REPORT NO. GDC-GPP-79-006(I)
CONTRACT NAS8-33527
JUNE 1980

GEOSTATIONARY PLATFORM SYSTEMS CONCEPTS DEFINITION STUDY

FINAL REPORT

VOLUME I • EXECUTIVE SUMMARY

Prepared by

GENERAL DYNAMICS
Convair Division
&
COMSAT

for the

National Aeronautics and Space Administration
GEORGE C. MARSHALL SPACE FLIGHT CENTER
Huntsville, Alabama

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Submitted to
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National Aeronautics and Space Administration
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GEOSTATIONARY PLATFORM SYSTEMS

CONCEPTS DEFINITION STUDY

FINAL REPORT

➧ VOLUME I	Executive Summary
VOLUME II	Technical Analysis, Tasks 1 - 5, 3A
VOLUME II(A)	Technical Appendices
VOLUME III	Costs & Schedules, Task 6

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Publication of this report does not constitute approval by the National Aeronautics and Space Administration of the report's findings or conclusions.

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1 July, 1980

PREFACE

In today's world of expanding space communications, military, and science satellite services, the geostationary orbit is rapidly becoming an extremely valuable and limited earth resource. Nations demand specific positions or "slots" in the orbit corresponding to their geographic longitude, seeking to maximize their territorial coverage and satellite performance. Common carriers within a developed nation demand equal rights for the best slots. Competition has been strong in the developed nations, and the developing nations are now voicing their concern.

At geosynchronous altitude, independent satellites operating at the same frequency must be separated by about 4 degrees of longitude to prevent RF interference (30 db separation), dictated by the large beam widths of the small affordable ground antennas now in use. About 90 "slots" therefore exist around the world, with about 12 over the U.S. and our northern and southern neighbors.

The frequency spectrum is also a valuable and limited resource which is rapidly approaching saturation, particularly in those regions of low noise and freedom from atmospheric attenuation.

Both resources are now allocated worldwide by the International Telecommunications Union operating through subservient multinational and national agencies. Reallocation cannot solve our basic orbital arc and frequency saturation problems. Recent studies have shown projected traffic demands which will saturate both the geostationary orbital arc and the optimal frequency spectra in the near future. In the U.S. alone, current domestic satellite capacity is about 100 transponders. Projections indicate a five-fold increase in traffic demand for voice, data and TV distribution in the next 10 years (by 1990); ten-fold by the year 2000. If video and audio conferencing expand as projected, the jump may be to 20 to 50 times the present traffic by 1990 and the year 2000, respectively.

Motivation for the rapid adoption of satellite communications services is primarily economic. Savings can be significant if the cost, complexity and size of ground stations can be reduced by application of advanced communications and support technologies to a few satellites with expanded capabilities.

What is the solution to our orbital arc and frequency spectrum saturation problems, a solution which also lends itself to reduction of user costs?

One viable solution is the aggregation of many transponders, large antennas, and connectivity switches on board a small number of large orbital facilities. Such facilities, or platforms, can provide common power and housekeeping services to a number of coexistent communications systems, making maximum use of a single orbital slot. Large antennas with multiple spot beams and good isolation, bandwidth reduction, polarization diversity and system interconnectivity can provide an equivalent transponder capacity over the U.S. capable of handling the projected traffic demand for the year 2000.

In the public interest, NASA has initiated studies to determine the feasibility and economic advantages of such Geostationary Platforms, anticipating the need for increased communications and other services in the near decades, at lower costs. In the past two years, initial NASA studies have established the need and requirements for, and the feasibility of these platforms. NASA's George C. Marshall Space Flight Center has the responsibility for carrying out in-depth studies of Geostationary Platforms and defining requirements for and characteristics of precursor NASA experimental platforms that can pave the way for the operational platforms of the 1990s.

This report summarizes the results of the Geostationary Platform Initial Phase A Study, performed by General Dynamics Convair Division of San Diego with Comsat Corporation of Clarksburg, Maryland, as subcontractor, under direction of the Marshall Space Flight Center. Period of performance was from 1 June 1979 to 30 June 1980.

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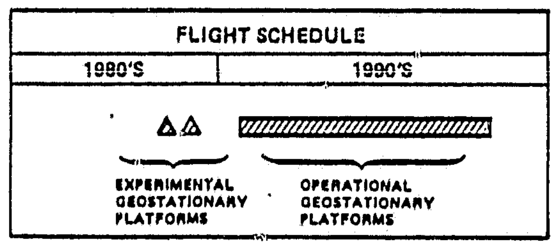
INTRODUCTION

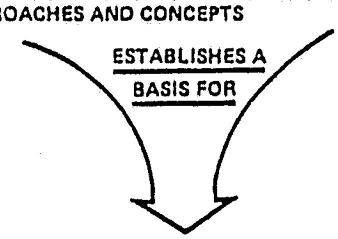
The George C. Marshall Space Flight Center has the responsibility within NASA for the Geostationary Platform - to initiate conceptual studies, develop feasible concepts, coordinate user needs and technology requirements, and promote activities aimed at system hardware solutions to the projected service demands of the 1990s.

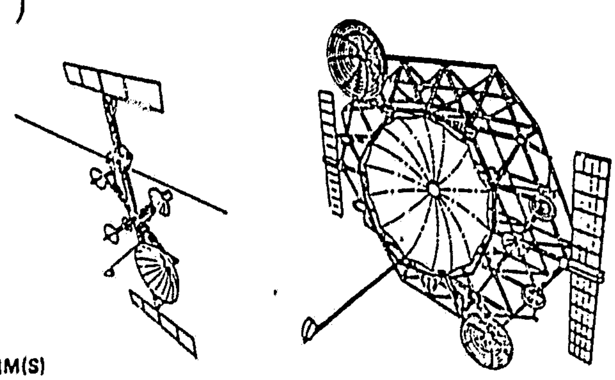
NASA's interest in Geostationary Platforms is to study the feasibility and economic benefits of the Geostationary Platform compared to the current approach of individual specialized satellites - to develop and demonstrate the platform and communications technologies required to pave the way for operational platforms of the 1990s. To this end, NASA is considering an Experimental Geostationary Platform which would fly in the late 1980s to demonstrate these technologies. The overall NASA approach is illustrated here:

- <u>OPERATIONAL GEOSTATIONARY PLATFORMS</u>
  - ESTABLISH TRAFFIC/MISSION MODEL(S) AS A FUNCTION OF TIME
  - CONDUCT TRADE STUDIES/ANALYSES OF CANDIDATE APPROACHES/CONCEPTS
    - SMALL SATELLITES ⇕ VERY LARGE PLATFORMS
    - SERVICING VS NON-SERVICING
    - TRANSPORTATION OPTIONS
    - EVOLUTIONARY BUILDUP OPTIONS

    } LOWEST COST
  - SELECT AND CHARACTERIZE PREFERRED APPROACHES AND CONCEPTS







- <u>EXPERIMENTAL GEOSTATIONARY PLATFORMS</u>
  - ESTABLISH NEED FOR EXPERIMENTAL PLATFORM(S)
  - IDENTIFY TECHNOLOGIES REQUIRED AND DEFINE EXPERIMENTAL PLATFORM
  - DEVELOP COSTS, SCHEDULES

Geostationary Platform program approach.

On 31 May 1979, General Dynamics Convair was placed under contract to do the Initial Phase A Concepts Definition Study for the Geostationary Platform. NASA/MSFC's planned approach includes a review and update of communications, military and science payloads and mission models, development and analysis of Operational and Experimental Platform concepts, identification of communications and platform technology requirements, and development of supporting programmatic data. Primary objectives of the study are to select and conceptually define Operational Geostationary Platforms based on time-phased mission and payload requirements, and to develop attendant costs, schedules, and supporting research and technology (SRT) requirements. This data will be used as a basis for definition of the NASA Experimental Geostationary Platform which will be the subject of follow-on studies, although some preliminary precursor work on the Experimental Platform was done during this initial phase of the study.

Six tasks were addressed in this study of the Geostationary Platform concept:

- Task 1 — Further define candidate missions and payloads.
- Task 2 — Define candidate approaches/concepts and conduct analyses and trades leading to selection of concepts.
- Task 3 — Define selected approaches and concepts for Operational Geostationary Platforms.
- Task 3A — Investigate the feasibility of an Experimental Geostationary Platform.
- Task 4 — Define supporting research and technology (SRT) and recommended space demonstrations.
- Task 5 — Define requirements on and interfaces with STS hardware elements.
- Task 6 — Define and develop cost and schedule data.

This document, Volume I of the Final Report, summarizes the technical and programmatic work done in satisfying the above tasks, with emphasis on the results, conclusions, and recommendations.

TASK 1

MISSIONS & PAYLOADS DEFINITION

A prerequisite for development of geostationary platform concepts is the identification of missions and payloads to satisfy projected needs. Platform size and geometry is strongly influenced by mission requirements and payload configuration. A large number of moderate size antennas requires many distributed structural attachment points, and large multiple beam antennas may limit structural design options, particularly when constrained by Orbiter cargo bay dimensional limitations.

Other important considerations are the locations of antennas, subreflectors, feed assemblies, and associated electronic units. Antennas and feeds must be separated to satisfy F/D requirements; preamplifiers and transmitters need to be close to feed systems; units with high heat dissipation must radiate to black space or be actively cooled by circulating fluids; antennas radiating very narrow pencil beams will require high accuracy pointing and a clear field of view; and RF system architecture must be compatible with frequency interference limitations. Extremely reliable payload interconnection networks are needed for power distribution, data management, communications, command and control, and malfunction investigation.

Payload accommodation is an integral part of platform design. The overall system concept is dependent on the nature and requirements of the payloads selected for inclusion in the platform configuration.

In Task 1, candidate missions were identified, traffic models developed, platform locations selected, payloads identified and allocated, and mission and payload requirements documented on data sheets to facilitate platform definition and selection in subsequent study tasks.

MISSION DEFINITION

All missions considered to be potential candidates for platform installation were identified and grouped according to function (communications, science, observation, etc.), sponsor (DOD, NASA, etc.), orientation, and pointing requirements. Missions found unsuitable for the geostationary orbital location were eliminated from the list.

The primary missions for geostationary platforms are satellite communications. For this study, the communications missions are grouped as follows:

- Fixed Point-to-Point Services. (Major requirement)
    - Direct-to-user (DTU) or customer premise services (CPS) network.
    - High volume trunking (HVT); domestic, regional, and international.
- Mobile Services.
    - Air mobile.
    - Sea mobile.
    - Land mobile.
- Broadcast & Relay Services.
    - TV distribution (separate Ku-band allocation)
    - Educational TV
    - Direct-to-home TV
    - Tracking and data relay
    - Data collection

TRAFFIC MODELS

To effectively size the payloads required to meet fixed point-to-point communications service requirements, models of estimated traffic demand for satellite communications during the years 1990 to 2000 were developed to determine needed levels of domestic, regional and transoceanic transponder capacity. These traffic model estimates cover the Americas, Western Europe, the Middle East, and Africa. The projected capacity levels incorporate voice, data, video distribution and video conferencing services.

Two traffic models were developed: a nominal traffic model and a high traffic model. The nominal traffic model is a conservative projection of existing services, developed in concert with other NASA-sponsored studies done by ITT and Western Union as part of the NASA 30/20 GHz program, and in conjunction with projected needs by users (e.g. Intelsat). The high traffic model adds one half of the video conferencing traffic that was estimated by Future Systems Inc. as a potential replacement for a fraction of business air travel, stimulated by the rising cost of travel. As an example, Figure 1 shows this relationship between the nominal and high traffic models, considering the U.S. only.

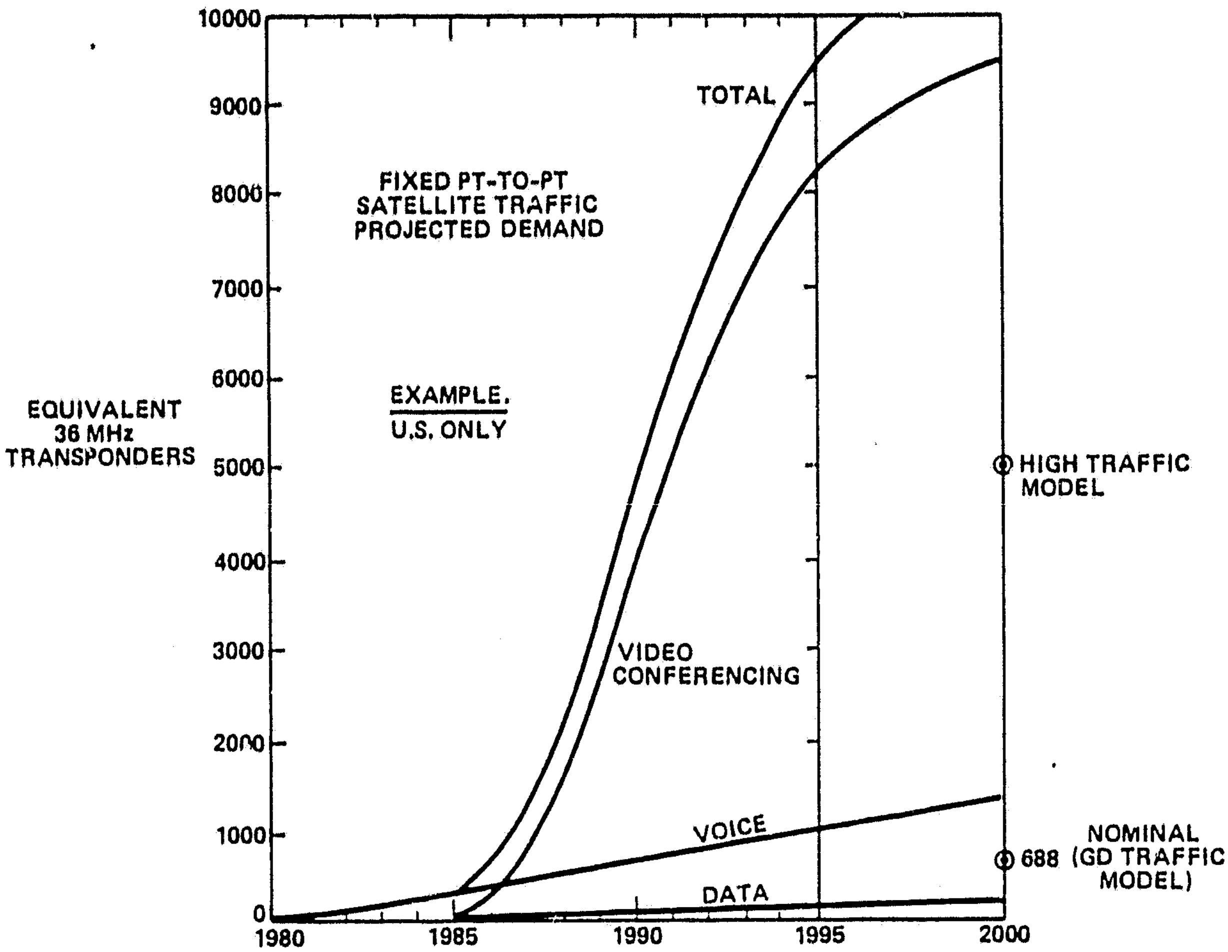


Figure 1. Potential impact of video teleconferencing.

Intelsat's projection of existing point-to-point service requirements in the Atlantic ocean area for the nominal traffic model is shown in Figure 2, expressed in number of equivalent two-way voice circuits. Figure 3 summarizes by geographical location the Nominal Traffic Model in terms of equivalent 40 MHz transponders. The high traffic model in the same year is shown in Figure 4. The primary difference between the two models, as mentioned earlier, is that the high traffic model contains conservative projections for video-teleconferencing - the nominal model contains no video-teleconferencing.

The greatest impact of this burgeoning demand will be on the fixed point-to-point communication services. Direct to User networks and High Volume Trunking

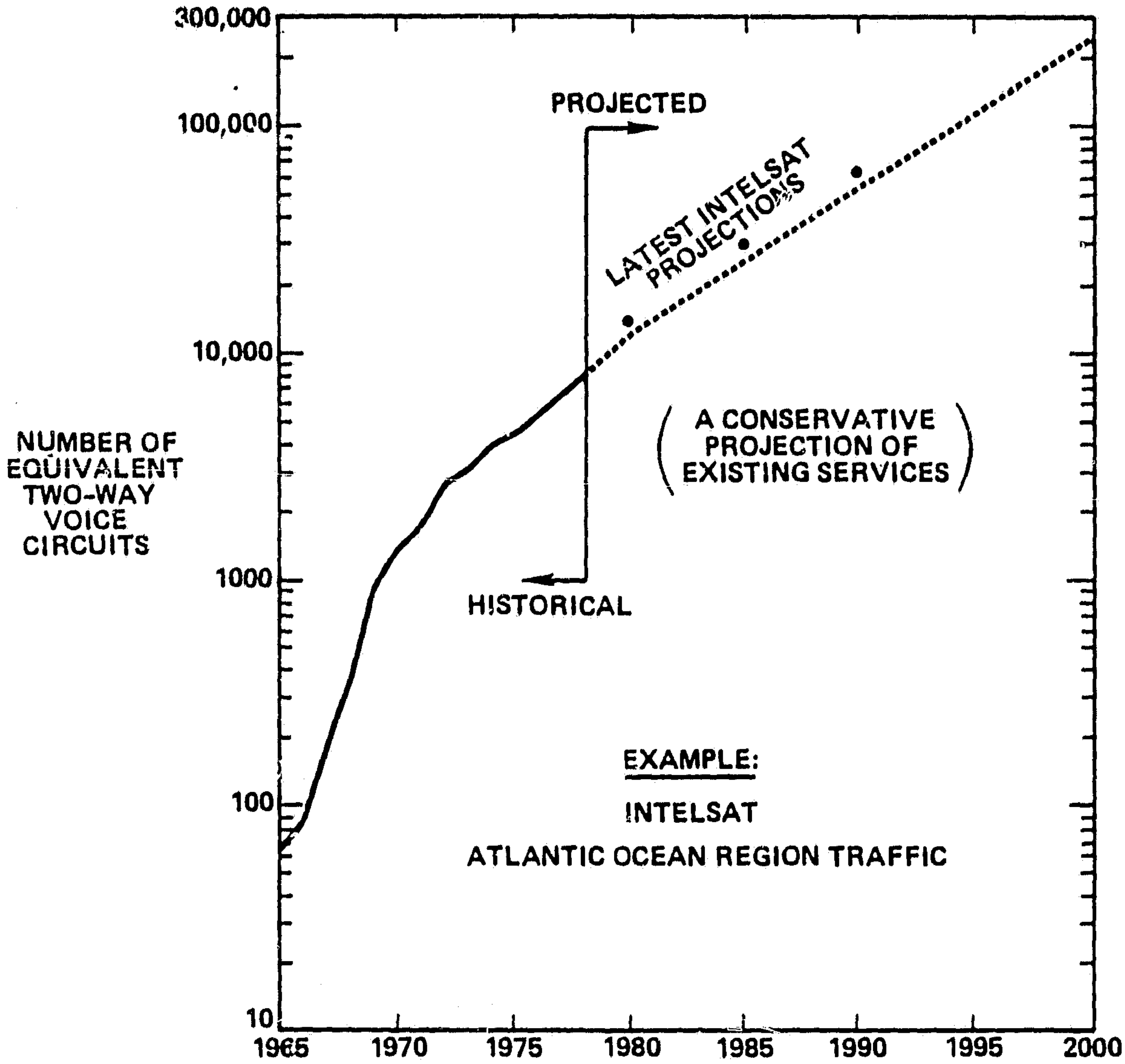


Figure 2. Nominal Traffic Model projection, Atlantic ocean.

services will require high capacity payloads employing multiple beam frequency reuse antennas, dual polarization and on-board switching to achieve the necessary effective capacity within available bandwidth. The size, weight, and power requirements of these communication payloads are the major drivers in determining total platform subsystem parameters.

ORBIT LOCATIONS

Two orbit locations were selected to satisfy the traffic model requirements, based on the advantages of integrating local, regional, and transoceanic traffic,

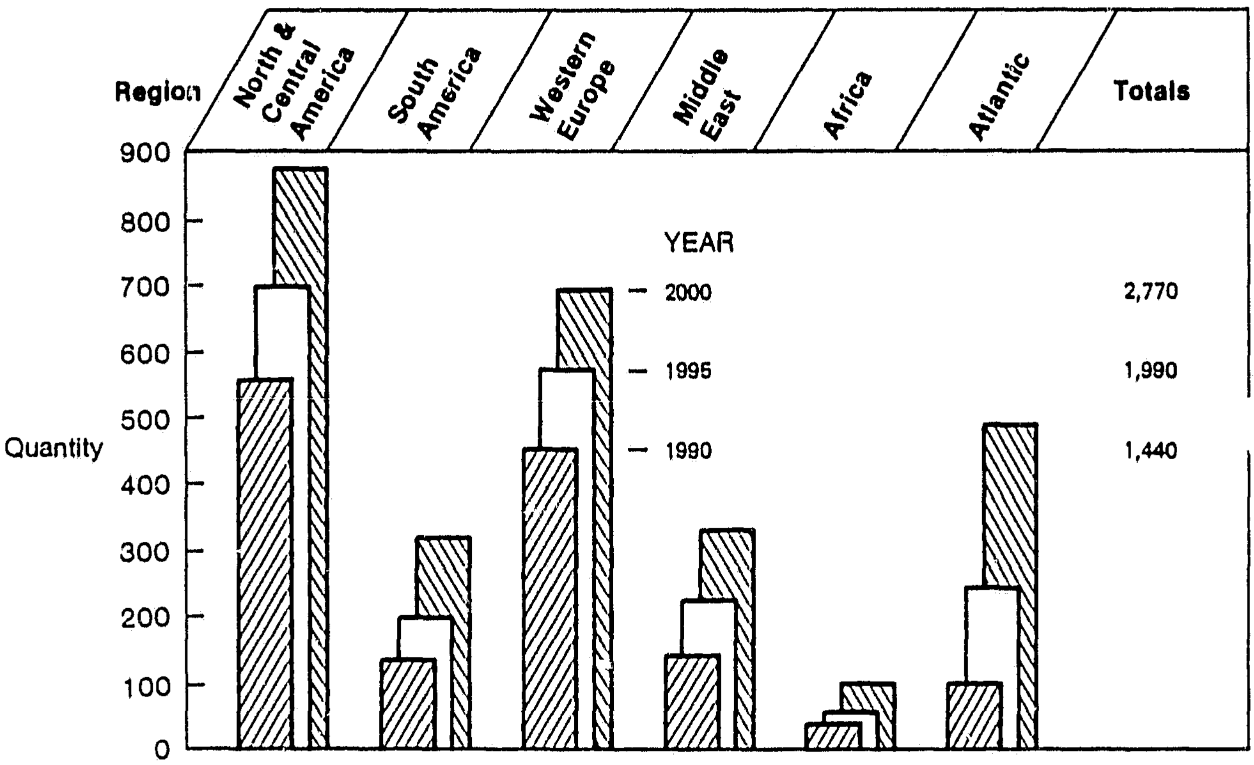


Figure 3. Nominal Traffic Model, Fixed Point-to-Point Service, in equivalent 40 MHz transponders.

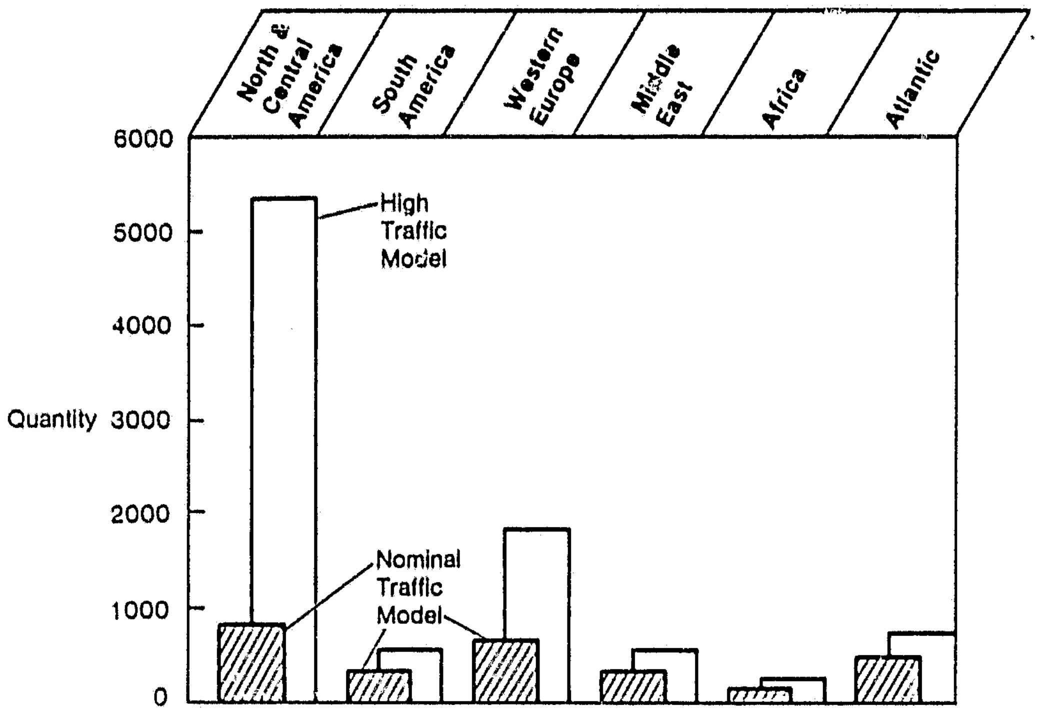


Figure 4. High Traffic Model, fixed Point-to-Point Service, in equivalent 40 MHz transponders.

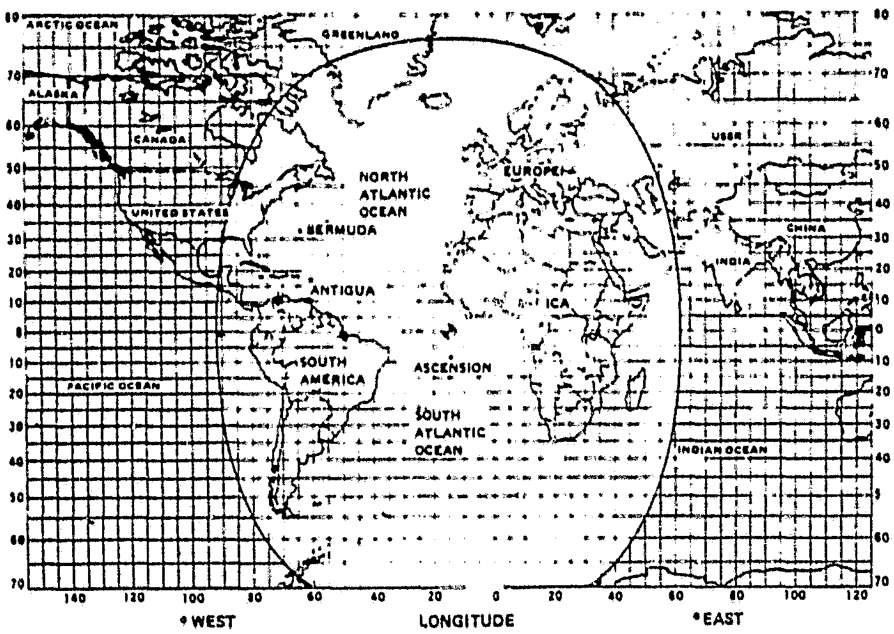
the need for equipment commonality, and community of interest. As shown in Figure 5, the Western Hemisphere location at 110° West longitude covers the Americas completely except for the Alaskan Northwest slope, assuming a 5° elevation angle. At 15° West longitude over the Atlantic, the coverage includes all of South America, the Eastern coast of North America, all of Europe, all of Africa, and transoceanic traffic.

COMMUNICATIONS SYSTEM ARCHITECTURE

The three primary objectives of the Geostationary Platform communications system are to reduce costs, expand services, and relieve saturation.

Previous studies have shown that cost reduction is achieved primarily through compatibility with small, simple, inexpensive earth stations giving rise to direct-to-user (DTU) or customer premise services (CPS) concepts. Additional savings are brought about in the space segment through economies of scale associated with combining many payloads on one platform.

ATLANTIC
15° W. LONGITUDE - 5° ELEVATION ANGLE



WESTERN HEMISPHERE
110° W. LONGITUDE - 5° ELEVATION ANGLE

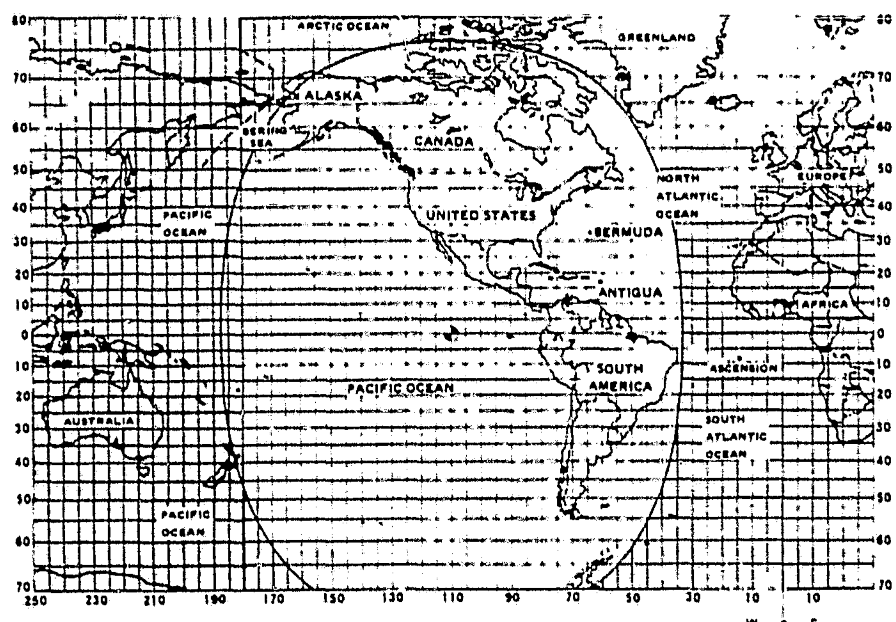


Figure 5. Geostationary Platform orbital arc locations.

Expansion of services comes mainly from providing connectivity between payloads.

Relief of orbital arc and frequency spectrum saturation is a function of communications system architecture, and is the subject of this section of the report.

Philosophy Behind Communications System Architectures

Basically, the scheme to relieve saturation involves extensive reuse of the frequency spectrum to get the greatest possible capacity from each individual orbital slot.

If the current trend continues, it is anticipated that most orbital slots in view of the United States will be occupied eventually by broadcast satellites. To guarantee the best possible point-to-point communications system with full connectivity, one or more slots should be earmarked for a system giving priority to fixed point-to-point traffic. The Geostationary Platform is such a system. All available bandwidth at C-band, Ku-band, and Ka-band is used exclusively for fixed point-to-point communications (high volume trunking and direct-to-user). Only those additional payloads (ETV, mobile, etc.) which have separate frequency allocations are incorporated on the Platform.

Initial Communications System Architecture

The architecture used for the Initial Study is an extreme case in which platform services are restricted to a single orbital slot for each of the two locations identified in Figure 5. This technological "worst case" establishes study boundary conditions and allows identification of maximum techology requirements. (The Follow-on to this study will consider Alternate Architectures in which the single-slot restriction is relaxed in order to allow use of more modest technology.)

The Initial Architecture described herein allows all point-to-point communications traffic in the Western Hemisphere projected for the year 2000 to be accommodated from a single orbital slot. If this can be accomplished, it will provide full connectivity with minimum transmission delay, make the remainder of the slots available for other purposes, and provide order of magnitude reductions in space segment costs. To do so, however, will require several technology advances. Identification of these advances was a major objective of our study.

Some of these advances (discussed more completely in Section 4 of this report) include the development of fast, high-capacity, long-life matrix switches, beam-forming networks with improved sidelobe suppression, and solid-state components for the new higher frequencies.

(Should such advances not materialize by 1990, it may be necessary to use two or more orbital slots to provide the same capacity. In this event, some connectivity will depend on inter-platform links, with an attendant increase in transmission delay, system complexity, and cost. Even in this instance, however, the platform would provide significant increases in the capacity of each orbital slot and would provide substantial cost reductions through economy of scale. Such Alternate Architectures will be studied in the Follow-on Contract).

The following paragraphs describe an advanced but apparently feasible architecture which serves the Western Hemisphere from one slot at about 100°W. and Europe, Africa, the Middle East, and the Atlantic from a second slot at about 15°W. It is sized to meet the best available projections of traffic demand in the year 2000. Particular attention is given to the geographic distribution of that demand and how the system will handle the concentration in the Northeast Corridor of the U. S.

Point-To-Point Communications System (Initial Architecture)

The payloads most sensitive to traffic demand are those which provide point-to-point communications. These payloads also make the heaviest demands on platform payload weight and power support capabilities. The approach to point-to-point communications payload architecture is based on recommendations resulting from the Geostationary Platform Feasibility Study conducted by Dr. Fred Bond of the Aerospace Corporation under contract to the Marshall Space Flight Center. Two basic types of service are proposed for point-to-point communications: a direct-to-user (DTU) system and a high volume trunking system (HVT). The existence of two systems provides potential customers with options which can be related to technical and economic needs. The extensive coverage requirements will be met by multiple beam antennas radiating patterns which include isolated spot beams, clusters of spot beams, and scanning beams for those areas with low population densities. Full connectivity between earth terminals will be maintained through onboard switching between receive and transmit beams.

The DTU system is based on contiguous coverage of the service area and service to large numbers of widely dispersed small-to-medium sized earth terminals with a range of capacities and transmission rates. The HVT system supplies coverage to selected high-capacity earth terminals located in the vicinity of high-population-density urban areas to support and complement existing terrestrial plants. Both systems employ dual frequency band operation. DTU traffic occupies uplink frequencies within the ranges 14.0 to 14.5 GHz and 27.5 to 28.7 GHz and downlink frequencies in the ranges 11.7 to 12.2 GHz and 17.7 to 18.9 GHz. HVT traffic occupies uplink frequencies in the ranges 5.925 to 6.425 GHz and 28.8 to 30.0 GHz and downlink frequencies in the range 3.7 to 4.2 GHz and 19.0 to 20.2 GHz. Frequency allocations to specific earth terminals are based on traffic demand and local atmospheric propagation conditions. In general, service will be provided at the lower frequency bands, with excess demand to be met by supplementary operation at the higher frequencies.

Direct-To-User (DTU) System (Initial Architecture)

The basic parameters of the DTU system are listed in Table 1. The system is designed to provide a maximum capacity of 1000 standard transponders.

Contiguous coverage is provided over populated areas in North, Central, and South America, as shown in Figure 6. Adjacent beams use separate segments of the available spectrum. Traffic distribution for the DTU system is assumed to be proportional to population density.

At Ku-band, the 500 MHz spectrum is split into three 160-MHz sub-bands. Since Ka-band is used for both DTU and HVT systems, 1200 MHz has been allocated to each, with the remainder of the total 2.5 GHz spectrum providing a buffer. The 1200 MHz segment of Ka-band assigned to DTU is split into three 400-MHz sub-bands. Beams radiating at the same frequency are spaced 1.7 beamwidths apart. Three multiple beam antennas are provided at Ku-band and three more at Ka-band. Beam patterns are interlaced to ensure crossover at the 3-dB points.

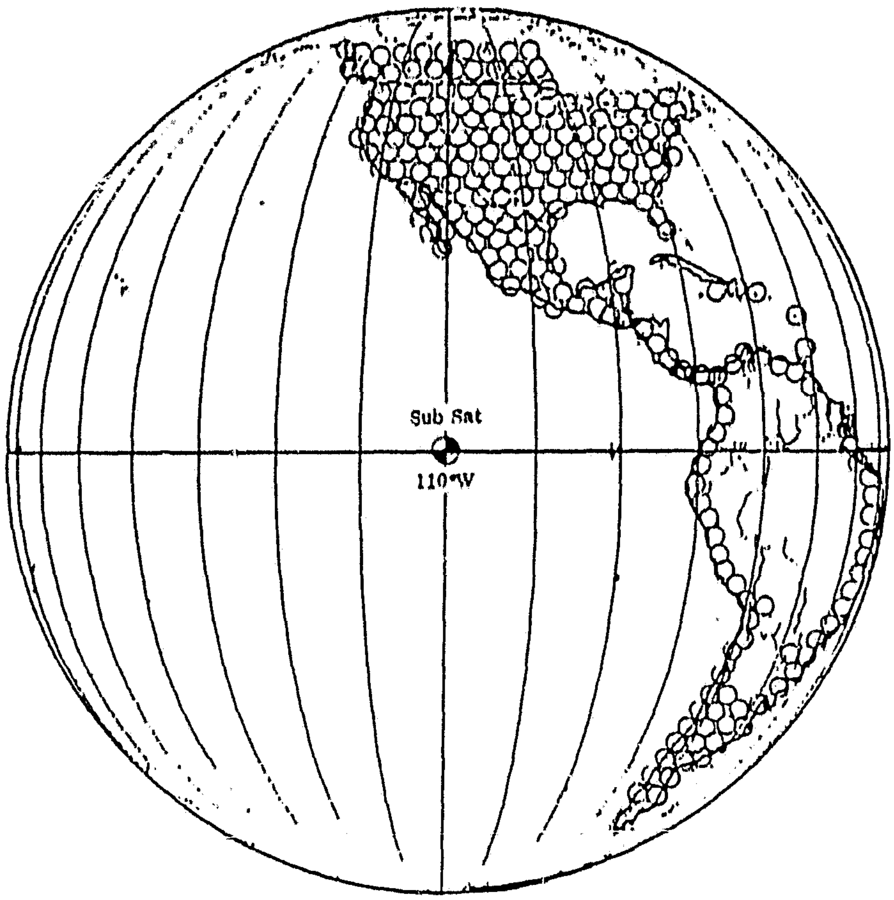
The highest population concentration in any cell corresponds to a forecast traffic demand of 7 standard transponders. The maximum number of transponders available is

Table 1. High capacity Direct-to-User communication payload characteristics.

Operating Frequencies:	14/12 GHz	30/20 GHz
Spectrum Bandwidth:	500 MHz	1200 MHz
Satellite Antenna Size:	6 meters (3)	4 meters (3)
Antenna Configuration:	Offset Cassegrain with Multiple Feed Array	Offset Cassegrain with Multiple Feed Array
Antenna Weight:	100 Kg	80 Kg
Beamwidth:	0.35°	0.35°
Beam Pointing:	0.03°	0.03°
Polarization:	Dual	Single
Transponder Bandwidth:	40 MHz	40 MHz
Transponder Power:	1 Watt	5 Watts
Number of Transponders:	500	500
Transponders/Beam (Max):	8	10
Transponder DC Pwer (Unit/Total):	5/2500 Watts	15/7500 Watts
Transponder Weight (Unit/Total):	1.8/900 Kg	2.2/110 Kg
Bit Rate per Transponder	64 MBPS	64 MBPS
Access:	SS-TDMA/FDMA	SS-TDMA/FDMA
Modulation:	QPSK	QPSK
Matrix Switch Size:	500 × 500	500 × 500
DC Power	4000	4000
Weight	240 Kg	240 Kg
Earth Terminal		
Antenna Size:	4.5 Meters	4.5 Meters
Transmit Power:	20 Watts	50 Watts
Noise Temperature:	385°K	665°K

Notes:

1. Antennas provide continuous coverage of populated areas with beams arranged individually and in clusters according to traffice requirements.
2. Dual frequency or single frequency earth stations can be provided.
3. Estimated traffic capacity is 1000 equivalent 40 MHz transponders.
4. Weather outages at 30/20 GHz compensated by switching to 14/12 GHz links.
5. Ku-Band frequencies: Uplink: 14.0 - 14.5 GHz
   Downlink: 11.7 - 12.1 GHz
   Ka-Band frequencies: Uplink: 27.5 - 28.7 GHz
   Downlink: 17.7 - 18.9 GHz



No. of Beams	
Canada	25
U.S.	120
Mexico	40
Central Am	15
South Am	60
Total	260

Figure 6. DTU Coverage, Western Hemisphere (110°W.)

18 transponders per beam, providing a substantial margin for growth. Of these 18 transponders per beam, 8 are at Ku-band (4 at each polarization) and 10 are at Ka-band.

The contiguous beam configuration tends towards an excess of transponder capacity in thinly populated areas if a minimum of one transponder per cell is required. An alternative approach would be to use scanning beams tailored to local traffic patterns and earth terminal distributions. Note that the scanning patterns must be synchronized to TDMA burst assignments and payload switch timing. Also, if a large number of locations are scanned by a single beam, a high burst rate is required with a corresponding increase in ground station complexity and cost.

High-Volume Trunking (HVT) System (Initial Architecture)

The basic parameters of the HVT system are listed in Table 2. This system is also designed to provide a maximum capacity of 1000 standard transponders. Its purpose is to connect a limited number of terminals located at points of high traffic concentration. The key objective is to provide full frequency reuse to designated urban centers with the coverage areas specific to the Western Hemisphere and Atlantic orbital locations. Both C-band and Ka-band frequency spectrum allocations are utilized via 0.35 degree spot beams. In most cases, beam separation is sufficient to permit full frequency reuse. In areas with closely spaced urban centers (less than two beamwidths), frequency sub-bands are allocated to adjacent or overlapping beams. Beams utilize single or dual polarization depending on capacity needs. Wideband transponders are employed to accommodate high burst-rate transmissions from the earth segment. Additional capacity in high-density areas is provided by higher level modulation schemes.

A possible multiple beam, high volume trunking coverage pattern for the Western Hemisphere is shown in Figure 7. C-band coverage from the 15-meter antenna would be provided at all the indicated locations with supplementary coverage at Ka-band as required by traffic demand.

CONUS presents the most difficult coverage problem in the Western Hemisphere because of the high population density and the concentration of urban centers in the Northeast.

Figure 8 shows one possible scheme for meeting the projected demand within this high population density region for the year 2000. The beam footprints are for 0.35° beams from a platform at 110° West. The matrix accompanying each footprint indicates what specific frequency sub-bands and polarizations are used within that beam. The modulation scheme is also indicated, as well as the total number of equivalent transponders within the beam. For each of the major trunking nodes within the corridor, the projected traffic demand is indicated, followed by the capacity of the beams to which it

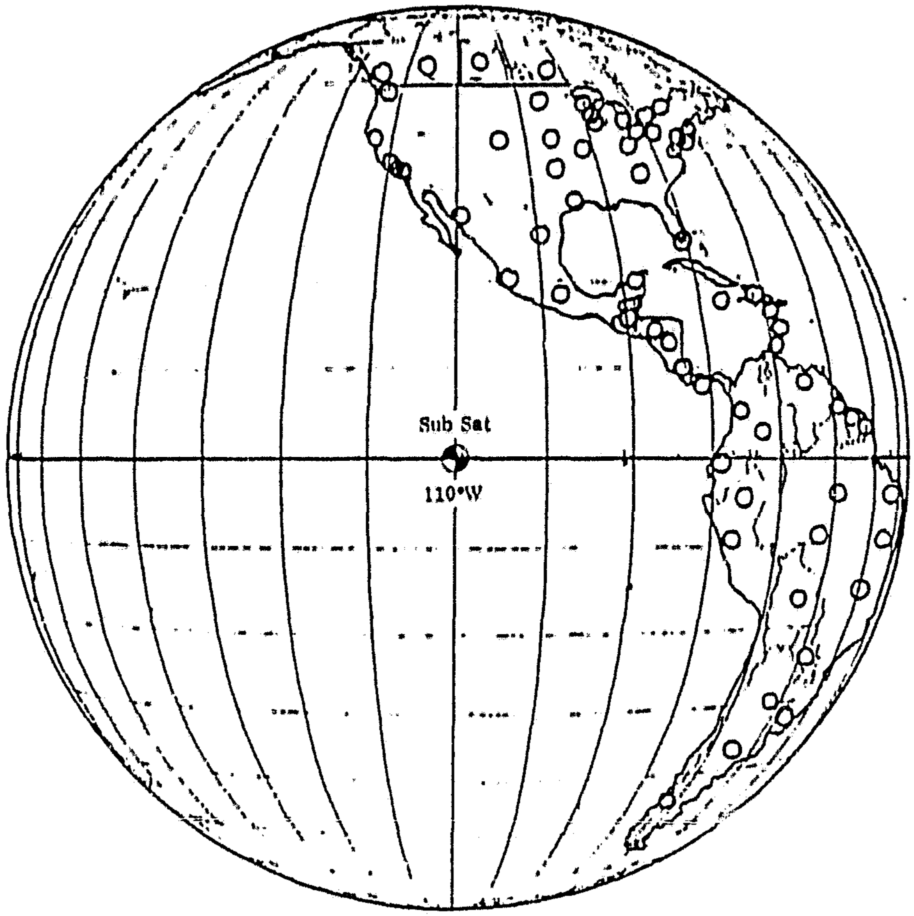
Table 2. High Volume Trunking communications payload characteristics.

Operating Frequencies:	6/4 GHz	30/20 GHz
Spectrum Bandwidth:	500 MHz	1200 MHz
Satellite Antenna Size:	15 Meters	4 Meters
Antenna Configuration:	Offset Cassegrain with Multiple Feed Array	Offset Cassegrain with Multiple Feed Array
Antenna Weight:	100 Kg	30 Kg
Beamwidth:	0.35°	0.35°
Beam Pointing:	0.03°	0.03°
Number of Beams:	Note 6	Note 6
Polarization:	Dual	Single/Dual
Transponder Bandwidth:	160 MHz	200 MHz
Transponder Power:	0.3 Watts	5 Watts
No. of Transponders:	125	100
Transponders/Beam (Max):	6*	6*
Transponder DC Pwr (Unit/Total):	1/300 Watts	20/2000 Watts
Transponder Weight (Unit/Total):	2.2/275 Kg	2.7/270 Kg
Bit Rate per Transponder	256 MBPS.	320 MBPS
Access:	SS-TDMA-FDMA	SS-TDMA/FDMA
Modulation:	QPSK	QPSK
Matrix Switch Size:	125 × 125	100 × 100
DC Power:	250 Watts	200 Watts
Weight:	30 Kg	30 Kg
Earth Terminal		
Antenna Size:	10 Meters	10 Meters
Transmit Power:	5 Watts	50 Watts
Noise Temperature:	155°K	665°K

* Equivalent to 24 standard 40 MHz transponders

Notes:

1. Antennas provide individual spot beams pointed at major traffic nodes which generally correspond with major urban centers.
2. Dual or single frequency earth stations can be provided at node locations.
3. Estimated traffic capacity is 1000 equivalent 40 MHz transponders.
4. Weather outages at 30/20 GHz are compensated by site diversity or switching traffic to 6/4 GHz links. Policy dependent on traffic levels and required availability.
5. C-band frequencies: Uplink: 5.925 - 6.425 GHz
   Downlink: 3.7 - 4.2 GHZ
   Ka-band frequencies: Uplink: 28.8 - 30.0 GHz
   Downlink: 19.0 - 20.2 GHz



No. of Beams	
Canada	5
CONUS	25
Mexico	5
Central AM	10
South AM	20

Figure 7. HVT Coverage, Western Hemisphere (110°W.)

has access. New York City, for example, is projected to have a requirement of 75 equivalent transponders. It lies within four overlapping beams, two of which have capacities of 56 transponders and two of which have 20. This gives New York City access to 152 equivalent transponders. The excess capacity is shared with other cities as shown. Considerable margin for traffic growth exists. This scheme depends, of course, on foreseeable advances in technology. Improved linear amplifiers with distortion cancellation will lead to practical 16-level APSK. Selective (automatic) use of redundant bit streams will greatly reduce depolarization and rain fade. Active sidelobe cancellation will improve isolation between beams spaced about 2 beamwidths apart.

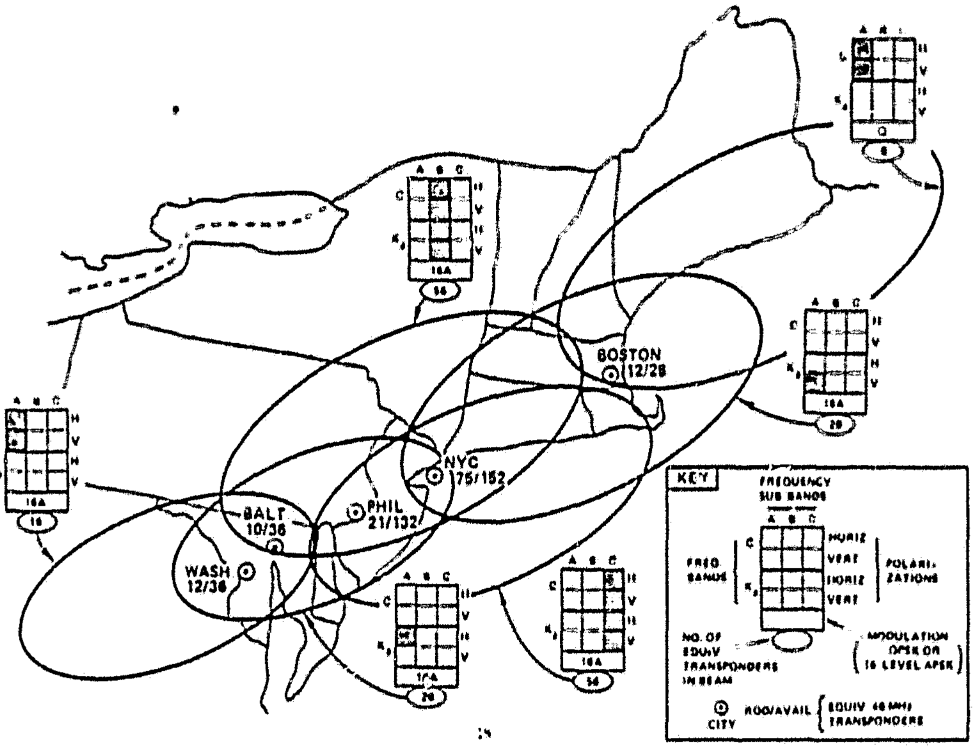


Figure 8. High Volume Trunking demands of the Northeast corridor.

PAYLOAD ALLOCATION

Allocation of payloads to the two selected orbit locations for both the nominal and high traffic models was based on equitable division of traffic, functional characteristics, and rough equalization of overall weight and power requirements where possible. Two such allocations are shown in Figure 9.

Not all payloads need to be placed in orbit at the same time. Communications payload requirements are a function of the development of markets for new services and growth in demand for existing services. This situation supports a modular growth approach to platform implementation in which platform capacity and capability can be made to grow with time. For each of the two platform locations, sub-allocations were made such that the payloads could be accommodated by either a constellation of platforms launched individually over a period of time or by a single platform which would grow with time by the addition of modules.

In the constellation concept, platform modules might be arranged in a rotating

*KEY W = WEST HEM.
A = ATLANTIC
E = EITHER
B = BOTH

NOMINAL TRAFFIC MODEL, WESTERN HEMISPHERE			
P/L NO.	MISSION	WEIGHT KG	POWER W
1, 2	PT-PT COMMUNICATIONS	3,490	20,900
3	TV DISTRIBUTION	400	4,000
4	TRACKING & DATA RELAY	330	680
5	EDUCATIONAL TV	200	200
6	DIRECT TV	400	2,100
7	AIR MOBILE	200	900
9	LAND MOBILE	530	4,000
11	INTERPLATFORM LINKS	70	120
12	DATA COLLECTION	100	100
17	LIGHTNING MAPPER	320	300
18	ATMOSPHERIC SOUNDER	190	50
19,20	RADIOMETERS	650	250
27	RF INTERFEROMETER	120	220
31	DMSP DATA RELAY	150	100
54	DOD EHF EXP.	230	500
55	DOD LASER COMM. EXP	320	550
32	ADV. OLS CLOUD IMAGER	150	150
38	AEROSOL & CLOUD HT SENSOR	50	100
42	GLOBAL UV RADIANCE	50	20
52	BOSS EVALUATION	150	400
33	MATERIALS EXPOSURE	10	25
43	MAGNETIC SUBSTORM MONITOR	10	5
50	FIBER OPTICS DEMONSTRATION	10	30
71	EARTH OPTICAL TELESCOPE	1,100	2,000
	TOTAL (PAYLOADS ONLY)	9,230	37,700

HIGH TRAFFIC MODEL BOTH HEMISPHERES				
P/L NO.	MISSION	*	WEIGHT KG	POWER W
1, 2	PT-PT COMMUNICATIONS (WH)	W	6,910	45,200
1,2,10	PT-PT COMMUNICATIONS (ATL)	A	4,030	24,700
3	TV DISTRIBUTION	B	400	4,300
4	TRACKING & DATA RELAY	B	330	680
5	EDUCATIONAL TV	B	200	200
6	DIRECT TV	B	400	2,100
7	AIR MOBILE	B	200	900
8	SEA MOBILE	A	400	600
9	LAND MOBILE	B	700	4,000
11	INTERPLATFORM LINKS	B	70	120
12	DATA COLLECTION	B	100	100
17	LIGHTNING MAPPER	B	350	300
18	ATMOSPHERIC SOUNDER	B	200	50
19,20	RADIOMETERS	E	650	250
27	RF INTERFEROMETER	B	150	250
31	DMSP DATA RELAY	B	150	100
54,55	DOD COMM. EXP (EHF, LASER)	E	550	1,050
32,38,42	EARTH OBSER.	E	250	270
39,40,41,44	DOD SOLAR GROUP	E	150	150
33,43,56	DOD EXPOSURE GROUP	E	30	70
34	ACOSS/HALO	E	1,100	500
52,36	BOSS/AOSP	E	500	1,100
51,78	CRYO LIMB SCANNER	E	570	6,000
71	EARTH OPTICAL TELESCOPE	E	1,100	2,000
63	GEMINI EVALUATION	E	820	1,800
73,75,76,77	OSS GROUP I	E	900	1,100
79	LLL TV	E	300	1,000
81,82,83,84	OSS GROUP II	E	1,250	3,350
	TOTAL (PAYLOADS ONLY)		33,522	114,640

Figure 9. Payload allocation by traffic model and orbital location, year 2000.

circular pattern within a ± 0.1° (from the earth) field of view. This could be done by placing the modules in geosynchronous orbits which deviate somewhat from geo-stationary, slightly inclined and slightly elliptical, with proper nodal point phasing. The platform module on-board propulsion systems would be used to maintain each module in its proper orbit and relative position within the constellation. Preliminary calculations indicate that an eccentricity of $e = 0.00011$ and an inclination of $i = 0.0125$ degrees would result in a circular constellation with a diameter of approximately 18 km.

Whether the platforms are docked or in a constellation, connectivity will be provided. For the constellation, this connectivity would be through microwave links. For the platform made up of docked modules, redundant data busses, probably fiber optics, would be provided.

DOCUMENTATION

Primary payload characteristics such as weight, power, thermal load, geometry, orientation and pointing accuracy were assessed for all payloads in sufficient detail to permit estimates of the levels of support required from the platform subsystems. All information for each payload was recorded on a standard three-page format as a data base for input to subsequent study tasks. These Payload Data Sheets, together with back-up data for communications traffic models, link analyses and budgets, etc., can be found in Appendices A through E of this final report (Volume IIA - Technical Appendices).

SUMMARY

- Considerable growth in communications traffic demand is anticipated in the next two decades.
- Demand for communications services can best be met by payloads combining multi-frequency operation with extensive frequency reuse provided by multiple beam antennas and onboard switching.
- Optimum platform configurations should be capable of modular growth in order to accommodate time-phased mission requirements and budgetary constraints.
- An Initial Architecture was derived which uses high technology to meet projected year 2000 traffic requirements from a single orbital slot over each hemisphere.
- Alternate, multi-slot architectures will be examined in the Follow-on Study.

TASK 2

CONCEPT ANALYSIS & SELECTION

Based on the mission and payload requirements identified in Task 1, candidate platform concepts were defined and analyzed in Task 2, and trade studies performed leading to recommendation of selected concepts for definition in Task 3.

Of 30 transfer vehicle (LEO to GEO) configuration and operating mode options identified from data supplied by NASA/MSFC, 18 viable candidates compatible with the Operational Geostationary Platform missions were selected for analysis. Each was considered using four platform operational modes: 8 or 16 year life, and serviced or non-serviced. Thus 72 major OTV/platform mode options were analyzed. Standard platform concepts were defined for each of the 72 options for both the nominal and the high traffic models, and payloads reallocated to these 144 options based on OTV performance capability and payload weight and power. For final trade study concept selection, a costing program was developed considering payload and platform costs and weight; transportation unit and total costs for Shuttle and OTV; and operational costs such as assembly or construction time, mating time, and loiter time. Servicing costs were added for final analysis and recommended selection.

The 144 candidate concepts were screened and the nine best options for combinations of launch and operating modes, transfer vehicles, and evolutionary buildup modes were analyzed. Four were recommended and selected by NASA for further study. Alternative #1 was designated for definition in Task 3. Alternatives #2, #3, and #4 were deferred to the Follow-On Study for further definition.

METHODOLOGY

System level trade studies were carried out to parametrically define and evaluate alternative platform design, transportation, operational and servicing approaches, and to select the most promising concepts for further definition. The quantitative evaluation criterion employed for evaluation of alternative concepts was comparative program cost for acquisition and operations.

To ensure that the full range of mission requirements was covered, trade studies were done for both the smallest and largest missions sets, i.e., Set N - Nominal Traffic model, Western Hemisphere location; and Set V - High Traffic Model, Atlantic and Western Hemisphere locations (Ref. Task 1, Figure 9). A third system model was also constructed for Mission Set P - Nominal Traffic Model, Atlantic and Western Hemisphere locations.

The basic trade study methodology was to (1) develop a family of platform concepts which would accommodate each of the Mission Sets using system options in four categories, (2) to evaluate these categories in terms of nine trade study areas, and (3) to determine program costs sensitive to platform system concept definitions. The trade study matrix is shown in Table 3, with study interdependence between areas shown by Xs under each option. Screening was necessary to eliminate the least promising candidates and make the matrix manageable.

Launch Mode Options

Launch mode options were considered that covered a range of platform sizes and assembly methods from simple satellites to single large assembled platforms, compatible with the entire range of STS capabilities. Four basic options and two sub-options were analyzed, Cases I and I', II, III and III', and IV. These are summarized in Figure 10.

Transfer Vehicle Options

By far the widest range of options was the potential choice of orbit transfer vehicles, Table 4. The data base provided by MSFC included the Inertial Upper Stage (IUS), Centaur, single and dual stage Orbit Transfer Vehicles (OTV) and

Table 3. Trade Study Matrix.

	Trade Study Areas	Platform System Options: Launch Mode	Transfer Vehicle	Opera-tional Mode	Evolution-ary Buildup
1.	Serviced vs Non-serviced			X	
2.	Single vs Multiple Platforms (Economy of scale)	X	X		X
3.	Evolutionary Buildup Options (Time phasing)				X
4.	Construction Location Options (LEO vs GEO)	X			X
5.	Transportation Options (OTV capabilities)	X	X		
6.	Structural Options				
7.	Deployment/Assembly Options		X	X	X
8.	Construction Base Options	X			X
9.	Logistic Support Options		X	X	X

the Interim OTV (IOTV). Some of these included different launch modes (ground or space-mated) and low or standard thrust engines. Expendable, reusable and round trip operational modes were also included. These various combinations resulted in 30 discrete vehicle/operating mode combinations to be considered. Screening of these candidates based on performance capability, $ cost/kg delivered to GEO, T/W ratio (structural weight penalty) and payload length availability reduced the number of vehicle candidates from 30 to 19, including the 2-stage IUS (Code s) that was used only for the individual satellite mode.

Operational Mode (Servicing) Options

The most important operational factor influencing platform design and life cycle cost is servicing. Suboptions include platform life for the non-serviced platform, and servicing frequency for the serviced platform approach. Nine options

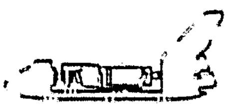
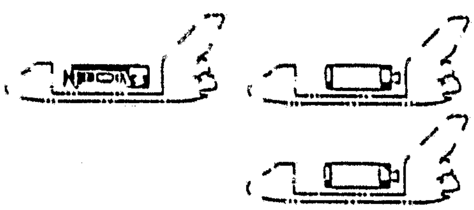
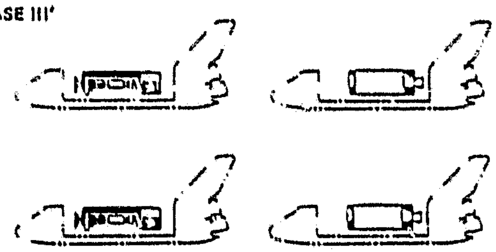
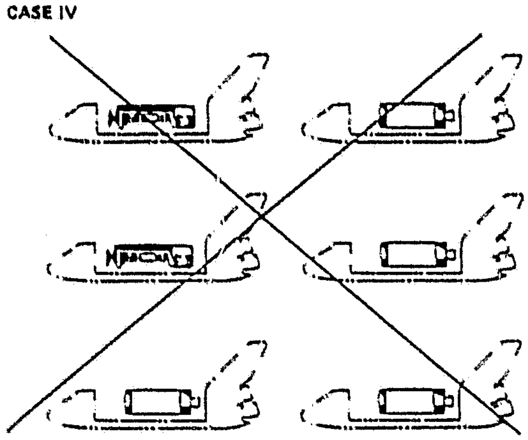
CASE I		Individual satellites with a wide variety of unique designs are employed to accommodate the mission model. Transportation is provided by the Shuttle, SSUS, and IUS as required.
CASE I'		A standard bus design (based on the TDRS, but with 1990 technology incorporated) is employed to accommodate the mission model. Transportation is provided by the Shuttle and 2-Stage IUS.
CASE II		A small platform and its OTV are launched to LEO by one Shuttle flight. OTV transfers platform to GEO.
CASE III		A medium size platform (or platform module) delivered to LEO in one Shuttle flight. One or two additional Shuttle flights deliver an OTV to LEO where it is mated with the platform prior to transfer to GEO.
CASE III'		Halves of a large platform module delivered in two Shuttle flights to LEO where they are mated. Two Shuttle flights deliver OTV stages to LEO where they are mated to each other and to the platform.
CASE IV		Single very large platform requires more than 4 delivery flights for platform elements and OTV's. Not feasible with STS as defined.

Figure 10. Launch Mode options.

Table 4. Transfer Vehicle Options.

CODE	2-STAGE IUS	4-STAGE IUS	CENTAUR	IOTV	1-STAGE OTV	2-STAGE OTV	LO. T. ENGINE	REUSABLE	EXPENDABLE	II GND MATED	III SPACE MATED	GROSS CAPACITY TO GEO (KG)	T/W	PENALTY (KG)	L P/L (FT)	COST/FLT $M	$/GRAM	CODE
a					X		LT	R		II		2,608	0.13	—	25	37	14	a
b			X				LT		E	II		4,763	0.19	—	26	62*	13	b
c				X			LT		E	II		5,670	0.08	—	24	59	10	c
d					X		LT		E	II		6,895	0.07	—	25	67	10	d
e					X				E	II		7,802	0.64	492	25	67	9	e
f				X					E	II		6,895	0.69	448	24	59	9	f
g				X			LT		E		III	9,100	0.06	—	60	100	11	g
h					X		LT		E		III	11,340	0.05	—	60	108	10	h
j						X	LT	R			III	16,878	0.035	—	60	124	7	j
k						X	LT		E		III	25,600	0.024	—	60	184	7	k
l						X		R			III	19,505	0.31	780	60	124	6	l
m						X			E		III	27,851	0.22	—	60	184	7	m
n					X				E		III	13,018	0.43	716	60	108	8	n
o				X					E		III	10,206	0.51	612	60	100	10	o
p					X			R			III	5,897	0.78	413	60	78	13	p
q					X			R		II		3,493	1.08	147	25	37	11	q
r			X						E	II		5,443	1.76	400	26	62*	11	r
s	X								E	I		2,313	2.35	N/A	33	46	20	s
v		X							E		III	9,072	1.86	857	60	134	15	v
t			X	DUAL					E		III	9,526	1.15	—	26	133	14	t
u		X	(2L, 2S)						E		III	5,216	1.25	—	46	92	18	u
i					X		LT	R			III	4,296	0.10	—	60	78	18	i
*	UPDATED CENTAUR COSTS —						—	—	—	—	—	— —	— —	— —	— —	— 50		

covering the range of feasible designs and operations were identified, Table 5, and parametric scaling laws developed for each option.

Table 5. Operational Mode options.

Mode	Description	Service Interval Years
A	Serviced, 16 year life, 5 year consumables capacity	2
B	Non-serviced, 8 year life, replaced	
C	Non-serviced, 16 year life, highly redundant design	
C'	Serviced as required, 16 year life, 8 year consumables	8
D	Serviced, 16 year life, 5 year consumables capacity	2
E	Serviced, 16 year life, 3 year consumables capacity	2
F	Serviced, 16 year life, 2 year consumables capacity	2
G	Serviced, 16 year life, 3 year consumables capacity	1/2
H*	Serviced, 16 year life, 3 year consumables capacity	1/2

*Used for evolutionary buildup trades.

To investigate the interaction of economy of scale and operating mode, sets of platform concepts were defined from a single large platform down to a set of 20 platforms, each set carrying the same payloads to satisfy a given traffic model. Payload and platform masses were adjusted to accommodate operational options A, B, C, and D, and assigned to compatible transfer vehicle options. Modes E and F were added to determine the sensitivity of platform mass to servicing interval. The influence of operating mode was evaluated on a basis of total mass delivered to GEO for each system concept. Mode A was judged unrealistic and dropped from further consideration.

Further analyses were made using updated mission payload sets with increased mass and power requirements, with updated OTV types, capabilities and costs, and with platform and payload costs included. Each iteration resulted in further screening and left operational modes B, C, C' and E as viable candidates for system trade studies.

Evolutionary Buildup Options

A variety of methods can be used to integrate platform modules into a complete platform system at Geosynchronous Orbit. To evaluate the feasibility and effects of payload addition, interdependent vs dependent modules, and docked vs clustered modules, four platform buildup options were selected, Table 6.

Evolutionary buildup permits time-phased delivery of payloads to GEO commensurate with user needs (traffic demand or experimental payloads) in a timely manner. Evolutionary buildup also permits development, production and module delivery costs to be spread over a longer time base to reduce peak funding requirements.

Option Summary

The range of system design options that was investigated is summarized in Figure 11. The basic trade study evaluated economy of scale, transfer vehicle launch mode and delivery capabilities, and platform operational mode using the following

Table 6. Evolutionary Buildup Options.

Mode H - Payload Addition

- o Single very large platform with small initial payload complement placed in GEO
- o Payloads added by servicing flights (2 per year)

Mode J - Docked Dependent Modules

- o Case II, III, or III'
- o Modules docked at GEO
- o Subsystems shared between modules

Mode K - Constellation

- o Independent modules flying in formation at GEO
- o Connectivity by microwave link

Mode L - Docked Independent Modules

- o No subsystem sharing
- o Hardwire connectivity

options:

a. Launch mode II, III, and III'

b. Transfer vehicles "a" through "v"

c. Operating modes B, C, C' and E

d. Buildup mode K

e. Mission sets N and V.

RESULTS

As shown in Table 7, 72 mode K concepts were analyzed and cost estimates developed for each of three combinations of mission set, traffic model, and orbital location. Detailed results of these analyses are contained in Volume II of the final report. In addition to these basic trade studies, several of the more promising concepts were selected to explore other modes of evolutionary buildup and are listed in the table for modes H, J, and L; for comparison, concepts and

LAUNCH MODE

- I — INDIVIDUAL SATELLITE (CONVENTIONAL)
- I' — INDIVIDUAL SATELLITE (STANDARD TDRSS BUS)
- II — SMALL MODULE + TV, SINGLE-SHUTTLE
- III — MEDIUM MODULE IN SHUTTLE, SPACE MATING
- III' — LARGE MODULE IN 2 SHUTTLES, SPACE MATING
- IV — SINGLE VERY LARGE PLATFORM

TRANSFER VEHICLE

a	OTV	LT	R	II	2,808 KG	$ 37 M
b	CENTAUR	LT	E	II	4,763	62
b'	CENTAUR					50
c	IOTV	LT	E	II	5,670	59
d	OTV	LT	E	II	6,895	67
e	OTV		E	II	7,802	67
f	IOTV		E	II	6,895	59
g	IOTV	LT	E	III	9,190	100
h	OTV	LT	E	III	11,340	108
j	2-OTV	LT	R	III	16,878	124
k	2-OTV	LT	E	III	25,600	184
l	2-OTV		R	III	19,505	124
m	2-OTV		E	III	27,851	184
n	OTV		E	III	13,018	108
o	IOTV		E	III	10,206	100
p	OTV		R	III	6,897	78
q	OTV		R	II	3,493	37
r	CENTAUR		E	II	5,443	62
r'	CENTAUR					50
s	2-IUS		E	I	2,313	46
v	4-IUS		E	III	9,072	134

OPERATING MODE

- B — THROWAWAY, UNSERVICED, REPLACED AFTER 8 YEARS
- C — HIGHLY REDUNDANT, UNSERVICED, 16 YEAR LIFE
- E — FREQUENTLY SERVICED, PERMANENT FACILITY, SERVICED EVERY 2 YEARS (AVERAGE)
- C' — HYBRID, HIGHLY REDUNDANT, SERVICEABLE, PERMANENT FACILITY, SERVICED EVERY 8 YEARS (AVG), P/L UPDATE BY NEW MODULES

BUILDUP MODE

- H — PAYLOAD ADDITION
- J — DOCKED DEPENDENT MODULES, SHARED SUBSYSTEMS
- K — CONSTELLATION, MICROWAVE LINKS
- L — DOCKED INDEPENDENT MODULES, NO SUBSYSTEM SHARING

MISSION SET

- N — NOMINAL, WESTERN HEMISPHERE
- V — HIGH, BOTH LOCATIONS

Figure 11. Summary of System Design Options for Trade Study.

costs were also developed and are listed for Mode K single-satellite launch cases I and I'. The four concepts selected by NASA for definition in Task 3 and in follow-on studies are listed in the lower section of Table 7, and are designated as Alternatives #1, #2, #3, and #4. These concepts include packaged platforms from less than half a cargo-bay length to full cargo-bay length; platforms accommodating nominal and high communications traffic models; constellations of platforms vs. docked platform modules; and transfer vehicles from IUS to Centaur and OTVs. The four selected concepts are shown in Figure 12; concept Alternative #1 was selected for definition in Task 3 of this study.

The basic trade studies, performed for buildup mode K, showed an economy of scale advantage for larger platforms, based on total program costs. Economy of scale is achieved through the use of a fewer number of larger platform modules, designed to

Table 7. System Concepts for Trade Study.

Buildup Mode	Mission Set	Traffic Model	Orbital Location	No. of Concepts	Launch Case	Opera-tional Mode	OTV Type
K	N	Nom.	W.Hem.	72	II, III, III'	B, C, C', E	a-v(1)
K	V	High	W.Hem.&Atl.	72	II, III, III'	B, C, C', E	a-v(1)
K	P	Nom.	W.Hem.&Atl.	72	II, III, III'	B, C, C', E	a-v(1)
H	N	Nom.	W.Hem.	2	III	E	j, m
H	V	High	W.Hem.&Atl.	2	III'	E	j, m
J	N	Nom.	W.Hem	1	II	C'	d
L	V	High	W.Hem.&Atl.	1	II	C'	d
J	V	High	W.Hem.&Atl.	1	II	C'	d
L	V	High	W.Hem.&Atl.	1	III	C'	j
J	V	High	W.Hem.&Atl.	1	III	C'	j
K	N	Nom.	W.Hem.	2	I	B, C	x(2)
K	N	Nom.	W.Hem.	2	I'	B, C	s
K	V	High	W.Hem.&Atl.	2	I'	B, C	s
K	P	Nom.	W.Hem.&Atl.	1	I'	B	s
K	P	Nom.	W.Hem.&Atl.	1	I'	B	x(2)
K	P	Nom.	W.Hem.	1	II	C'	d Alt #1
J	P	Nom.	W.Hem.	1	II	C'	d Alt #2
K	V	High	W.Hem.&Atl.	1	III	E	j Alt #3
J	V	High	W.Hem.&Atl.	1	III	C'	1 Alt #4

(1) Except s

(2) x = SSUS-A, -D, and IUS-2

match the performance of larger, more economical orbit transfer vehicles.

The impact of transportation mode on total program costs is shown in Figure 13. The extreme righthand bar shows that 62 individual satellites with appropriate upper stages sharing Shuttle launches are required to satisfy the mission model (Nominal Traffic Model). Some cost savings are available by going to 39 standardized multiple-payload busses optimized to the capability of the IUS (second bar from right). Moving further to the left, the figure indicates the dramatic cost reductions obtained by optimizing to the capacity of the

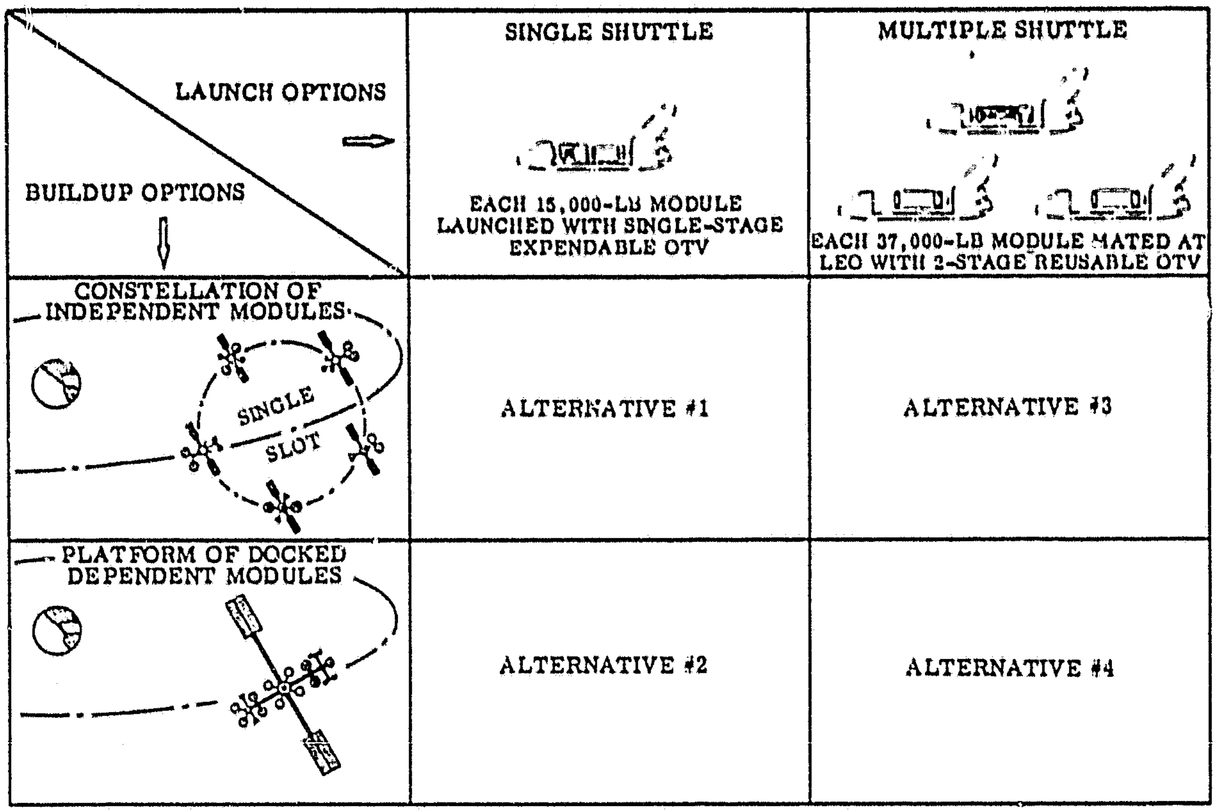


Figure 12. Operational Geostationary Platform Alternative Concepts.

Shuttle with various high-energy liquid upper stages. The most significant result is that the economy of scale obtainable with modest-sized platforms launched together with their upper stages in a single Shuttle is nearly as great as that obtained from larger platforms requiring multiple-Shuttle flights. The same payloads can be supported using 6 single-Shuttle platforms with a single-stage liquid expendable OTV as require 62 individual satellites. The difference in total cost is a factor of four.

Examination of the individual cost elements shows that there are two major contributors to this economy of scale. One is the bus costs, where the savings from shared support subsystems is substantial. The other even larger contributor is in the transportation costs, where the use of more efficient upper stages, the reduction of total mass on orbit, and the optimum use of Shuttle weight and volume combine to greatly reduce the total number of Shuttle launches required.

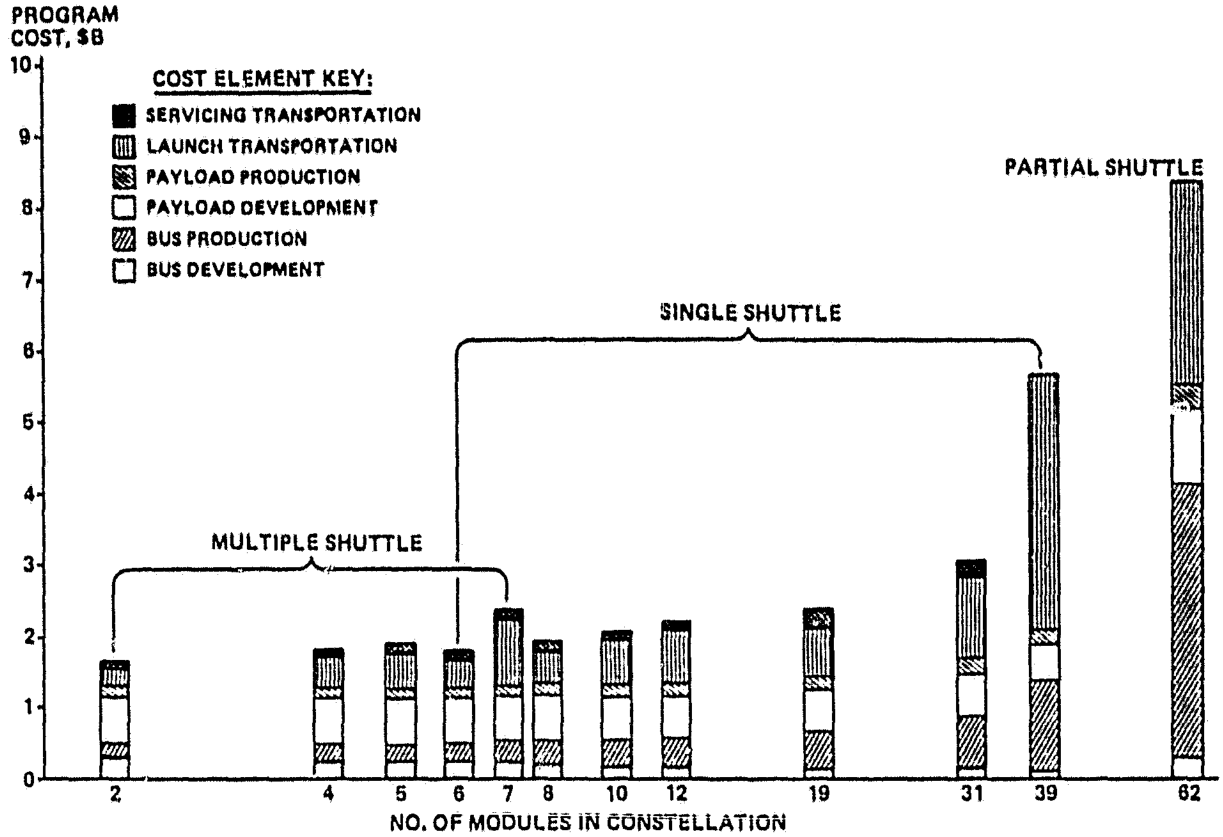


Figure 13. Impact of transportation mode on total program costs.

Figure 13 is but one of many such sets of results which together provide firm economic guidance for what may be called Shuttle-Optimized Design.

One clear result of the study is that OTV reusability, either for delivery or servicing, is only economical with large, 2-stage vehicles. Single stage vehicles are in every case more expensive in the reusable mode than in the expendable mode. Reusability will, of course, be required for other than economic reasons - satellite retrieval and manned operation for example. But economic advantages should not be expected for vehicles with delivery capability from LEO to GEO of less than about 10,000 kg in the reusable (OTV returns empty) mode.

Operational mode C', a platform with 16-year subsystem life and consumable resupply at 8 years, yielded the lowest program costs. Although weight /cost penalties are incurred to obtain redundancy and longer life, the reduced transportation costs more than outweigh the penalties and yield an overall economic advantage.

CONCLUSIONS

In summary:

- Platforms enjoy significant economic advantage.
  - Major savings between individual satellites and single-Shuttle launched platforms.
  - Additional marginal savings with fewer, larger, multiple-Shuttle launched platforms.
- Shuttle-optimized design (platform mass/STS performance compatibility) greatly reduces transportation costs.
- High energy liquid transfer vehicles maximize economy.
- Built-in reliability and redundancy maximize economy.
- Limited servicing is beneficial.
  - Replenish consumables.
  - Exchange predictable wearout components.
  - Allow payload update.
  - Add capacity to match demand growth.
- Servicing is not a substitute for quality control.
- Only very reliable spacecraft are worth servicing.

TASK 3

CONCEPTS DEFINITION

The objective of Task 3 is to define selected Operational Geostationary Platform concepts to a depth sufficient to verify feasibility, identify required technology, identify STS interfaces, and develop supporting cost and schedule data.

Alternative concept #1 was selected by NASA for definition in this study. This concept (ref. Figure 12, Task 2) consists of two constellations of platforms, one at 110° W. longitude, and one at 15° W. longitude. Each constellation consists of six platforms, and together satisfy the nominal traffic model. The twelve platforms are similar but not identical; each must support its assigned payloads, with variations in support requirements.

Each platform must meet the following requirements:

- 26 ft. long, maximum, in the packaged configuration.
- 15,000 lbs, maximum.
- delivered to LEO attached to a low-thrust single-stage expendable OTV in a single Shuttle flight.
- deployed, checked out, and transferred to its assigned orbital location in the constellation.

Payloads were allocated to the twelve platforms based on an equitable distribution of weight and power requirement. To minimize duplication of design effort, three platforms were chosen for further definition, representing the extremes in design requirements. These were Platform Nos. 1, 2, and 6 in the Western Hemisphere constellation. Platform definition, by direction, included the following subtasks:

a. Platform definition

b. Transportation requirements

c. Mission (logistics) plan

d. Specialized communications/integration equipment.

Results of these tasks are summarized in the following paragraphs.

PLATFORM DEFINITION

Platform, payload and OTV packaging within the allocated Orbiter cargo-bay space proved to be the major design constraint in this study. Viable concepts considered for packaging structures and payload components included:

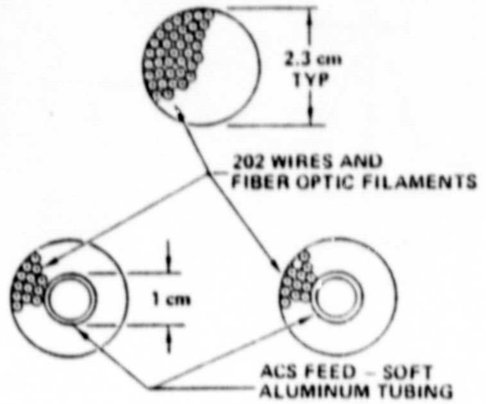
- Deployable structure - Astro Research Corporation's coilable and articulated Astromasts, Figure 15; General Dynamics' expandable On-Orbit-Assembly truss beam, Figure 16; telescoping masts; rotating, folding and pivoting arms.
- Deployable antennas, Figure 17 - Lockheed's Wrapped Rib, General Dynamics' Parabolic Expandable Truss Antenna (PETA), and TRW's Sunflower. Each has its own special application to accommodate particular RF frequency and location requirements.
- Deployable (hinged) feed assemblies - a new concept.

Definition of the platform configurations included docking capability for servicing, Figure 18; antenna and feed assembly location to meet communication systems technical and operating requirements; power system sizing and definition, and control systems definitions.

Following definition of each platform's packaged and deployed configurations, structure was sized for strength and stiffness, and dynamic analyses made.

The packaged configuration for Alternative #1 Platform No. 1 is shown in Figure 19; the deployed configuration is shown in Figure 20. A weight breakdown for both the platform and its payloads is summarized in Table 8.

- EXISTING ASTROMAST (SHOWN BELOW), HAS 0.35 cm DIA LONGERONS AND A ~0.8 cm DIA ELECTRICAL HARNESS.
- PLATFORM 1 EMPLOYS A 100 cm MAST WITH APPROX. 2 cm DIA LONGERONS
- THREE 2.3 cm ELECTRICAL/FLUID HARNESSES SHOULD BE WITHIN ASTROMAST'S ACCOMMODATION CAPABILITY.



VOYAGER ASTROMAST

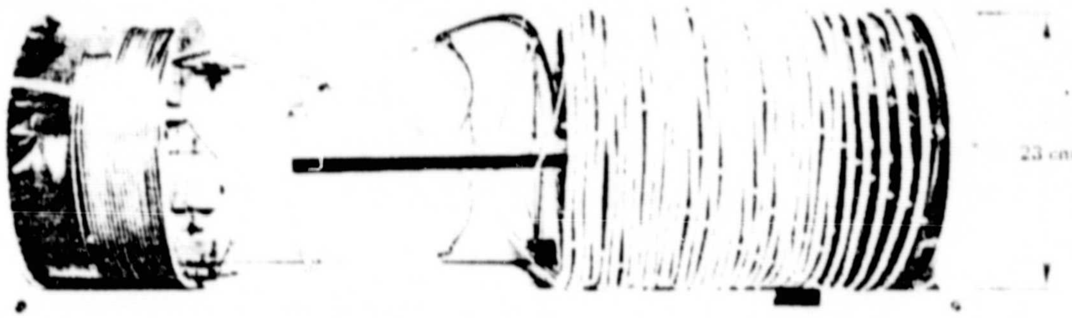
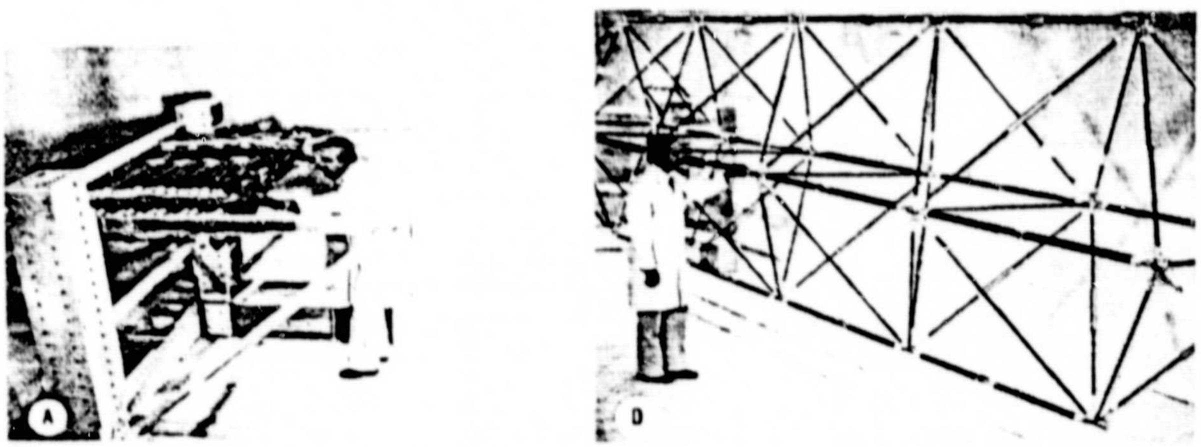


Figure 15. Expanding mast (Astromast) with utilities accommodation.



FOLDED

DEPLOYED

Figure 16. GDC Deployable Space Truss beam.

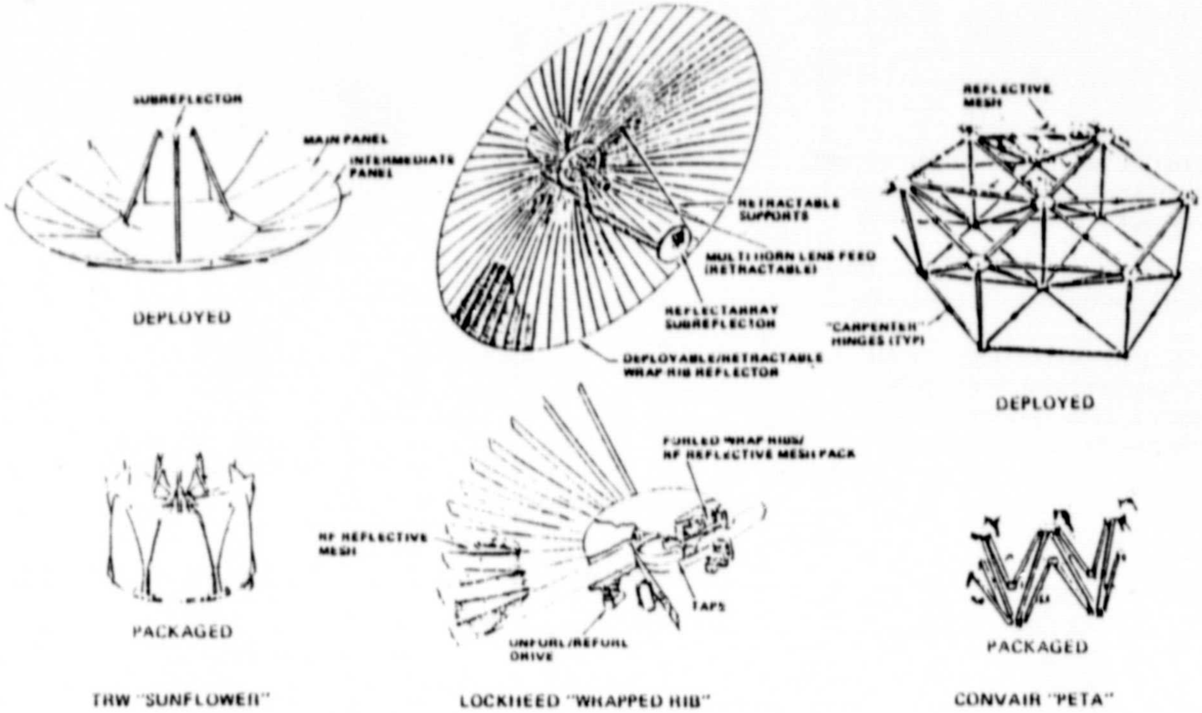


Figure 17. Deployable antenna concepts.

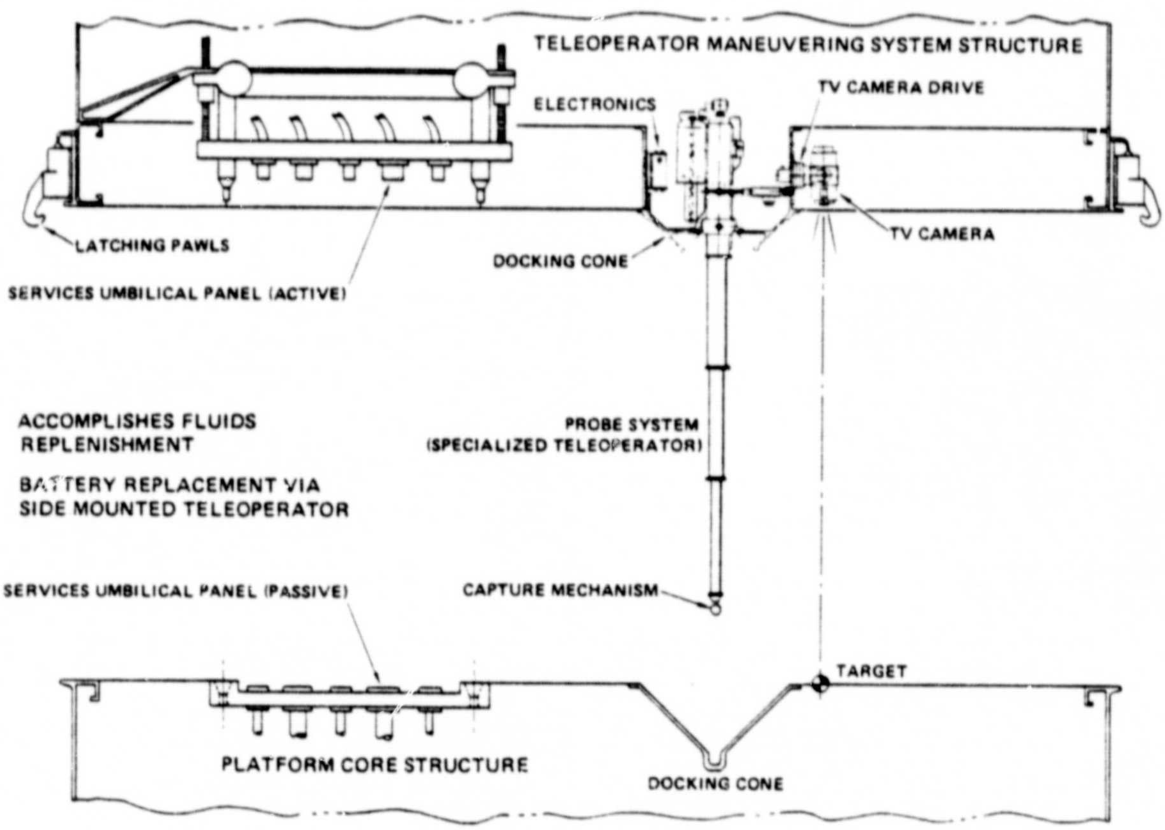


Figure 18. Orbital servicing interface concept.

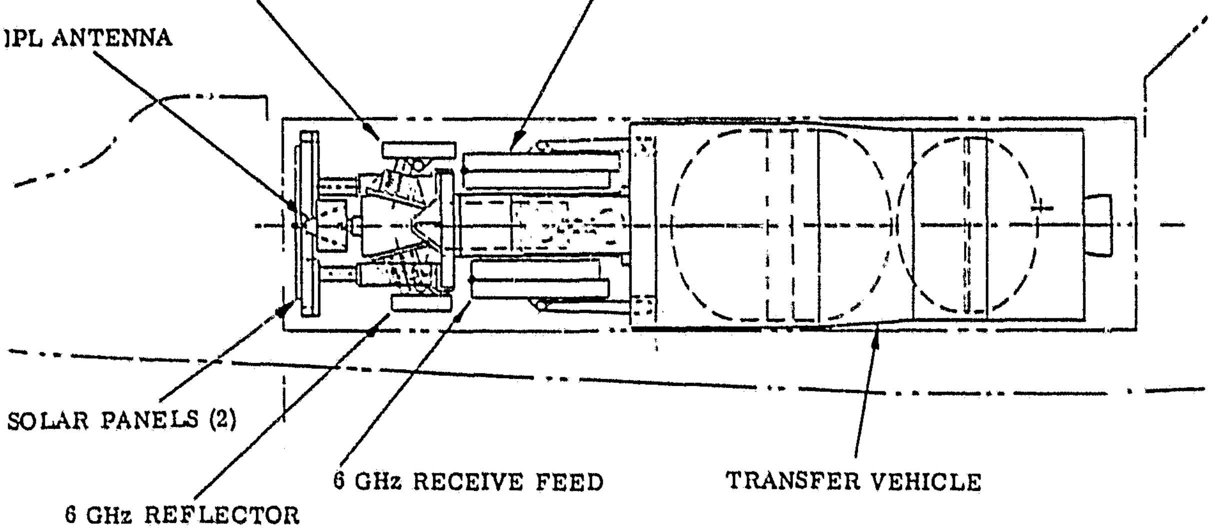


Figure 19. Alternative Concept #1, Platform No. 1, packaged.

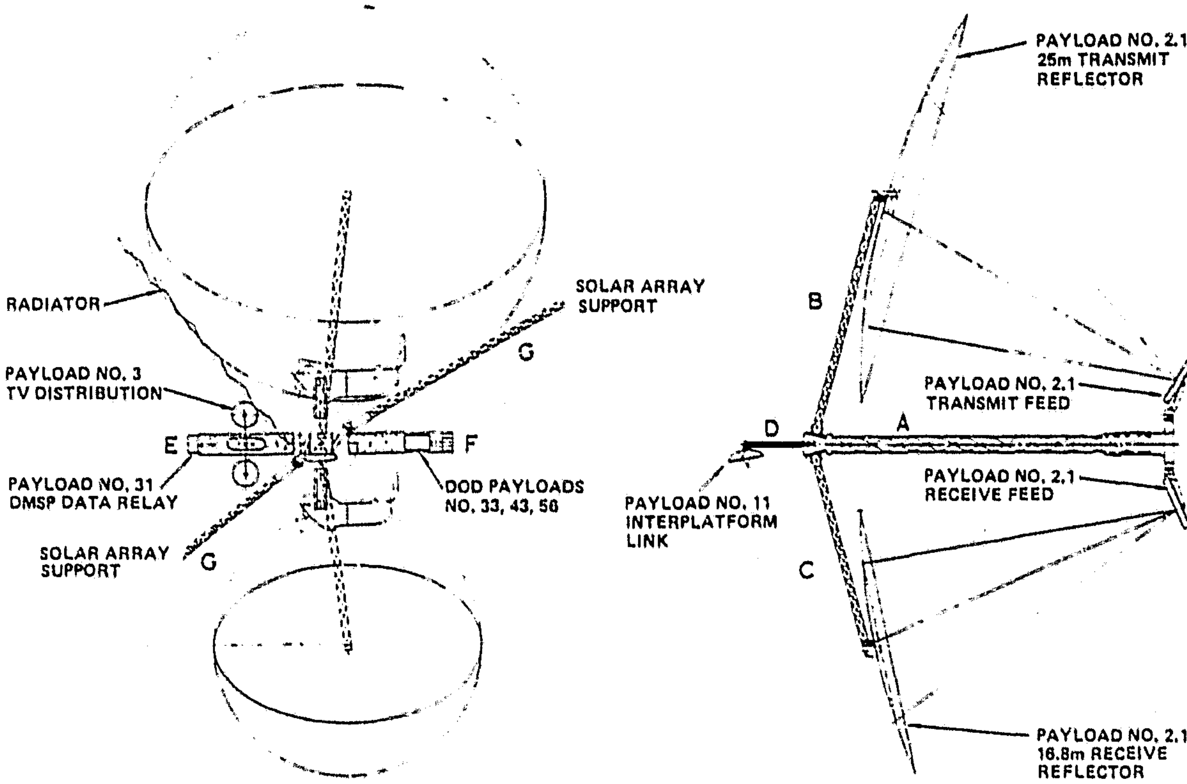


Figure 20. Alternative Concept #1, Platform No. 1, deployed.

Table 8. Weight Summary, Platform No. 1, Alternative Concept #1.

		Weight (kg)
Platform		4358
Structure	1592	
Thermal Control	161	
Attitude Control	1173	
Electric Power	718	
Avionics	146	
Contingency (15%)	568	
Payload		2283
No. 2.1 HVT C-Band	1145	
No. 3 TV Distribution	515	
No. 11 Interplatform Link	130	
No. 31 DMSP Data Relay	195	
Contingency (15%)	298	
Total Platform & Payload Weight		6641
Low Thrust OTV (Off-Loaded) (1)		19326
Total Separation Weight from Orbiter at LEO		25967
OTV ASE		2566
Margin Available for Payload ASE (2)		951
Total Liftoff Weight in Shuttle Orbiter (3)		29484

Notes:
1. OTV weights: burnout = 2843 kg, in-flight losses = 260 kg, main propellants = 16233 kg.
2. Preliminary estimate of payload ASE: 685 kg.
3. Shuttle can insert 29484 kg in LEO.

TRANSPORTATION

Both platform design and program costs are directly coupled to the transportation mode selected for platform delivery and platform servicing, and transportation costs are a significant fraction of total program costs. For concept Alternative #1, transportation accounts for 34% of the total program cost.

Transportation missions are of two types: delivery of platform modules to their assigned Geostationary orbital locations, and delivery of servicing items to Geosynchronous orbit for periodic platform servicing missions. In both cases, the Shuttle is used to place an OTV mated with a platform module or servicing items into a low-earth circular parking orbit at 296 km (160 n. mi.) altitude, inclined 28.5 degrees. The Shuttle can deliver 29,484 kg (65,000 lb) of cargo to this reference orbit. 19 OTV configuration/operating mode combinations were analyzed and evaluated for the LEO-to-GEO missions.

The OTV selected for the platform delivery mission is the single stage expendable OTV with a low-thrust engine, offloaded to meet the Shuttle cargo weight limit. When the OTV/platform is delivered to LEO by the Shuttle, the assembly is first rotated out of the cargo bay and positioned relative to the Orbiter while the platform elements are deployed and checked out by the crew. Subsystems and payloads are pre-attached and pre-wired to the maximum extent consistent with Orbiter volume and operational constraints. Some installation tasks may be accomplished by planned EVA where this procedure yields an advantage in reduced platform complexity or cost and/or in higher reliability. Unplanned EVA is also available as a backup mode to correct anomalies.

After platform/OTV deployment and checkout, the assembly is released from the Orbiter, ready for LEO-to-GEO transfer. The OTV transfers the platform to a designated delivery point near its assigned orbital slot using a multiple perigee burn, single apogee burn trajectory. When the earth station command and control link is established and the platform attitude control subsystem is activated and acquires its references, the OTV releases the platform without imparting significant velocity or attitude perturbations, backs away to a safe distance, and then transfers itself to a supersynchronous (debris) orbit.

The OTV selected for the platform logistics missions is the single-stage reusable OTV with a standard thrust engine. The Teleoperator Maneuvering System (TMS) is used for transferring logistic resupply items to the platforms, and returns to low earth orbit with the OTV, for reuse.

LOGISTICS PLAN

The Alternative #1 Logistics Plan is based on a geosynchronous platform concept of two constellations, one at 110°W longitude over the Western Hemisphere, and one at 15°W longitude over the Atlantic. Each constellation consists of six platforms rotating in a circle 18 km in diameter.

The platforms are designed for a nominal 16-year life and are launched with an 8-year supply of ACS and stationkeeping propellants, and batteries, on board. Only these expendables are planned for re-supply on an 18-month schedule during the first eight years, and every 9 months during the next eight years. If unscheduled payload, equipment or maintenance servicing is required, they can be flown in place of a scheduled logistics mission, and the logistics payload can be flown later on an added Shuttle flight.

The logistics plan identifies payloads, sequence of events, timelines, operational modes, OTV and servicing vehicle configurations, and the flight schedule. The plan is summarized in Table 9. The flight schedule is shown in Figure 21.

Table 9. Logistics Plan

- Platform Placement Flights - Once every 16 months 1992 thru 1998.
- Logistics Resupply Flights
  - Once every 18 months 1993 - 1999.
  - Once every 9 months thereafter.
  - This provides replacement of consumables (batteries and hydrazene for 16 year lifetime, each platform having initial supply for 8 yrs.
- OTV
  - For Placement Flts - NASA Low-Thrust Expendable
  - For Logistics Flts - NASA High-Thrust Reusable
- Servicing Vehicle - Teleoperator Maneuvering System (TMS)
  - Subsystems
    - Servicing Manipulator
    - Docking Probe
    - TV
    - Navigation Kits

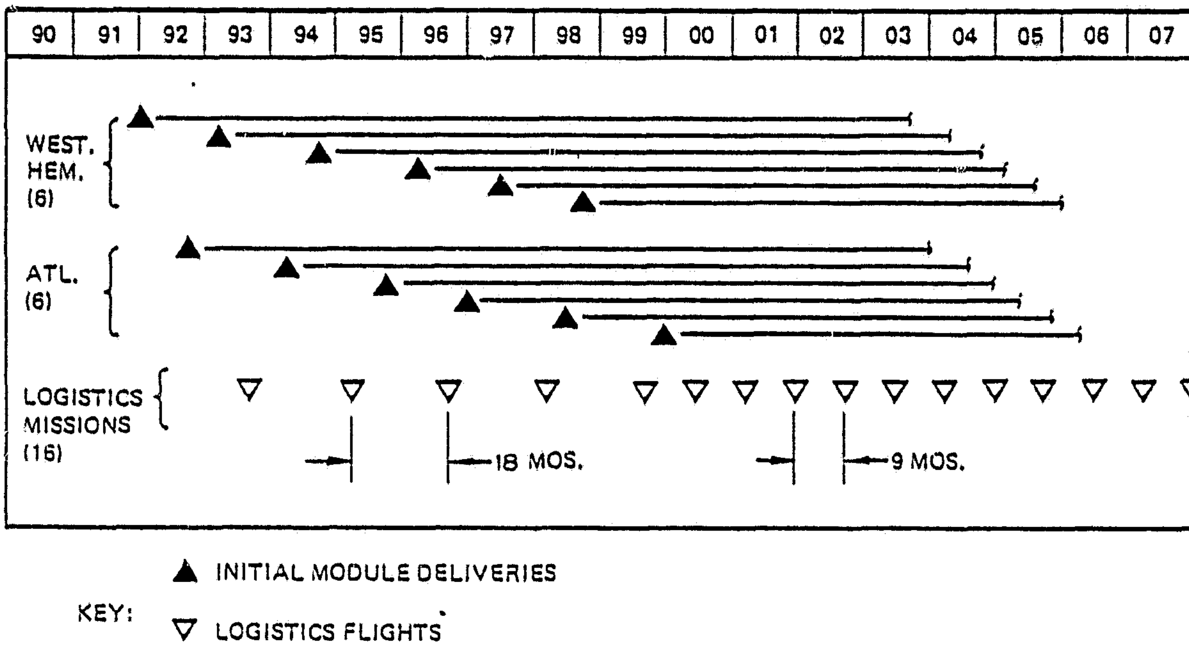


Figure 21. Concept Alternative #1 Flight Schedule.

SPECIALIZED COMMUNICATIONS/INTEGRATION EQUIPMENT

To successfully meet platform communications requirements, particular attention must be focused on the following items of specialized equipment:

- Antennas
- Feeds
- High accuracy pointing equipment
- Switch matrices
- On-board regeneration
- Interplatform links
- High power amplifiers

Antennas

Very high reuse of the frequency bands is required for platform communications systems, and results in complex antenna systems. The requirements specified for Direct-to-User and High Volume Trunking necessitates offset antenna geometries with large effective f/D ratios which can provide low side-lobes, low cross-pol and minimum scan loss performance. Efforts to increase a reflector system's scan angle to as much as $\pm 10^{o}$ are presently being made. Continued effort should produce a solution consistent with the schedule requirement for the operational geostationary platforms.

Feeds

Generating a component beam from a single feed horn does not produce acceptable isolation between non-adjacent scanned beams. One practical way of implementing the three-frequency system needed for frequency reuse on the platforms is to use a cluster of possibly 7 or 9 horns to form each component beam. The horn cluster must be able to operate over large bandwidths (50%) and generate very little cross-pol interference. Feed systems operating at Ku-band over a 30% bandwidth have already been built, but a feed system consistent with the Ka-band requirements needs further development.

High Accuracy Pointing

Antenna pointing accuracies down to 0.02° are required by the platform systems. To operate a tracking/pointing system, a sensor, a controller and an antenna positioner are needed to close the control loop. For the high pointing accuracies required, a monopulse sensor is ideal for detecting pointing errors along two orthogonal directions. The key advantage of this type of sensing system is its use of the communication antenna as a sensor to point that same antenna, eliminating several types of pointing errors present in other configurations.

Switch Matrices

The Geostationary Platform will require a variety of matrix switches to provide the connectivity desired. At present, considerable effort is being directed towards development of these switches:

- COMSAT Labs - 8 x 8 wideband Microwave Switch Matrix (MSM) at 4 GHz as well as a Baseband Switch Matrix (BSM)
- TRW - 4 x 4 MSM for the TDRSS.
- Hughes Aircraft Corporation - 8 x 8 MSM at 4 GHz.
- Nippon Electric Co. - 4 x 4 IFSM at 140 MHz (delivered).

The basic problem areas in the development of matrix switches includes:

- Reliability (and redundancy)
- Isolation
- Insertion loss
- Switching time
- Size - current units are excessively large.
- Weight - current units are excessively heavy.

The implementation of Satellite-Switched Time Division Multiple Access (SS-TDMA) systems is implicit in the application of matrix switches. The baseband switch matrix is particularly applicable to high capacity SS-TDMA and requires development. It can be applied to call routing, packet switching, and particularly to on-board traffic storage to facilitate the use of large transponder capacity by small data users.

On-Board Regeneration

The use of on-board regenerative repeaters has the advantage of separating up and down-link impairments and integration with baseband switching technology. Disadvantages include signal standardization, uplink power control, and greater on-board complexity and reliability requirements. Development of on-board regeneration for platform systems will require stable reference oscillators, temperature stable integrated microwave circuits, traffic standardization and CQPSK-CQPSK integrated circuit development.

Interplatform Links (IPL)

Interplatform communications capability is actually a two-part problem. If the platform is a single structure rather than a constellation of structures, all frequency diversity interconnections can be effectively hard-wired in place and the concern is only with the 32/25 GHz IPL between platforms in different orbital slots. The constellation of platforms, as represented by Alternative #3, presents an additional requirement: an intra-constellation link (ICL) between platforms within a constellation to interconnect different missions and/or frequency diversity approaches, and is highly dependent on the flight formation employed.

The areas requiring development and investigation include:

- Inter-platform and intra-constellation stationkeeping and the ability to track links.
- Identification and impact of missions requiring interconnection.
- Frequency assignments for the intra-platform links.

The choice of frequencies, geometry and traffic to be switched or interconnected ultimately determines the shape of the interplatform link. COMSAT Labs has done considerable work in the area of intersatellite links which are equally applicable to interplatform links. The approach deals primarily with a 6/4 GHz earth-station link, but can be modified to 14/12 GHz and with certain restraints to a 30/20 GHz link.

Two versions of link circuitry for platform use have been investigated using FM remodulation and heterodyne repeaters. In both versions, the IPL is essentially "transparent". The FM version expands the bandwidth and uses saturated transmitters. The heterodyne repeater operates in a 12-MHz bandwidth with backed-off transmitters.

An alternative approach to RF communications capability between platforms is the use of laser communication links, a system which shows promise and should be considered for development.

With respect to acquisition and tracking, a 3-level system is recommended using platform closed loop tracking, programmed pointing (open loop) and ground controlled tracking (closed loop). System response must be conditioned to include attitude changes and relative drift during stationkeeping maneuvers, relative daily drift between platforms, and long term drift.

High Power Amplifiers

Current and projected (1990) state-of-the-art for both transmitter tubes and solid-state amplifiers is shown in Tables 10 and 11. Emphasis is presently on the 14/11 GHz area, and additional effort is needed on 30 GHz components, particularly on high power helix tubes. Solid state amplifiers have yet to achieve the power levels needed at the higher frequencies and additonal effort is needed.

Table 10. Satellite TWTA Status

Frequency	Type		Current SOA	1990 SOA
20 GHz	Helix	Saturated Power, Watts	10-20	40-80
		Efficiency, %	35	38
		Approximate Weight, Kg	2.3	4.5
20 GHz	Coupled Cavity	There is no coupled cavity tube available but a 200 W unit could be developed.		
12 GHz	Helix	Saturated Power, Watts	150-200	150-200
		Efficiency, %	42	42
12 GHz	Coupled Cavity	Saturated Power, Watts	400-600	400-600
		Efficiency, %	44	44
		Approximate Weight, Kg	23	23

Table 11. Solid-State Amplifier status

Frequency (GHz)	Type	Current SOA Pout/Efficiency	1990 SOA Pout/Efficiency
4	FET/Bipolar	4-5 W/40 %	≈ 70 W/50 %
6	FET/Bipolar	2-3 W/30 %	≈ 30 W/35 %
12	FET	0.5-1 W/15 %	≈ 9 W/25 %
12	IMPATT	2.5 W/18 %	
14	FET	0.4 W/15 %	≈ 6 W/25 %
20	FET	0.2 W/7 %	≈ 3 W/15 %
20	IMPATT	1.0 W/10 %	
30	FET	0.1 W/3 %	≈ 1 W/10 %
30	IMPATT	0.5 W/8 %	

TASK 3A

EXPERIMENTAL GEOSTATIONARY PLATFORM

As Operational Geostationary Platform concepts and their corollary technology requirements began to emerge in Tasks 1 and 2 of this study, the need for an Experimental Geostationary Platform to demonstrate the advanced technologies, systems, and uses required to pave the way for the Operational Platforms of the 1990s became obvious. These technologies would advisedly be demonstrated early in the Geostationary Platform program to verify concept feasibility and would form a basis for further program planning. As an adjunct to Task 3, a preliminary feasibility assessment of an Experimental Platform (Task 3A) was therefore authorized, to be performed and reported on early in Task 3, prior to definition of the selected Operational Platform concepts and without the benefit of completed Task 3 and Task 4 results. This feasibility study is summarized here.

GROUNDRULES

Ground rules for the feasibility study were simple - define Experimental Geostationary Platform concepts which:

- Could be launched in a single Shuttle flight (low cost) with a mated transfer vehicle, but also take a look at concepts and capabilities for a two-Shuttle flight mission for comparison.
- Will be compatible with transfer vehicles with a probable availability in the mid-to-late 1980s, i.e., Centaur, IUS, and OTV.
- Could accommodate user-supplied payloads.

MISSION REQUIREMENTS

Three primary requirements constrain the Experimental Platform concept and its configuration:

- Low cost.
- Must demonstrate high-risk technologies which will be needed on the Operational Platforms.

- o Must represent a significant step toward operational platforms in terms of configuration (structure and subsystems), platform and communications technologies, and operations.

RESULTS

In our analysis, six concepts were defined covering a full range of communications and other payload combinations. The concepts were configured either for a single Shuttle flight with mated OTV, or for a full-cargo bay payload (OTV to be delivered to LEO in a second Shuttle flight). The range of options is shown in Table 12.

Table 12. Experimental Platform mission options.

STS REQUIREMENT	MISSION				OPERATIONS					MAX. P/L, KG
	OPTION NO.	FLIGHT NO.	OTV	CARGO	TO LEO	DEPLOY	MATE	XFER TO GEO	MATE	
SINGLE SHUTTLE FLIGHT	I-A	1	CENT	26'	—	*		—		4772
	I-B	1	IUS (3 STG)	32.5'	—	*		—		2636
	I-C	1	IOTV	24'	—	*		—		5670
TWO SHUTTLE FLIGHTS	II-A	1	CENT	26'	—	*		—	√	9544
		2	CENT	26'	—	*		—		
	II-B	1	IUS (3 STG)	32.5'	—	*		—	√	5272
		2	IUS (3 STG)	32.5'	—	*		—		
	II-C	1	IOTV	24'	—	*		—	√	11340
		2	IOTV	24'	—	*		—		
	II-D	1		56'	—	*	√	—		9190
		2	IOTV		—					

For each of the six concepts, packaged and deployed configurations were drawn, weights tabulated, antenna characteristics and requirements listed, and payloads defined. A typical payload accommodation is shown in Table 13, for Platform Concept #6.

Table 13. Experimental Platform Concept #6 payloads & technologies.

PAYLOADS

- C BAND – ONE 10-METER ANTENNA; 100 REUSE SWITCH; BASEBAND PROCESSOR
- IPL – TWO 2-METER ANTENNAS
- Ka BAND – TWO 4-METER ANTENNAS; 10 X 10 SWITCH; BASEBAND PROCESSOR
- DOD #31 – DMSP DATA RELAY
- DOD TACTICAL AF SATELLITE COMMUNICATIONS
- DOD #33 – MATERIALS EXPOSURE
- DOD #43 – MAGNETIC SUBSTORM MONITOR
- DOD #60 – FIBER OPTICS DEMONSTRATOR
- OSTA #17 – LIGHTNING MAPPER

PLUS

ALTERNATIVE 1		ALTERNATIVE 2	
• OSS #75	– IMAGING SPECTROMETER	• Ka BAND	– FIVE 1-METER ANTENNAS; 25 X 25 SWITCH
• OSS #79	– LOW LIGHT LEVEL TV		

TECHNOLOGY DEMONSTRATIONS

- ADVANCED COMMUNICATIONS TECHNOLOGY – C AND Ka BANDS
- C BAND BEAM SHAPING/RECONFIGURABILITY
- C AND Ka BAND DIRECT-TO-USER
- FREQUENCY SELECTIVE SUBREFLECTOR SURFACE – C BAND, 4 AND 6 GHz
- LARGE DEPLOYABLE ANTENNA – C BAND
- Ka BAND BEAM SCANNING
- HIGH FREQUENCY DEPLOYABLE SOLID SURFACE ANTENNAS
- IPL TECHNOLOGY
- ALL PLATFORM TECHNOLOGIES

Results of the analysis are summarized in the following paragraphs.

Single Shuttle Flight Mission Platforms

These Experimental Platform concepts show:

- o Lowest overall program costs.
- o Weights (4100 to 5300 kg) far exceeding the 3-stage IUS capability of 2700 kg.
- o Low density for predominantly communications payloads (4100 to 4700 kg), in the low-thrust Centaur capability range.

- o High density for predominantly DoD and Science experiments (4700 to 5700 kg), in the low thrust IOTV capability range.

Two Shuttle Flight Mission Platforms (Separate platform and transfer vehicle flights)

These platform concepts show:

- o Total platform weights to 9,190 kg.
- o Economy of scale.
- o Possible advantage of cryo transfer vehicle launch to LEO after platform deployment and checkout, offset by transfer vehicle/platform mating operation.

Two Shuttle Flight Mission Platforms (Mated platform/OTV in each flight, different payloads)

These platform concepts show:

- o Total platform weights to 11,340 kg.
- o Maximum payload flexibility - simultaneous Western Hemisphere and Atlantic operations.
- o Interplatform link and docking demonstration capability.

General

Selection of a platform configuration is dependent on three separate program priorities:

- o Funding limitations - which will determine a one or two Shuttle-flight Experimental Platform program.
- o Transfer stage availability - Centaur or IOTV.
- o Payload priorities - communications, DoD, or Science combinations.

The variety of structural configurations, payload combinations, concepts and options is almost limitless. Those developed in this study are only samples of what the Experimental Platform could be. If the basic platform structure provides flexibility of geometry, such as the expandable truss concept used in this study, the platform configuration can be easily tailored to fit any combination of the three constraining program priorities noted.

TASK 4

SUPPORTING RESEARCH & TECHNOLOGY

To place Operational Geostationary platforms in orbit in the 1990s, capable of supporting the high capacity, expanded services needed in our near future, a significant advancement in both platform and communications technologies will be needed. In most cases, these technologies have been foreseen and are already in partial development. Others have surfaced as a result of this study.

In any case, to minimize program funding and schedule risks, the required technologies must be identified, defined, and planned for - the objective of this task.

Scope of the task was restricted to a study of the SRT needed for Concept Alternative #1. Alternatives #2, #3 and #4 will be addressed in follow-on studies to determine what additional technologies might be required for full-cargo bay platforms, and platforms docked together in GEO.

RESULTS

Seventeen major platform and communications technologies were identified as requiring development for the Operational Platforms of the 1990s. Each of these technology areas requires attention within the time frame that will provide for a 1988 Experimental Platform launch capability. Research and development should be scheduled to permit fabrication of test hardware by early 1985 and testing in 1986, as shown in Figure 22.

The seventeen major technologies areas requiring development are listed in Figure 23, together with the existing or recommended status of each.

Large solar arrays for long term geostationary orbit service represent a technology which can probably benefit markedly from long-term studies. Power management and distribution are complex technologies and also need long-term R&D schedules, as do high power amplifiers. Definition studies in these areas

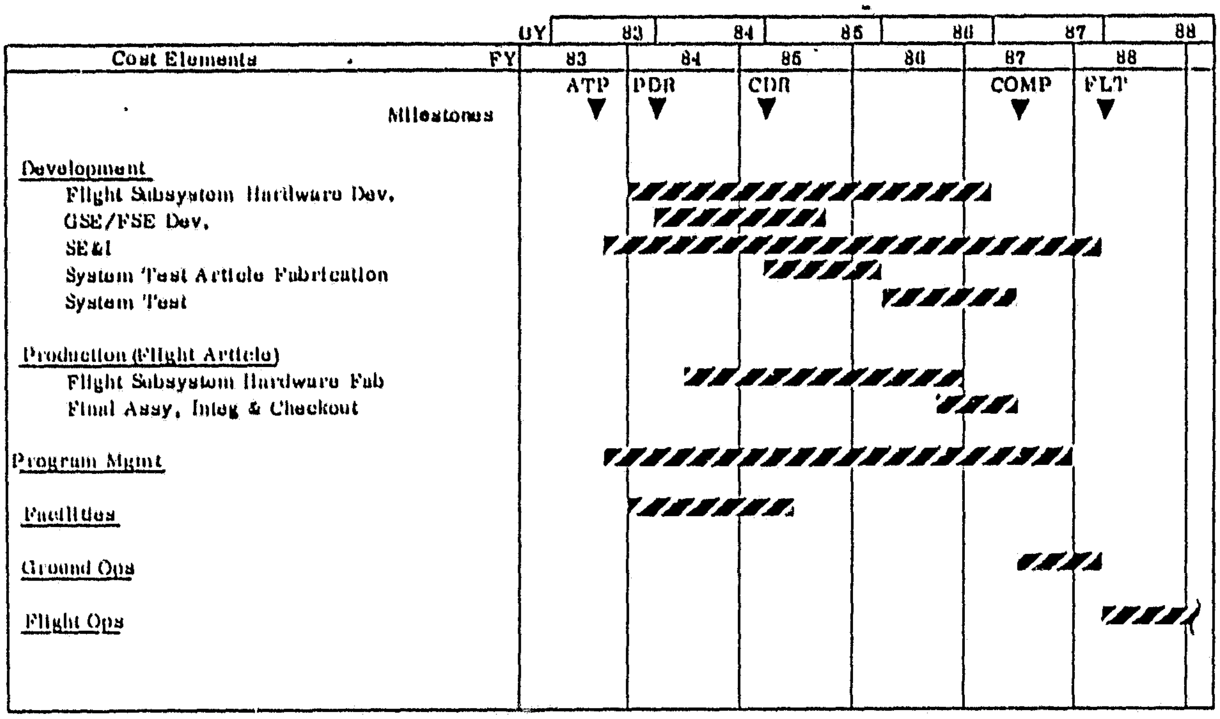


Figure 22. Experimental Platform development schedule.

		Begin Studies Now	Defer to Presently On-going Efforts	Begin Study When Experimental Platform is Defined	Begin Study When Operational Platform is Defined
1	Space Construction		✓		
2	Active Control of LSS		✓		
3	Solar Array for Geoplatform	✓			
4	Power Mgmt & Distribution	✓			
5	Secondary Power Source		✓		
6	Increased RCS Performance			✓	
7	Thermal Management				✓
8	Automatic Docking & Servicing		✓		
9	Matrix Switch/Processor	✓			
10	Deployable Antenna Surfaces		✓		
11	Phased Array Antennas		✓		
12	Lens Antennas		✓		
13	MBFRA Feed Assemblies	✓			
14	Interplatform Links	✓			
15	Electromagnetic Compatibility	✓			
16	Fiber Optics Data Transmission		✓		
17	30/20 GHz HPAs	✓			

Figure 23. Recommendations for technology development.

should be initiated as soon as possible. Switch development is also a major task, but it may be desirable to rely heavily on independent development efforts when the extent of such efforts becomes clearer. Layout work on platform configurations has revealed feed modules to be a major packaging problem both in weight and in geometry. Much work appears to be necessary to achieve better definition and to reduce the dimensions and masses of these devices.

Two other categories of effort are noted. Where effort is currently known to be underway, it is recommended that work specifically directed to geostationary platform requirements be temporarily deferred, at the same time making attempts to make requirements known to those conducting current studies. The remaining efforts are judged capable of being worked more effectively when the Experimental Platform has been well enough defined to provide specific requirements to the studies.

TASK 5

STS INTERFACE REQUIREMENTS

To ensure compatibility of the Geostationary Platform program with elements of the Space Transportation System, an analysis of the support and interfact requirements imposed on the STS elements by the platform was made. Concept Alternative #1 for the Western Hemisphere location was used as a typical option, to develop the interface requirements data.

Requirements on each STS element were defined to a depth sufficient to determine compatibility of the platform with element capabilities. Results were segregated and arranged for access by the supporting program offices - Orbiter, OTV, and TMS.

RESULTS

Platform interfaces and resultant requirements relative to STS elements stem from two missions - placing the platforms at GEO, and providing logistic support for the platforms during their lifetimes, as shown in Figure 24. All interfaces were analyzed in depth to ascertain specific interface requirements, and summarized by specific area. Orbiter subsystems support requirements for both the platform delivery and for the logistics missions, for example, are summarized in Table 14; all are within existing or planned Orbiter support capability.

OTV guidance and navigation (G&N) subsystem support requirements are listed in Table 15, as another typical example. With respect to the interface requirements shown here, tolerances are compatible with the rendezvous and docking techniques developed during the Air Force On-Orbit Assembly Study (GDC - 1978), and have been related to existing microwave and optical sensing systems, including both search and tracking radars, AME/DME sensors, scanning

	ORBITER	TRANSFER VEHICLE	TMS
DELIVERY MISSION	PERFORMANCE STOWAGE DEPLOYMENT OPERATIONS SUBSYSTEMS CREW	PERFORMANCE STOWAGE DEPLOYMENT OPERATIONS SUBSYSTEMS	
LOGISTICS MISSION	PERFORMANCE STOWAGE DEPLOYMENT OPERATIONS SUBSYSTEMS CREW	PERFORMANCE STOWAGE DEPLOYMENT OPERATIONS SUBSYSTEMS	PERFORMANCE STOWAGE DEPLOYMENT OPERATIONS SUBSYSTEMS

Figure 24. Geostationary Platform/STS interfaces.

Table 14. Orbiter subsystems support requirements.

• STRUCTURAL INTERFACE	ASE SUPPORT FORE & AFT, 75° ASE ROTATION WITH CLEARANCE
• POWER/ENERGY	kW/50 kWH MAXIMUM
• COMMUNICATIONS	S-BAND: 32 KBPS UPLINK, 6.4 KBPS COMMAND 192 KBPS DOWNLINK, 128 KBPS DATA
• PROPULSION/RCS	< 4000 LB N_2H_4 FOR & DAY STATIONKEEPING, ACS, AND RENDEZVOUS & DOCKING (7-DAY SERVICING MISSION)
• G & N	NO SPECIAL REQUIREMENT
• FLUID	OTV LH_2/LO_2 FILL & DRAIN, ABORT DUMP, AND VENT LINES ABORT DUMP SIZED FOR 300-SECOND DUMP REQUIREMENT
• THERMAL	NO PLATFORM REQUIREMENT
• ENVIRONMENTAL CONTROL	NO SPECIAL REQUIREMENT; G/P MEETS REQUIREMENTS
• LIGHTING	TABULATED. PAYLOAD BAY, DOCKING, & RMS LIGHTING WITHIN ORBITER CAPABILITIES.
• CLOSED CIRCUIT TV	5 CAMERAS: 2 - RMS, 1 - NO. 4 KEEL POSITION, 1 - FORWARD BULKHEAD, 1 - AFT BULKHEAD.
• RENDEZVOUS & DOCKING	RENDEZVOUS CAPABILITY WITH OTV ON RETURN FROM SERVICING MISSION.

Table 15. OTV subsystems support requirements, Guidance & Navigation.

SERVICING MISSION

- ▲ DELIVERY CAPABILITY FROM LEO TO 96 km BEHIND,
  16 km BELOW GEOSYNCHRONOUS TARGET LOCATION, ±8 km (RENDEZVOUS POINT)
- ▲ APPROACH TO TARGET LOCATION (CENTER OF CONSTELLATION)
  ±0.1 km
  ±1 m/SEC RESIDUAL TRANSLATIONAL VELOCITY
  ±1.0° OF REQUIRED ATTITUDE
- ▲ STATIONKEEP
- ▲ RENDEZVOUS AND REDOCK WITH SERVICE MODULE
  ±1° SUN ORIENTATION
  ±3 cm/SEC RESIDUAL TRANSLATIONAL VELOCITY
  ±0.05°/SEC ROTATION
- ▲ RENDEZVOUS WITH ORBITER
  RETURN CAPABILITY FROM GEO TO 96 km FWD,
  16 km ABOVE THE ORBITER, ±8 km (RENDEZVOUS POINT)
- ▲ APPROACH TO ORBITER (SAME TOLERANCES AS GEO TARGET)
- ▲ STATIONKEEP
  ±1° SUN ORIENTATION
  ±3 cm/SEC RESIDUAL TRANSLATIONAL VELOCITY
  ±0.05°/SEC ROTATION
- ▲ PASSIVE DURING FINAL DOCKING

laser radars, and low-light-level TV.

The Cubic Corp ELF-III system, for example, is a 9.7 GHz AME/DME interferometer rendezvous system employing three pairs of antennas. Angular rate accuracy is .0057 degrees/second, almost an order of magnitude better than specified here. Distance measuring range is from 20 feet to 150 n.mi., with an accuracy within 12 inches. For docking, ITT/Gilfillen has demonstrated a scanning laser radar with a range of 1000 ft, with a positioning (sensing) accuracy of 1/2 inch.

Review of the interface and support requirements imposed by the platform program on the STS elements (Orbiter, OTV, and TMS) shows that the conceptual configurations and operations developed in this study are compatible with the STS capabilities as now planned, with few exceptions. No changes have been imposed on the Orbiter. For the OTV and TMS, the necessary rendezvous and docking capabilities can be incorporated in the design within existing or planned state-of-the-art.

CONCLUSIONS

While the mass of technical concepts and data derived during this study provides a solid foundation for further program development, the key findings from a program standpoint can be summarized in the following points:

- Platforms represent a logical extension of current trends toward larger, more complex, multi-frequency satellites.
- Geostationary platforms offer significant cost savings compared to individual satellites, with the majority of these economies being realized with single-Shuttle-launched platforms. Further cost savings can be realized, however, by having larger platforms.
- Platforms accommodating communications equipment that operates at multiple frequencies and which provide larger scale frequency reuse through the use of large aperture multi-beam antennas and onboard switching maximize the useful capacity of the orbital arc and frequency spectrum. Projections of market demand indicate that such conservation measures are clearly essential if orderly growth is to be provided for.
- Extended life through redundancy with limited automated revisit has economic advantages.
- High energy liquid upper stages maximize economies.
- Needed technology advancements are significant but reasonable.
- A NASA experimental geostationary platform is required to demonstrate the platform and communications technologies necessary for operational geostationary platforms of the 1990's.

FUTURE WORK

The thrust of this Initial Study was toward the characterization of Operational Geostationary Platforms of the 1990s.

In the course of the study, it was recognized that a NASA Experimental Geostationary Platform was required to demonstrate critical technologies.

NASA's primary interest in the Follow-on Study is to lay the basis for a Phase B Study of the Experimental Geostationary Platform. To do this, it is necessary to further characterize the most probable concepts for Operational Platforms, so that the proper technologies can be demonstrated on the Experimental Platform.

In some cases, this requires expanding the range of options considered in the Initial Study. For example, a range of multi-slot Alternate Architectures will be examined in addition to the single-slot Initial Communications System Architecture which was the basis for the Initial Study. This will enable NASA to determine the economic and system impact of using less ambitious communications technology than was postulated in Task 1 and characterized in Task 4.

In other cases, the range of options will be narrowed. For example, single-Shuttle launch concepts will be emphasized, since the economic return of going to the more complex concepts involving assembly at LEO appears to be marginal. An attempt will be made to determine with greater precision the relative merits of the Constellation and Docked Module Concepts represented by Alternatives #1 and #2 identified in Task 2. This will enable NASA to prioritize the requirements for demonstration of the very different technologies associated with those concepts.

In order to give both NASA and the communications industry a better feel for platform economics, a Return On Investment (ROI) analysis of Alternatives #1 and #2 will be performed considering only communications payloads (Fig. 9, payload numbers 1 through 11).

Continuing interaction with potential commercial and governmental user agencies and payload suppliers will result in a refined (and hopefully prioritized) list of candidate payloads for the Experimental Platform.

An updated set of candidate upper stages for possible use with the Experimental Platform will be considered and the weight, volume, g-level, and other constraints on the platform determined.

Finally, a few experimental platform concepts will be developed which relate the candidate upper stages to appropriate subsets of the candidate payloads. Program costs for these concepts will be estimated to provide NASA with a basis for selecting the experimental platform concept(s) which satisfy critical mission requirements at an affordable price. These may include:

(1) A modest experimental program using a solid upper stage and small platform deployed at GEO with a very limited number of payloads.

(2) More realistic demonstrations with low thrust liquid upper stages which allow deployment, checkout, and initial experimentation at LEO before transfer.

(3) A quasi-operational prototype platform employing significant user payloads.

The degree of user interest and participation may well influence the nature of the Experimental Platform program.