K)
K-band: +21 and +27
S-band: -6 and +12

Platform Support Requirements

DC Input (W)
K-band: 182
S-band: 262
444

RF Radiated (W)
K-band: 13.9
S-band: 42.8
56.7

Heat Radiated (W): 387.3

Thermal Constraints (C): 0 to 40

Weight Estimate (of transponders): 70.3 kg

Weight Estimate (of antennas): one each 2 m and 5 m -31 kg

Telemetry or Data Link Requirements (approximate): 30

Commands (approximate): 30

Platform Location (west longitude)

North America: 120°
South America: 80°
Western Europe: 0°

Field of View:

Global
White Sands elevation angles
North America: 50°
South America: 40°
Europe (via ISL): 50°

Antenna Pointing Accuracy (deg): The KSA and SSA provide their own pointing control. The MA and trunk-link are platform-mounted; a $\pm 0.1°$ platform stabilitly results in a 0.2-dB loss at K-band and negligible losses at S-band (MA).

Contamination: Lubricants from the KSA and SSA antenna drives may migrate to optical surfaces. Motions from the KSA and SSA antennas may impact the overall platform stability.

Stationkeeping (deg): The low-orbit satellites and the White Sands antennas place no important requirements on stationkeeping.

Earth Station Description (White Sands, New Mexico)

Up-link

Frequency (GHz): 14.7
Bandwidth (GHz): 1 GHz*
Modulation/multiple access: FDMA/TDMA
Transmitt power (W): 5.0
Antenna diameter (m): 18

*Increased from 50 MHz to 1 GHz per NASA direction in letter dated September 18, 1979.

Down-link

Frequency (GHz): 13.7
Bandwidth (MHz): 20
Modulation/multiple access: FDMA/TDMA
System noise temperature (K): 450
Antenna diameter (m): 18

(Low-Orbit Satellite)

Up-link (LEO to GEO)

Frequency (GHz): 2.25, 2.2875, and 15.0034
Bandwidth: 50 kHz, 12 MHz, and 25 MHz (at 1 bit per Hz)
Modulation/multiple access: SCPC/TDMA
Transmitter power (W): 0.72 and 20
Antenna diameter (m): 1.5

Down-link (GEO to LEO)

Frequency (GHz): 2.05, 2.10641, and 13.775
Bandwidth: 50 kHz, 20 MHz, and 25 MHz
Modulation/multiple access: FDMA/TDMA (SCPC)
System noise temperature (K): 450
Antenna dimater (m): 1.5

Mission 4. Tracking and Data Relay Transmissions Link Data[a]

Link	Nominal Frequency (GHz)	RF Beam-width (MHz)	Transmit Power (W)	Actual e.i.r.p. (dBW)	Antenna: Transmit: Diameter	Antenna: Transmit: Field of View (deg)	Antenna: Transmit: Peak Gain (dBi)	Antenna: Transmit: Field of View Gain (dBi)	Antenna: Receive: Diameter	Antenna: Receive: Field of View (deg)	Antenna: Receive: Peak Gain (dBi)	Antenna: Receive: Field of View Gain (dBi)	G/T_e (dBi/K)	No. of Beams	Output Backoff (dB)	C/N + M(dB)	Remarks	T_e (K)
Down	13.775	25	1.6	54.7	5	0.30	54.5	53.3	1.5	1.0	44.0	41.0	+14	2	0	16	KSA	450
Down	2.050	20	26	50.1	5	2.0	44.8	44.6	1.5	6.8	27.5	24.5	-2	2	0	13	SSA	450
Down	13.70	20	30	57.3	2	0.77	46.4	46.2	18	0.08	66.2	63.2	+36	1	2	30	-	450
Down	2.10641	50 (kHz)	50	28.7	20 el[b]	14.5	~24	~21	1.5	6.8	27.5	24.5	-2	many	5	17	MA	450
Up	15.0034	25	0.72	41.4	1.5	0.93	44.7	44.8	5	0.28	55.3	53.8	+27	2	0	15	KSA	450
Up	2.25	12	20	35.8	1.5	6.2	28.4	25.4	5	1.9	38.8	38.7	+12	2	0	15	SSA	450
Up	14.7	1000	5.0	68.6	18	0.08	66.3	63.3	2.0	0.7	47.2	47.0	+21	1		20	-	450
Up	2.2875	50 (kHz)	20	31.1	1.5	6.1	28.5	25.5	20 el[b]	14.5	~24	~21	-6	many	5	15	MA	450

[a] Similar to TDRS's.
[b] Phased array.

Mission 5

Mission Number: 5

Mission Name: Educational Television

Objective: Provide access to the learning resource centers of remote schools, colleges, and interested groups.

Methodology: The title implies the use of television in educational institutions; however, the application is much wider, including on-the-job training in industry and in-the-home teaching (when coupled with existing terrestrial distribution facilities such as CATV and broadcast TV stations).

User Community: Schools, colleges, universities, on-the-job training, retraining, and adult education.

Mission Payload Description

Time-zone down-link beams are used in the US with eight channels per beam (due to bandwidth limitations). In South America, four similar sized but nationally located beams are used with eight TV channels per beam. One-degree up-link beams are used to feed the signal into the satellite.

These missions may be turned off during an eclipse.

The earth stations are modest (3-m) antennas and 100 K receivers. Since the geostationary platform power level (3 W per TV channel) is so low, some degradation of the earth segment may be permitted (e.g., 30 W in the geostationary platform would permit an earth station G/T_s of +7 dBi/K and a C/N of 16 dB after the adjacent satellites are eliminated).

Space Segment Description

Antennas: Four 2- x 2.8-m and four 1.5-m antennas (one per beam).

Receivers: Four dual receivers with system noise temperatures of 525 K.

Transmitters: Thirty-two 3-W transmitters with eight spares.

Frequency, Up-link (GHz): 14.00 - 14.500*

Frequency, Down-link (GHz): 2.500 - 2.655

Harmonics: Third harmonic falls into 7-GHz band, and sixth harmonic falls into KSA up-link at 15 GHz.

Antenna Surface Tolerance:** (2.5, 2 x 2.8, >0.01, 0.5) and (14.45, 1.5, 0.1, 0.28)

Candidate Antenna Types: Offset fed nondeployable reflectors with fixed feeds and reconfigurable arrays.

e.i.r.p. (dBW): 35.9 (per channel)

G/T_s (dBi/K): +17

* The 6.425- to 7.115-GHz band should be considered if approved at GWARC-79.

**Order of data (frequency in GHz, antenna diameter in m, surface loss in dB, surface tolerance in rms mm).

Platform Support Requirements

DC Input (W): 368

RF Radiated (W): 96

Heat Radiated (W): 272

Thermal Constraints (C): 0 to 40

Weight Estimate (of transponders): 424 kg

Weight Estimate (of antennas): 54.8 kg (for eight antennas)

Telemetry or Data Link Requirements (approximate): Thermal, DC supply volts (2), status (per transponder) = 84

Commands (approximate): On/off, spare in/out (per transponder = 84

Platform Location (west longitude)

North America: Four time zone beams (3° x 4°)
South America: Four national beams (about 3.5° each)

Antenna Pointing Accuracy (deg): Area service - ±0.1° results in a 0.4-dB pointing loss in the worst case.

Contamination: None

Stationkeeping (deg): Established by the fixed receive-only earth stations. For 3-m stations, a stationkeeping error of ±0.1° amounts to 0.015 dB. The TV program-origination earth stations are capable of tracking.

C-2

Earth Station Description

Up-link

- Frequency (GHz): 14.45 (typical)*
- Bandwidth: 17.5 MHz per channel
- Modulation/multiple access: FM/SCPT
- Transmitter power (W per channel): 2
- Antenna diameter (m): 5

Down-link

- Frequency (GHz): 2.517 (typical)
- Bandwidth: 17.5 MHz (per channel)
- Modulation/multiple access: FM/SCPT
- System noise temperature (K): 100
- Antenna Diameter (m): 3

*The band 6.425 to 7.115 GHz should be considered if approved at GWARC-79.

Mission 5. Educational Television — Transmissions Link Data

Link	Nominal Frequency (GHz)	RF Beam-width (MHz)	Transmit Power (W)	Actual e.i.r.p. (dBW)	Antenna								G/T_s (dBi/K)	No. of Beams	Output Backoff (dB)	C/N + M(dB)	Remarks	T_s (K)
					Transmit				Receive									
					Diam-eter	Field of View (deg)	Peak Gain (dBi)	Field of View Gain (dBi)	Diam-eter	Field of View (deg)	Peak Gain (dBi)	Field of View Gain (dBi)						
Down	2.517	17.5	3	35.9	2 x 2.8	3 x 4	33.5	30.1	3	2.8	35.3	35.0	+15	4	0	14.5		100
Up	14.45	17.5	2.0	56.1	0.28	5	54.8	54.7	1.5	1.0	44.3	44.2	+17	2	0	21.5		525

Mission 6

Mission Number: 6

Mission Name: Direct Television Broadcast

Objective: Provide color television programming directly to ths home with minimum investment on the part by the homeowner.

Methodology: TV programs are transmitted to the satellite via a 14-GHz up-link.* The programs are then fed to four UHF beams in the South American and Western European geostationary platforms. Multilingual sound is included in the European transmissions. Pursuant to WARC/ST footnote Spa 2-10, frequency modulation, UHF, and TV/FM receivers are used. Services of this class were pioneered in India with ATS-6. Presently, the Ekran satellites provide this service; INSAT-1 and 1-B are under construction.

Antennas of 2.5-m wire grid are used at the home. The system noise temperature (1,000 K) is typical of today's TV sets.

User Community: Pay television, movie companies, and national governments.

Mission Payload Description

UHF-TV 100-W (per channel) transmitters are used with 7.5- x 10-m reflectors to beam 3° x 4° patterns. Two programs per beam (and four beams per geostationary platform) are used.

During the eclipse, it may be possible to turn off the power to these tubes to reduce DC power storage requirements.

*The 6.425- to 7.115-GHz band should be considered if it is approved at the GWARC-79. Use of this band could reduce the weight of the space segment equipment and possibly raise the price of each earth receiver.

Space Segment Description

Antennas
    Receive: 1.5 m
    Transmit: 7.5 x 10 m (or a portion of larger reflector)
    Quantities: 1 each, transmit and receive

Receivers: 371 K, 40 MHz wide

Transmitters: 100 W per channel operated on a single channel per 40-MHz transponder basis. Eight active transmitters per platform with four spare TWTAs.

Frequency, Up-link (GHz): 14.25 (typical)

Frequency, Down-link (MHz): 700 (typical*)

Harmonics: Third (NASA S-band) and sixth (4 GHz)

Antenna Surface Tolerance: 4.5-mm rms results in 0.2-dB loss at 700 MHz.

Candidate Antenna Types: Center-fed under-illuminated parabolas, phased array, or multiple yagi-type antennas.

e.i.r.p. (dBW): 51.3

G/T_s (dBi/K): +18.5

*The 6.425- to 7.115-GHz band should be considered if it is approved at the GWARC-79. Use of this band could reduce the weight of the space segment equipment and possibly raise the price of each earth receiver.

Platform Support Requirements

DC Input (W): 2,064

RF Radiated (W): 505

Heat Radiated (W): 1,559

Thermal Constraints (C): 0 to 40

Weight Estimate (of transponders): 362 kg

Weight Estimate (of antennas): 1.5 m, 4.9 kg

Feeds for UHF: 2.4 kg, 7.5- x 10-m reflector (see high-volume trunking antenna).

Telemetry or Data Link Requirements (approximate): 30

Commands (approximate): 30

Platform Location (west longitude)
- South America: 80°
- Western Europe: 0°

Field of View
- South America & Caribbean
- Western Europe & Africa

Antenna Pointing Accuracy (deg): A $\pm 0.1°$ platform stability results in a worst-case error of 0.4 dB at 700 MHz and 1.4 dB at 14.25 GHz.

Contamination: None

Stationkeeping (deg): A ±0.1 stationkeeping results in less than 0.01-dB loss to the 700-MHz earth stations. The transmit stations track the satellite.

Earth Station Description

Up-link (network feed)

- Frequency (GHz): 14.25 (typical)*
- Bandwidth (MHz): 40/channel
- Modulation/multiple access: TV/FM SCPT
- Transmitter power (W): 15
- Antenna diameter (m): 4.5

Down-link (home)

- Frequency (MHz): 700 (typical)
- Bandwidth (MHz): 40/channel
- Modulation/multiple access: TV/FM
- System noise temperature (K): 1,000
- Antenna diameter (m): 2.5

*The 6.425- to 7.115-GHz band should be considered if it is approved at the GWARC-79. Use of this band could reduce the weight of the space segment equipment and possibly raise the price of each earth receiver.

Mission 6. Direct TV Broadcast — Transmissions Link Data

Link	Nominal Frequency (GHz)	RF Beam-width (MHz)	Transmit Power (W)	Actual e.i.r.p. (dBW)	Antenna								G/T_s (dBi/K)	No. of Beams	Output Backoff (dB)	C/N + M(dB)	Remarks	T_s (K)
					Transmit				Receive									
					Diameter	Field of View (deg)	Peak Gain (dBi)	Field of View Gain (dBi)	Diameter	Field of View (deg)	Peak Gain (dBi)	Field of View Gain (dBi)						
Up	14.25	40	15	61.5	4.5	0.33	53.9	52.4	1.5	1.0	44.3	44.2	+18.5	3	0	25		371
Down	0.7	40	100	51.3	7.5 x 10	3 x 4	33.5	33.1	2.5	11.5	23.0	23.0	-7	4	0	15		1000

Mission 7

Mission Number: 7

Mission Name: Mobile, Air

Objective: Provide communications and navigation to/from commercial aircraft.

Methodology: Links to/from commercial aircraft are provided at 1.6/1.5 GHz in internationally allocated aeronautical mobile satellite bands. At the geostationary platform, these channels are converted to the 5-GHz band (as used by Aerosat) for connection to air traffic control and navigation centers.

User Community: Airlines and the national aerospace administrations (e.g., F.A.A.).

Mission Payload Description

Three 10° coverage beams illuminate the earth.

The air traffic control centers are connected via a global beam at 5 GHz to permit full interworking. Alternatively, this link could be handled by the onboard satellite switch in the direct-to-user service.

Navigation, search and rescue services are connected at the aircraft and earth station ends.

This scenario closely follows the protocols jointly agreed to by European, U.S., and Canadian interests and the resulting memorandum of understanding.

Spage Segment Description*

Antennas: The antennas at 1.6/1.5 GHz use a fixed phased array of helical elements. The 5-GHz services are provided via a 0.2-m horn. There are two 0.2-m horns per platform.

*The equipment is based on the Aerosat requirements.

Receivers: Each geostationary platform has four dual 354 K receivers.

Transmitters: 5 W and 90 W at 1.5 GHz, and one pair of 10 W at 5.125 GHz.

Frequency, up-link (GHz):
1.5 and 5.125 (aircraft to geostationary platform)
5.880 (land to geostationary platform)

Frequency, down-link:
1.6 and 5.880 (geostationary platform to aircraft)
5.125 (geostationary platform to land)

Harmonics: Fourth harmonic of 1.5 GHz falls in 6-GHz receive band, fifth harmonic falls in 7-GHz band, and seventh harmonic falls in 11-GHz band. Troublesome harmonics of 5.125 GHz are the second (11-GHz band) and third (KSA up-link).

Antenna Surface Tolerance: Not applicable for 1.6/1.5-GHz global helix. A loss of 0.7 dB results from a 7-mm rms at 1.6 GHz; and 0.4-mm rms at 5.88 GHz results in a loss of 0.04 dB.

Candidate Antenna Types: Helical arrays and front-fed reflectors using rigid and mesh deployed reflectors. (The 5-GHz global beam may use a horn antenna.)

e.i.r.p. (dBW): 38.0 (per channel) at 1.5 GHz and 20.1 at 5.125 GHz.

G/T_s (dBi/K): -11.3 at 1.6 GHz and -16.5 at 5.88 GHz.

Platform Support Requirements

DC Input (W): 869

RF Radiated (W): 176

Heat Radiated (W): 693

Thermal Constraints (C): 0 to 40

Weight Estimate (of transponders): 128.9

Weight Estimate (of antennas): 23.6 kg

Telemetry or Data Link Requirements (approximate): Power supply (2), status (per transponder) = 21

Commands (approximate): On/off, redundant switch (per transponder) = 21 (total)

Platform Location (west longitude):
- North America
- South America
- Western Europe

Field of View: Global

Antenna Pointing Accuracy (deg): A $\pm 0.1°$ pointing accuracy results in a worst case loss of 0.06 dB for the 10° beams.

Contamination: None

Stationkeeping (deg): Not applicable because of hemispheric aircraft beams and tracking earth stations.

Aircraft and Earth Station Descriptions

Up-link

Frequency (GHz)
- Aircraft: 1.6
- Land station: 5.88

Bandwidth
- Aircraft: 80 kHz
- Land station: 400 kHz

Modulation/multiple access: SCPC/FM

Transmitter power (W per channel)
- Aircraft: 220 W
- Land station: 50 W (for 400 kHz)

Antenna diameter (m)
- Aircraft: 0.8
- Land station: 7

Down-link

Frequency (GHz)
- Aircraft: 1.5
- Land station: 5.125

Bandwidth
- Aircraft: 80 kHz
- Land station: Up to 400 kHz

Modulation/multiple access: SCPC/FM

System noise temperature (K)
- Aircraft: 354
- Land station: 195

Antenna diameter (m)
- Aircraft: 0.8
- Land station: 7

$GT/_s$ (dBi/K)
- Aircraft: -7.4
- Land station: +26

Mission 7. Mobile, Air — Transmissions Link Data

Link	Nominal Frequency (GHz)	RF Beamwidth (kHz)	Transmit Power (W)	Actual e.i.r.p. (dBW)	Antenna: Transmit: Diameter	Antenna: Transmit: Field of View (deg)	Antenna: Transmit: Peak Gain (dBi)	Antenna: Transmit: Field of View Gain (dBi)	Antenna: Receive: Diameter	Antenna: Receive: Field of View (deg)	Antenna: Receive: Peak Gain (dBi)	Antenna: Receive: Field of View Gain (dBi)	G/T_s (dBi/K)	No. of Beams	Output Backoff (dB)	C/N + M(dB)	Remarks	T_s (K)
Down	1.5505	80	90	38.0	--[a]	10[b]	19.5	16.4	0.8	17.0	19.6	16.6	-7.4	3	2	15		354
Down	5.125	400	10	20.1	0.2	--[c]	19.1	15.5	7.0	0.6	49.0	48.9	+26.0	1	2	19		195
Up	1.6515	80	220	38.0	0.8	17.0	19.6	16.6		10[b]	19.5	16.4	-11.3	3	0	17		600
Up	5.880	400	50	63.3	7.0	0.6	49.0	48.9	0.2	--[c]	19.1	15.5	-16.5	1	0	20		200

[a] Helix.
[b] Shaped.
[c] Global.

Mission 8

Mission Number: 8

Mission Name: Mobile, Sea

Objective: Provide communications by satellite between the shore and ships on the high seas. These communications are principally directed to shore stations where they are transmitted via the terrestrial telecommunications networks to shipping offices and homes. Navigation and search and rescue services are also provided.

Methodology: A shipboard station transmits to and receives SCPC signals from the geostationary platform. The platform converts these signals to TDMA and routes them to and from a terrestrial earth station. INMARSAT has been established to handle this traffic.

User Community: Merchant ships (e.g., oil, freight, container, bulk and cargo); fishing ships (e.g., trawlers and floating factories); oceanographic vessels and platforms (e.g., oil drilling and production equipment and underseas mining).

Mission Payload Description

This service operates in the internationally assigned 1.5- and 1.6-GHz bands (L-band). Therefore, it is characterized by large antennas. Two types of coverage are provided: global and one or several specific fishing grounds or busy traffic lanes.

With a spare geostationary platform (or one serving a different geographical region), ranging and direction determination may be used for navigation and for collision avoidance. This service may also be used for calling mayday in the event of a disaster at sea. A low-data-rate channel is also provided for the search and rescue of survivors.

The traffic capacity is sized to service the world's cargo fleet.

The antennas feed receivers with a noise temperature of 1000 K. The transmitters are sized at 70 and 2 W for the global and spot beams, respectively.

The up-link SCPC for signals are demodulated, digitized, timed, and formatted for compatiblity with the terrestrial TDMA down-link. The reverse link uses the inverse process. This eliminates all demands on timing at the individual ship terminals and allows a reduction in their power or antenna pointing requirements.

Space Segment Description

Antennas

Global: Three helical antennas in an array are shared with the mobile and air service. The 6/4-GHz band is handled by horns.

Spots: 14 m (achieved by under illumination of the high-volume trunking 30-m antenna).

Receivers: Each L-band receiver consists of a low-noise amplifier (1000 K), filters, and a down-converter to the common IF used onboard the platform (e.g., 70 MHz). There are two dual receivers per geostationary platform at 1.6 GHz, and one pair at 6 GHz.

Transmitters

Global: 60 W

Spots (2): 2 W each

Frequency, Up-link (GHz)

Ship to satellite: 1.5

Shore to satellite: 6

Frequency, Down-link (GHz)

Satellite to ship: 1.6

Satellite to shore: 4

Harmonics: The third harmonic of 1.6 GHz may fall near the 4-GHz down-link. A harmonic filter will be needed.

Antenna Surface Tolerance: Helical antennas will be used for the global service; thus, this section does not apply. The spot beams use a parabolic reflector and need a 7-mm rms surface tolrance to achieve less than 1.0-dB loss.

Candidate Antenna Types
- Global: Triple helix (1.6/1.5 GHz), horns (6/4 GHz)
- Spot: Parabola section

e.i.r.p. (dBW)
- Global: 29.5
- Spot: 36.7

G/T_s (dBi/K)
- Global: -17
- Spot: 10.3

Platform Support Requirements

DC Input (W): 437

RF Radiated (W): 21

Heat Radiated (W): 416

Thermal Constraints (C): 0 to 40

Weight Estimate (of transponders): 52 kg

Weight Estimate (of antennas)
- Helical: (see mobile, air)
- Spot feed: 4 kg (reflector)
- 6/4-GHz horns: 3 kg

Telemetry or Data Link Requirements (approximate)

Transmitters: 5 points each x 6 = 30
Receivers: 2 points each x 6 = 12

Commands (approximate)

Select receivers: 3
Select transmitters: 3

Platform Location

Pacific/Caribbean: 120°
Eastern Pacific/Western Atlantic/Caribbean: 80°
Atlantic/Indian: OE

Field of View (deg from subsatellite point): ±8.75

Antenna Pointing Accuracy (deg)

Spot: plus/minus 0.1° (1.4 dB)

Contamination: None

Stationkeeping (deg): Not applicable (ships and shore stations use tracking antennas)

Shipboard Station Description*

Up-link

Frequency (GHz): 1.6 GHz
Bandwidth (Hz)
- Voice: 3 kHz
- Data: 4.8 kbit/s
- Mayday: 100 Hz

Modulation/multiple access: Voice and data SCPC/FDMA (ship to and from satellite)
Transmitter power (W): 0.07 (spot); 4 (global)
Antenna diameter (m): 1.2

*Ship terminal must be stabilized to reduce antenna pointing error losses due to pitch, roll, yaw, and heave of the ship. These requirements are identical to MARISAT.

Down-link

Frequency (GHz): 1.5
Bandwidth (Hz): Same as above
Modulation/multiple access: SCPC/FDMA
System noise temperature (K): 500
Antenna diameter (m): 1.2

Shore Station Description

Up-link

Frequency (GHz): 6.075
Bandwidth (kHz): 600
Modulation/multiple access: FDMA/TDM
Transmitter power (w): 30
Antenna diameter (m): 12

Down-link

Frequency (GHz): 4
Bandwidth (kHz): 600
Modulation/multiple access: FDMA/TDM (regenerates)
System noise temperature (k): 100
Antenna diameter (m): 12

Mission 8. Mobile, Sea — Transmissions Link Data

Link	Nominal Frequency (GHz)	RF Beamwidth (kHz)	Transmit Power (W)	Actual e.i.r.p. (dBW)	Antenna								G/T$_s$ (dBi/K)	No. of Beams	Output Backoff (dB)	C/N + N(dB)	Remarks	T$_s$ (K)
					Transmit				Receive									
					Diameter	Field of View (deg)	Peak Gain (dBi)	Field of View Gain (dBi)	Diameter	Field of View (deg)	Peak Gain (dBi)	Field of View Gain (dBi)						
Down	1.538	200	60	29.5	--[a]	--[b]	18.5	15.0	1.2	12	23	23	-4	1	3	13		500
Down	4.900	600	5	18.8	--[c]	--[b]	19.1	15.5	13	0.4	52	52	+32	1	5	23		100
Down	1.540	200	2	36.7	14	1.0	44.3	40.8	1.2	12	23	23	-4	2	5	20		500
Up	1.6395	3	4	28.0	1.2	11.0	23.5	23.5	--[a]	--[b]	17.8	14.0	-17	1	0	16		1,000
Up	6.075	600	30	62.4	12	0.3	55.0	55.0	1.7	2.0	38.2	38.1	0	2	5	33		5,456
Up	1.6415	3	0.07	9.7	1.2	11.0	23.5	23.5	13.0	1.0	44.3	40.8	+10.3	2	0	25		1,000

[a]Helix.
[b]Global.
[c]Horn.

Mission 9

Mission Number: 9

Mission Name: Mobile, Land

Objective: Provide communications to terminals located on moving (or transportable) stations in the land mobile service. These stations are intended for use only in remote (bush) areas and for navigation and for location determination.

Methodology: Small, simple earth stations are placed on moving or transportable objects on the earth's surface. Voice and low-speed data services may be provided. Navigation information is obtained by relaying an Omega receiver raw output to a remote computer for decoding and ambiguity resolution. The return link provides the location.

User Community: Long distance (over the road) transportation companies (bus, truck, train), salesmen, and other distance drivers. Single-voice channel services to remote (bush) communities or exploration camps.

Mission Payload Description

This service uses half bandwidth (20-MHz) transponders to connect with relatively simple earth terminals (nominal G/T = -15.5 dBi/K) on mobile (or transportable) platforms.

A cluster of beams is used to subdivide the country (CONUS) for frequency reuse. Beams of 1° are used to synthesize a (CONUS) 48-state coverage. In South America, 1° spot beams illuminate populated areas or bush areas of special interest (e.g., oil exploration or mineral extraction). There are 19 beams in the U.S. and 10 in South America.

The transponders operate on a multichannel per transponder (MCPT) basis. Individual links operate on a single channel per carrier (SCPC) basis with typical bandwidths of 30 kHz and a 0.4 voice activity. The transponder has a 7-dB output power backoff; 10 dB is allowed in the link for trees and other forms of link blockage.

The services are voice (or alternate voice/data) grade in a net bandwidth of 100 to 3,000 Hz per channel. There is no intent to provide a high-fidelity service, as this mission is a space equivalent (and replacement) for today's terrestrial mobile radiotelephone.

Each beam will accommodate a maximum of 250 simultaneous users (depending upon bandwidth assignment for the beam). This assumes that one-half of the spectrum is occupied.

Space Segment Description

Antennas: 1° spot beams are generated using portions of the 30-m high-volume trunking antenna.

Receivers: A pair of uncooled FET (200 K) receivers per beam.

Transmitters (power varies with bandwidth)

2 MHz:	60 W
7 MHz:	220 W
14 MHz:	440 W
17 MHz:	560 W

Frequency, Up-Link (GHz): 0.928 - 0.947 (bandwidth = 19 MHz)*

Frequency, Down-link (GHz): 0.881 - 0.902 (bandwidth = 19 MHz)*

*These frequencies are taken from the existing table of FCC allocations. The band 0.806 to 0.890 GHz is being proposed to the GWARC by the United States. If granted, the 84 MHz would be divided into up- and down-links and shared with terrestrial services.

Harmonics:

Second harmonic falls into meteorological satellite band (1.77-1.79 GHz).

Third harmonic falls into broadcast satellite band (2.55-2.690 GHz) and fixed satellite band (2.655-2.690 GHz).

Seventh harmonic falls into fixed satellite band (2.655-2.690 GHz).

Ninth harmonic falls into fixed satellite band (7.9-8.025 GHz).

Antenna Surface Tolerance: 10 mm produces a 0.8-dB loss.

Candidate Antenna Types: Yagi or helical arrays illuminating parts of a 30-m reflector.

e.i.r.p. (dBW): 53.2 (per MHz)

G/T_s (dBi/K): +1.6

Platform Support Requirements

DC Input (W)

North America: 7920
South America: 2080

RF Radiated (W)

North America: 499.7
South America: 130.9

Heat Radiated (W)

North America: 7420
South America: 1949

Thermal Constraints (C): 0 to 40

Weight Estimate (of transponders): 1,644 (638 kg)*

Weight Estimate (of antenna feeds only): 45 kg, reflector (shared-section of the high-volume trunking)

Telemetry or Data Link Requirements (approximate): Thermal, DC supply volts (2), status (per beam) = 76 (total)

Commands (approximate): On/off, spare in/out (per beam) = 76

Platform Location (west longitude):
North America: 120°
South America: 80°

Field of View:
North America: CONUS (20 beam cluster of 1° beams)
South America: Key population centers (10 beams at 1° each)

Antenna Pointing Accuracy (deg): Area service $\pm 0.1°$ results in a 1.2-dB loss due to pointing (see transmitters).

Contamination: None

Stationkeeping (deg): Not applicable for mobile services

*The first number is for the North American platform, and the second is for that of South America. This assumes one active transmitter per beam (plus a spare). Alternatively, 60-W transmitters may be positioned in parallel to obtain the required power, thus permitting a reduction in number of spares.

Earth Station Description

Up-link

Bandwidth: 3 kHz (audio/data) 30 kHz (modulator)
Modulation/multiple access: SCPC
Transmitter power (W per channel): 3.5
Antenna diameter (m): 0.5 (46° beamwidth)
Frequency (GHz): 0.928-0.947*
Margin (dB): 10

Down-link

Bandwidth: 2 to 19 MHz (receiver), 30 kHz (demodulator), 3 kHz (audio/data)
Modulation/multiple access: MCPT/SCPC
System Noise temperature (K)
- Galactic noise: 200 K
- Tropo noise: 20 K (10° elevation)
- Receiver noise: 450 K

Antenna diameter (m): 0.5 (46° beamwidth)
Frequency (GHz): 0.88-0.902*
G/T_s (dBi/K): 15.5
Margin + threshold (dB): 10 + 13 = 23

*These frequencies are taken from the existing table of FCC allocations. The band 0.806 to 0.890 GHz is being proposed to the GWARC by the United States. If granted, the 84 MHz would be divided into up- and down-links and shared with terrestrial services.

RF Power Requirements (W)

Transponder Bandwidth (MHz)	RF Power (rounded)	North America		South America	
		Transponders	Total RF	Transponders	Total RF
2	60	6	360	4	240
3	100	1	100	1	100
4	125	1	125	2	250
5	150	4	600	3	450
7	220	2	440		
10	300		300		
14	440	1	440		
15	475	1	475		
17	560	2	1,120		
Rated Output From Tubes (RF W)			3,960		1,040
Efficiency			(0.50)		(0.50)
DC W Input			7.920		2,080
Output Backoff (7 dB)			3,168		832.5
Actual RF Output			792		207.5
RF Line Losses (2 dB●			292.3		76.6
Actual Power Radiated as RF			499.7		130.9
Thermal			7,420		1,949

Mission 9. Mobile, Land — Transmissions Link Data

Link	Nominal Frequency (GHz)	RF Beam-width (MHz)	Transmit Power (W)	Actual e.i.r.p. (dBW)	Antenna								G/T$_s$ (dBi/K)	No. of Beams	Output Backoff (dB)	C/N + M(dB)	Remarks	T$_s$ (K)
					Transmit				Receive									
					Diameter	Field of View (deg)	Peak Gain (dBi)	Field of View Gain (dBi)	Diameter	Field of View (deg)	Peak Gain (dBi)	Field of View Gain (dBi)						
Down	0.8910	2	60	56.2	22.4	1	44.2	41.2	0.5	46	10.5	10.5	-15.5	19(10)	7	23		400
Down	0.8910	17	560	65.2	22.4	1	44.2	41.2	0.5	46	10.5	10.5	-15.5	19(10)	7	23		400
Up	0.9375	30 (kHz)	3	14.1	0.5	46	10.5	10.5	22.4	1	44.2	41.2	+16	19(10)	0	20		660

Mission 10

Mission Number: 10

Mission Name: International

Objective: Provide transoceanic and intercontinental communications. These link domestic and regional areas of common interest.

Methodology: 6/4-, 14/11-, and 29/19-GHz up- and down-links.

Due to the contract-specified satellite locations (North America, South America, and Western Europe), little or no international traffic is involved.

User Community: National postal, telephone, and telegraph authorities, exclusively.

Mission Payload Description

In North America, spot beams are projected onto selected Regional Switching Centers. (RSC's are at the top of the North American switching hierarchy.) The selected cities are White Plains (CT-1), Rockdale, Sacramento, and Montreal.

The South American feed points are in Caracas, Venezuela; Rio de Janeiro, Brazil; and Santiago, Chile. 6.4 GHz is used.

Due to its small size, no center is designated in Western Europe.

The spot beams are 1.0° wide and operate on a point-to-point basis.

The onboard direct-to-user switch and intersatellite link will be needed to permit connectivity. This is a direct consequence of the point-to-point nature of this service.

Alternative methods involve the use of channel dropping filters and the combination of multiplexers or the use of transmultiplexers.

Space Station Description

Antennas: 0.75, 1.1, 1.5, 1.9, 3.5, and 5.3 m (illuminated diameters)

Receivers

6 GHz: T_s = 920 K
14 GHz: T_s = 377 K
29 GHz: T_s = 830 K
Total quantities of dual receivers: 9 (South America and 15 (north America)

Transmitters

4 GHz: 10 mW
12 GHz: 1.5 W
19 GHz: 50 W each
Total (active): 9 (South America) and 15 (North America)

Frequency, Up-link (GHz: 6, 14, and 29 GHz

Frequency, Down-link (GHz): 4, 10.95-11.20, 11.45-10.70 and 19 GHz

Harmonics

Second harmonic of 11 GHz falls into 20 GHz band.
Third harmonic of 4 GHz falls into 11 GHz band.
Second harmonic of 14 GHz falls into 28 GHz band.

Antenna Surface Tolerance:* (3.950, 0.2, 5.3, 1.5), (6.175, 0 06, 3.5, 0.5), (11.325, 0.15, 1.9, 0.4), (14.250, 0.1, 1.5, 0.3), (18.950, 0.1, 1.1, 0.2), and (28.750, 0.03, 0.75, 0.15)

Candidate Antenna Types: Front and offset fed antennas with parabolic reflectors and multiple feeds.

*The data are in the following order: frequency in GHz, surface loss in dB, diameter in m, and surface tolerance in rms mm.

e.i.r.p. (dBW)

4 GHz:	16.2
11 GHz:	44
19 GHz:	59.5

G/T_s (dBi/K)

6 GHz:	+14.5
14 GHz:	+18.5
29 GHz:	+15

Platform Support Requirements

	4 GHz Each	Total	11 GHz Each	Total	19 GHz Each	Total
No. of Transponders						
DC Input (W)		3(3)*		10(6)		2(0)
Transmitter Power	6	18(18)*	5	50(30)	200	400(0)
Receivers, etc., Power		25(25)*		80(50)		25(0)
Total		43(43)*		130(80)		425(0)
RF Radiated	0.02	0.06(0.06)*	1.0	10(6)	30	60(0)
Thermally Radiated		43(43)*		120(74)		365(0)

*The first number is for North America; Second is for South America.

Thermal Constraints (C): 0 to 40

Weight Estimate (of transponders)

6/4 GHz:	28.9(18.9)*
14/11 GHz:	76(45.6)
30/20 GHz:	28(0)
Total:	123(65) kg

Weight Estimate (of antennas): One each 2.5 and 6.0 m - includes oversizing for multiple beams. Antenna totals: 46 kg (reflectors) + 7 kg (feeds) = 53(53) kg

Telemetry or Data Link Requirements (approximate): Thermal, DC supply volts (2), status (per transponder) = 60(36)*

Commands (approximate): On/off, spare in/out (per transponder) = 30(18)*

Platform Location (west longitude)

North America:	120°
South America:	80°

Field of View: Spot beams to White Plains, New York; Rockdale, Illinois; Sacramento, California; Montreal, Canada (North America); and Caraccas, Venezuela; Rio de Janeiro, Brazil; and Santiago, Chile (South America)

Antennas Pointing Accuragy (deg): All operate on a single station per beam (point-to-point); ±0.1° results in a 0.12-dB pointing loss

Contamination: None

Stationkeeping (deg): This is not applicable. All earth stations track the geostationary platform

*First number is North America; second is for South America.

Earth Station Description

Up-link			
Frequency (GHz):	6	14	29
Bandwidth (MHz):	5*	80	100
Modulation multiple access:	FDMA	TDMA	TDMA
Transmitter power (W):	1 mW	15	700
Antenna diameter (m):	30	5	3
Down-Link			
Frequency (GHz):	4	11	19
Bandwidth (MHz):	40*	80	100
Modulation/multiple access:	FDMA	TDMA	TDMA
System noise temperature (K):	90	320	320
Antenna diameter (m):	30	5	3

*Up-link is per station, down-link is per transponder.

Mission 10. International — Transmissions Link Data

Link	Nominal Frequency (GHz)	RF Beam-width (MHz)	Transmit Power (W)	Actual e.i.r.p. (dBW)	Antenna: Transmit Diameter	Transmit Field of View (deg)	Transmit Peak Gain (dBi)	Transmit Field of View Gain (dBi)	Receive Diameter	Receive Field of View (deg)	Receive Peak Gain (dBi)	Receive Field of View Gain (dBi)	G/T_s (dBi/K)	No. of Beams	Output Backoff (dB)	C/N + M(dB)	Remarks	T_s (K)
Down	3.950	40	0.01	16.2	5.3	1.0	44.3	44.2	30.0	0.18	59.4	59.0	+40.7	2	5	13		90
Down	11.325	80	1.5	44.0	1.9	1.0	44.3	44.2	5.0	0.39	55.3	55.1	+30.0	8	0	18		320
Down	18.950	100	50.0	59.5	1.1	1.0	44.3	44.2	3.0	0.39	55.3	55.1	+30.0	2	0	28		320
Up	6.175	5	0.01	41.2	30.0	0.11	63.5	63.0	3.5	1.00	44.3	44.2	+14.5	2	0	17		920
Up	14.250	80	15.00	64.5	5.0	0.30	54.8	54.8	1.5	1.00	44.3	44.2	+18.5	8	0	22		371
Up	28.750	100	700.00	83.0	3.0	0.25	56.5	56.3	0.75	1.00	44.3	44.2	+15.0	2	0	33		920

Mission 11

Mission Number: 11

Mission Name: Inter-platform Links

Objective: Provide direct platform-to-platform links.

Methodology: Traffic may need to be passed from one geostationary platform to another through an intermediate earth station ("via" connection) or directly by an intersatellite link (ISL). To avoid confusion with the tracking and data relay (TDR) mission (which has links between low-earth orbit satellites and a geostationary platform), the term inter-platform link (IPL) has been coined for traffic between platforms.

The lowest presently allocated frequency is 55 GHz.* As an alternative an optical link may be used.

This link may be used to control remotely located platforms from the U.S.

User Community: Platform operators (for remote command, control, and communications).

Mission Payload Description

Transmitter power is either 13 or 60 W depending upon the use of a sub-platform stabilized antenna mount. The 13-W transmitter requires a $\pm 0.03°$ pointing precision; the 60-W transmitter assumes $\pm 0.1°$ platform pointing. The IPL beams are 0.13° (or 2.26 milliradians).

*A 25.25- to 26.25-GHz band has been proposed to the GWARC for this service. For a given antenna aperture, the beamwidth (and pointing accuracy requirements) doubles.

Space Segment Description

Antennas: The transmit and receive antennas (two per platform per link) are 3 m in diameter and operate within the 55-GHz band.* The antennas are rigid.

Receivers: A system noise temperature of 600 K has been selected based on the 55-GHz requirement. Very little noise contribution comes from the antenna (assuming proper location) or the 6 K space temperature. When the moon is behind the distant platform, the noise increases by 1.7 dB. (Thus the margin drops from 14 to about 12 dB over a threshold of 11 dB). When the sun is behind the distant platform, the link experiences a sun outage. The apparent motion of the sun is 15° per hour; therefore, it remains within the half-power beamwidth only 0.52 min. This will occur twice per year at predictable times. A dual receiver is included.

Transmitters: (Refer to previous discussion concerning the effect of antenna pointing accuracy on the choice of 65- or 300-W transmitters). A 2-dB line loss and three-for-one redundancy are assumed.

Frequency, Cross-link (GHz): 55*

Harmonics: Second and third harmonics may fall into the microwave radiometer passbands at 118 and 183 GHz.

Antenna Surface Tolerance: The current rigid 3-m reflectors are attributed (by JPL) to have surface tolerances of 0.3-mm rms which would result in a surface loss of 2 dB. To obtain the 0.1-dB surface tolerance, a 0.075-mm rms surface will be needed.

*A 25.25- to 26.25-GHz band has been proposed to the GWARC for this service. For a given antenna aperture, the beamwidth (and pointing accuracy requirements) double.

Candidate Antenna Types: The IPL is a true point-to-point service with no adjacent areas. (Unless there are adjacent co-frequency platforms.) Hence, the antenna requirements may be substantially relaxed. At 55 GHz, the earth's atmosphere blocks stray (off-axis) signals, which combine to allow poor sidelobe performance. The challenge is to determine if the surface tolerance and pointing requirements may be relaxed by an illumination of the reflector.

Front-fed reflectors should be considered.

e.i.r.p. (dBW): 75.5 or 78.7 (depending on pointing)

G/T_s (dBi/K): +29.7 or +33 (depending on pointing)

Platform Support Requirements (per IPL)

Antenna Pointing (deg):	+0.1	+0.03
Pointing Loss (dB):	4.6	1.38
DC Input (W):		
Transmitter (1 active)	1200	300
Receivers (1 pair active)	8	8
	1208	308
RF Radiated (W):		
Transmitters	+300	+65
Internal losses (2 dB)	-110	-24
Radiated	190	41
Heat Radiated (W):	1018	267

Thermal Constraints (C): 0 to 40

Weight Estimate (of transponders): (1 dual receiver and 3 transmitters) = 48 or 160 kg (65 and 300 W, respectively)

Weight Estimate (of antennas): 2 antennas at 3 m with feeds and a precision surface - 40 kg (excludes platform pointing mechanism mass)

Telemetry or Data Link Requirements (approximate): 8

Commands (approximate): 8

Platform Location (west longitude)

North America: 120°
South America: 80°
Western Europe: 0°

Field of View: Adjacent platform antennas should be separated for isolation. Shielding the receive antenna from the transmit antenna may be desired.

Antenna Pointing Accuracy (deg): (See discussion).

Contamination: None

Stationkeeping: $\pm 0.1°$ results in a link loss of 4.6 dB. This may lower the 25-dB threshold and margin allowance to approximately 20 dB in the worst case.

Earth Station Description

(Not Applicable)

Mission 11. Inter-Platform Link Transmissions Link Data[a]

Link	Nominal Frequency (GHz)	RF Beam-width (MHz)	Transmit Power (W)	Actual e.i.r.p. (dBW)	Antenna								G/T_s (dBi/K)	No. of Beams	Output Backoff (dB)	C/N + M(dB)	Remarks	T_s (K)
					Transmit				Receive									
					Diam-eter	Field of View (deg)	Peak Gain (dBi)	Field of View Gain (dBi)	Diam-eter	Field of View (deg)	Peak Gain (dBi)	Field of View Gain (dBi)						
Cross	55	500[b]	300	78.7	3	0.13	62.1	57.5	3	0.13	62.1	57.5	29.7	1	0	25		600
Cross	55	500	65[c]	75.5	3	0.13	62.1	60.7[c]	3	0.13	62.1	60.7[c]	33.0[c]	1	0	25		600

[a] TDMA, range up to 100°.
[b] Each way.
[c] Equals ±0.03° pointing.

Mission 12

Mission Number: 12

Mission Name: Data Collection

Objective: Obtain data from insitu sensors. These data may include earthquake (seismic), hydrological (river stage), meterological (snow, rain, and temperature), weapons testing, and other data for telemetering.

Methodology: Sensors are placed at strategically selected locations; and the data are accumulated for subsequent burst transmission to the geostationary platform. These burst transmissions may be either on a random multiple access basis (using one or several reservation schemes) or upon request from an interrogating signal from the geostationary platform. Due to the wide range in types of data, both types of transmissions are envisioned.

For some forms of data, very infrequent transmissions may be adequate (e.g., the total rainfall per day). In others (e.g., an intrusion into an area), real time is important. Occasionally, burst frequency may vary depending on local activity (seismic) or the instantaneous needs of the data user (flood stage).

The collected data are switched to a down-link in another service (e.g., high-volume trunking) for transmission to the data user's facility.

User Community: Governmental agencies and environmental research organizations.

Mission Payload Description

Internationally allocated frequencies between 400.150 and 402.000 MHz are used for the interrogation. The sensor to geostationary platform link utilizes 402.000 to 403.000 MHz.

A 5° beam (or equivalent beam coverage area, such as CONUS) is used to collect the data.

The earth stations use a 1-m antenna and operate similarly to those deployed in the U.S. Geological Survey network.

Space Segment Description

Antennas: One 11-m antenna at 400 MHz.

Receivers: 1,000 K, 1 MHz wide at 402 to 403 MHz. A band stop filter must be provided for the 400.15- to 402-MHz interrogation, or the output of the receiver must be blanked during an interrogation. A pair of receivers is needed. The output is at IF or baseband to a switch point in the high-volume trunking portion.

Transmitter: Narrowband, single interrogation per time interval, 300 mW. One active and one standby transmitter are required. These transmitters may be solid-state.

Frequency, Up-link: 402-403 MHz for data, another service for commands.

Frequency, Down-link: 400.15-402 MHz (actually utilized part: about 3 kHz and preferably as far away from 402-403 MHz as possible).

Harmonics

Second harmonic may fall in UHF-TV band.
Fourth harmonic may fall in aero and maritime mobile band.

Antenna Surface Tolerance: 6-mm rms surface tolerance results in less than 0.1-dB loss at 400 MHz.

Candidate Antenna Types: Yagi-fed reflector (or under illumination of a larger reflector) or a phased array. Due to the long wavelength (74.95 cm), a gridded reflector may be used.

e.i.r.p. (dBW): 19.7

G/T_s (dBi/K): -3

Platform Support Requirements

DC Input (W): 18

RF Radiated (W): 190 mW

Heat Radiated (W): Approximately 18

Thermal Constraints (C): 0 - 40

Weight Estimate (of transponders): 17.5 kg

Weight Estimate (of antenna): 25 kg (or utilizes part of a larger antenna), feeds - 4 kg.

Telemetry or Data Link Requirements (approximate)
Telemetry: 10 channels
Data Link: 1 MHz

Commands (approximate)
Commands: 10 channels
Interrogation Link: 3 kHz

Platform Location (west longitude)
North America: 120°
South America: 80°
Western Europe: 0°

Field of View: 5° (or equivalent) beam anywhere on earth (in field of view). This beam equivalence would cover CONUS.

Antenna Pointing Accuracy (deg): ±0.1° results in a maximum loss of 0.24 dB to an edge of coverage station.

Contamination: None

Stationkeeping (deg): The earth stations have an 18° beamwidth; thus, a ±0.1° stationkeeping error results in negligible pointing losses (under 0.01 dB).

Earth Station Description

Up-link

- Frequency (MHz): 402-403
- Bandwidth, modulated signal: 30 kHz (3 kHz voice or data input)
- Modulation/multiple access: coded digital bursts in RMA/FM
- Transmitter power (W): 10
- Antenna diameter (m): 1

Down-link

- Frequency (MHz): 400.15-402
- Bandwidth: 3 kHz
- Modulation/multiple access: SCPC/FM
- System noise temperature (K): 500
- Antenna diameter (m): 1

Mission 12. Data Collection — Transmissions Link Data

Link	Nominal Frequency (GHz)	RF Beam-width (kHz)	Transmit Power (W)	Actual e.i.r.p. (dBW)	Antenna: Transmit: Diam-eter	Antenna: Transmit: Field of View (deg)	Antenna: Transmit: Peak Gain (dBi)	Antenna: Transmit: Field of View Gain (dBi)	Antenna: Receive: Diam-eter	Antenna: Receive: Field of View (deg)	Antenna: Receive: Peak Gain (dBi)	Antenna: Receive: Field of View Gain (dBi)	G/T_s (dBi/K)	No. of Beams	Output Backoff (dB)	C/N + M(dB)	Remarks	T_s (K)
Up	0.4	30	10.00	15.7	1	52	9.8	9.8	11	5	30.0	27.0	-3	1	0			1,000
Down	0.4	3	0.30	19.7	11	5	30.0	27.0	1	52	9.8	9.8	-17.2	1	0	20		500

Mission E3

Mission No.: E3

Mission Name: Severe Storms Research

Objective: Gain information concerning severe storms; determine methods for improving severe storm forecasting by use of remote sensing; and demonstrate the potential usefulness of satellite observations to severe storms forecasting.

Methodology: Sensors on a geostationary platform measure spatial, temporal, and spectral characteristics of specific weather systems, particularly storms, with a high degree of resolution. Water vapor content of such systems is also determined. The data are transmitted from the platform to a central data processing facility where weather system images are reconstructed for analysis. New sensor pointing commands are calculated and transmitted to the geostationary platform to point the sensors in a different direction on the earth disc. Thereby, storm systems may be tracked during the course of their travels.

User Community: The initial demonstration phase involves scientific researchers as the "customer." When the capabilities of the system are demonstrated, the user community broadens to include, conceptually, anyone who may benefit from accurate storm predictions (e.g., agriculture, maritime, aviation, municipalities, etc.).

Mission Payload Description

The data required for weather structure imaging fall in the visible and infrared band and the elevated microwave band. Two instruments will provide these data. A high-resolution optical radiometer with scanning capability in several bands is used, by virtue of sequential images (at different bands) of an area, to construct weather system images. The sequential imaging imposes, for purpose of image registration, a pointing stability requirement of 0.5 μrad upon the payload. With a full earth image requiring about 20 min at a given band and sequential imaging, the pointing stability may need to be maintained on the order of 1 to 2 hr. The scanning mirror and filter wheel commonly used to implement the functions of the radiometer must be considered as disturbance for achieving the pointing stability. Less than full earth coverage imaging can be achieved in corresponding shorter time periods.

The second instrument required is a microwave imaging radiometer. The operating frequencies lie in the 100- to 200-GHz band. Within this band, two frequencies can be identified: 118 GHz (oxygen absorption line,) and 183 GHz (water vapor line). The antenna aperture for the necessary resolution is 4.4 m. The approximate antenna beamwidth is 0.03°. Hence, the antenna beam must be scanned to image the full earth disc. The conventional approach is to consider an offset-fed paraboloidal reflector in which the entire assembly is mechanically scanned. The relatively large mass of the reflector will cause significant disturbance torques on the payload pallet. Because of the pointing stability requirements of the infrared radiometer and the anticipated disturbances from the scanning microwave radiometer, simultaneous operation of the two instruments may be undesirable. Alternate scanning techniques that reduce disturbance torques, such as feed scanning with a nominally fixed torus reflector, are highly desirable.

The specified pointing stability represents the most difficult requirement of the high resolution infrared and visible radiometer. The 0.05 μrad specified is equivalent to 0.00003° or 20-m deviation on the ground. The fulfillment of this requirement will include a detailed trade-off study between modifications of the platform and requirements for payload isolation. Comparable pointing stabilities have been achieved in space but with individual satellites and usually with suppression of all mechanical motion.

The major platform disturbances will probably be caused by gimballed reflectors for beam pointing, thruster firings, solar array drive, and momentum wheels. Other possibilities, which include microwave circulators and mechanical relays, are fairly small and should not present a problem.

Effects of beam pointing can be minimized by using counterweights and the appropriate bearings. Thruster firings may frequently be programmed around selected times, although due to the large mass of the platform, the total time of firings will probably be longer than that for conventional spacecraft. The solar array drive can be stopped for short periods (one half hour) if a small decrease in power is tolerable. The momentum wheels will be larger than those of conventional satellites. The platform will also have larger amounts of inertia, since they cannot be stopped. It will be necessary to choose bearings and isolation to minimize the effects of the momentum wheels.

Analysis of this payload requirement will result in decisions on the platform specifications; the rest of the decisions will be based on analysis of the payload mounting. It would be expected that the pointing of the radiometer will be accomplished by the payload attitude control. Stability can be obtained by isolating the payload from the platform. To some extent, this isolation is easier in zero gravity, although ground testing will still be required. Since significant deviations from zero gravity will occur during thruster firing, either isolation must work during firings, or programming of firing times will still be required.

The selection of this radiometer as a geostationary platform candidate means that the maximum stability requirement is probably represented. Results of studies can be applied to other observational payloads by relaxing the requirements; that is, as the stability requirements become easier, the constraints on platform specifications and payload isolation are reduced.

The payload, which requires a data link of up to 6 Mbit/s capacity, may have its own data transmission capability or share one of the communications payloads coexisting on the geostationary platform. The command link is used for instrument pointing, scan amplitude, filter selection stepping, and microwave switching, as well as other housekeeping chores.

The infrared radiometer is expected to utilize a radiative cooler to maintain detector temperatures. Such coolers perform best when they have a clear view of space without sun input. The north or south face of the payload pallet may be used. The geostationary platform design and the position of this payload on the platform must be chosen to minimize cooler blockage.

Satellite Equipment

Antennas: ~0.03° beamwidth, 4.4-m aperture microwave radiometer. 1-m aperture infrared and visible radiometer.

Receiver: 118-GHz, 183-GHz microwave radiometer. ~3- to 15-μm infrared and visible radiometer, TT&C.

Transmitter: Spot beam to central processing facility, platform service.

Frequency, Up-link: Radiometer - 118 GHz, 183 GHz and infrared and visible.

Frequency, Down-link: Data, platform service.

Candidate Antenna Types: Microwave radiometer - parabola (rigid, deployable).

DC Input: Visible radiometer, 100 W; microwave radiometer, 150 W; data link, platform service.

Thermal Constraints: Radiative cooler field of view.

Weight Estimates

- Visible radiometer: 500 kg
- Microwave radiometer: 300 kg

Data Link: 6 Mbit/s, platform service

Commands

- Visible radiometer
  - Scan range
  - Scan center aim point
  - Filter select
- Microwave radiometer
  - Scan range
  - Scan center aim point

Antenna Pointing Accuracy

- 0.03° absolute
- 0.5 μrad stability, 1-2 hr

Contamination: Not a source, but optics are subject to contamination.

Stationkeeping: Orbit determination within 300 m.

Mission E3. Meteorological — Transmissions
Link Data

Link	Nominal Frequency (GHz)	RF Beamwidth (MHz)	Transmit Power (W)	Actual e.i.r.p. (dBW)	Antenna								G/T$_s$ (dBi/K)	No. of Beams	Output Backoff (dB)	C/N + M(dB)	Remarks	T_s (K)
					Transmit				Receive									
					Diameter	Field of View (deg)	Peak Gain (dBi)	Field of View Gain (dBi)	Diameter	Field of View (deg)	Peak Gain (dBi)	Field of View Gain (dBi)						
Up	0.150	50 (kHz)	2	27.4	--[a]	8	26.1	26.1	3	47	6	6	-21	1	0	20	Command	500
Down	0.137	20 (kHz)	20 mW	-3.4	--[b]	--[c]	19.0	14.7	--[b]	8	26.1	23.1	0	1	0	15	APT	200
Down	17	6	1.25	43.3	1.25	1.0	44.2	42.8	6	0.20	58.0	56.0	30	1	0	25		400

[a] Yagi.
[b] Helix.
[c] Global.