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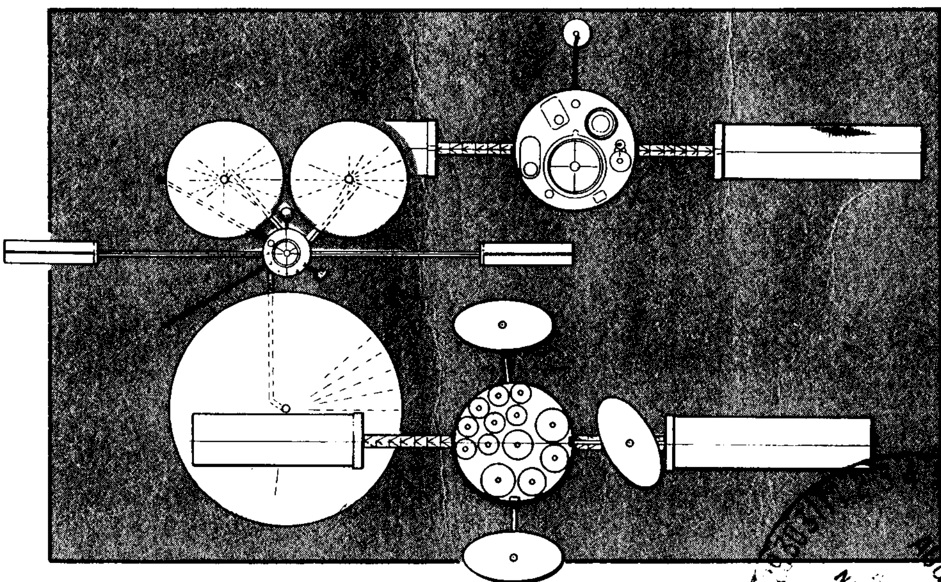
GEOSYNCHRONOUS PLATFORM DEFINITION STUDY

Volume I

EXECUTIVE SUMMARY REPORT



JUNE 1973

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Downey, California 90241

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GEOSYNCHRONOUS PLATFORM DEFINITION STUDY

Volume I

EXECUTIVE SUMMARY REPORT

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JUNE 1973

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FOREWORD

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

This reports consists of the following seven volumes:

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

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INTRODUCTION

This study was undertaken to examine the feasibility of employing space platforms for geosynchronous operations. This objective was carried out by: (1) examining the nature of currently planned and new evolutionary geosynchronous programs; (2) investigating alternate ways of conducting these missions and the required logistics support; and (3) developing potential concepts for new systems to support geosynchronous programs in an effective and economical manner. The resulting data will contribute to a planning data base for future space activities.

The development of low-cost concepts that meet necessary levels of performance is paramount in today's economic environment. Toward this end, geosynchronous programs offer the potential of grouping adjacent payload functions in a manner which retains their earth access geometry. Payload or functional grouping offers potential economies through reduced individual spacecraft inventories and their attendant transportation costs. Additional benefits from on-orbit servicing are also possible. Serviceable spacecraft concepts are currently being explored by NASA and the industry to determine their potential application to low-cost program approaches. Grouping of individual satellite functions into space platforms would offer added logistics benefits to these approaches through the concentration of servicing operations into fewer orbiting elements.

Potentially dramatic growth projections for geosynchronous operations contributed to the need for this study. Major growth is forecast for both domestic and international communications relay services. Enhancement of astromony and earth-observation programs is envisioned with payloads in geosynchronous orbits. Other useful benefits, such as navigation and traffic control, can best be provided by means of geosynchronous elements. Also, new and advanced geosynchronous concepts for space power and light have been identified. The delivery and operating economies resulting from space shuttle and reusable tug operations will accelerate these geosynchronous orbit activities. Such growth projections raise questions concerning the possibility of overcrowding this limited natural resource if all functions continue to be performed by individual satellites. Planning to avoid such a condition is vital. Progress in achieving the benefits available from space must not be impeded by the lack of timely planning information.

APPROACH AND SCOPE

The basic approach adopted for the study involved the definition of two geosynchronous traffic models. The first, called the "baseline traffic model," was based upon current NASA mission planning information, most notably the Updated NASA Mission Model , 6 June 1972. The second, called the "new traffic model," was derived during the study from forecasts and demand models of individual user functions. Each model was analyzed separately with the following objectives: (1) to determine the nature and degree of satellite congestion;

(2) to define practical geosynchronous payload groupings; (3) to define platform system level requirements (including variations in on-orbit servicing modes); and (4) to establish representative platform conceptual designs. Alternative geosynchronous programs were constructed with various platform configurations and operational modes. These programs were then evaluated to determine a recommended geosynchronous program approach. Finally, transportation interfaces were defined and compared with the geosynchronous platform concepts developed earlier.

The study was divided into six basic tasks. Task 1.0 comprised all the efforts leading to the construction of the new traffic model. Task 2.0 provided basic geosynchronous orbit characteristics and EM spectrum utilization data for use in other tasks. In Task 3.0, satellite distributions were analyzed for local crowding and potential physical or EM interference conditions. Separate analyses were conducted for each traffic model. Task 4.0 produced functional grouping options and resultant system level requirements for space platforms (including remote and manned on-orbit servicing modes). Conceptual platform designs were synthesized in Task 5.0, with emphasis on configurations favoring evolution from remote to manned servicing concepts. In Task 6.0, program options and evaluations were structured with platform configurations and servicing modes derived in the study. Evaluation results, along with key findings from all study tasks, were used to derive a recommended geosynchronous program approach. Figure 1-1, Volume II, details the study logic flow.

SIGNIFICANT RESULTS AND CONCLUSIONS

TRAFFIC ANALYSIS AND SYSTEM REQUIREMENTS

Baseline Traffic Model. Separate efforts were applied to the construction of the "baseline" and the "new" traffic models. The construction of the baseline traffic model centered around the compilation of related mission planning and systems definition data and involved the use of three main data sources. The resulting geosynchronous traffic model contains 180 satellites distributed among five categories as shown in Table 1. Part "A" was derived principally from the Updated NASA Mission Model, dated June 1972. Part "B" was obtained from the "Fleming" Mission Model of October 1971, and Part "C" was assembled from scattered sources in the open literature.

New Traffic Model. The new traffic model was based on a "bottom-up" approach utilizing forecasts of user demands and needs. Twenty-two major functions were identified which require the unique features provided by geosynchronous operations. Forecast models of user demand levels and their projected growth profiles were constructed for each function. Commercial functions (long distance telephone, television broadcast, etc.) were based on estimates of user populations; first for the United States and then for other world areas by extrapolation. Scientific and developmental functions were based on budget forecasts of United States and foreign national space programs. For convenient comparison with the baseline traffic model, the functional demand profiles were converted into the number of individual satellites required to satisfy the demands. The resulting traffic summary for the new model is shown in Table 2. As can be seen, 413 satellites are projected, in comparison to the 180 in the baseline model.

Table 1. Baseline Traffic Model Summary

PART "A" (NASA MISSION MODEL, JUNE 1972)

CATEGORY	TITLE	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL	SUB-TOTAL	CUM TOTAL
		SCHEDULE (CALENDAR YEAR)																				
ASTRONOMY	EXPLORERS						1			1			1			1			1	5	5	5
EARTH OBSERVATIONS	SYNCHRONOUS EARTH OBSERV. SAT								1		1			1		1			1	5		
	SYNCHRONOUS METEOROLOGICAL SAT	1				1				1	1									4		
	SYNC. EARTH OBSERV. SAT./PROTO																		1	1	10	15
EARTH AND OCEAN PHYSICS	GEOPAUSE							1	1											2	2	17
COMMUNICATIONS & NAVIGATION	APPLICATIONS TECHNOLOGY SATELLITE	1		1			1	1			1	1		1		1		1		9		
	COOPERATIVE APPLICATIONS SATELLITE			1			1													2		
	SMALL APPL. TECHNOLOGY SATELLITE				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15		
	TRACKING & DATA RELAY SATELLITE					1	2					3						3		9		
	DISASTER WARNING SATELLITE						1	1												2		
	SYSTEM TEST SATELLITE								1	1	1	1	1	1		1	1			8	45	62
NON-NASA OPERATIONAL SPACECRAFT	COMMUNICATION SATELLITE	1		2	3		2	2	1	1		2	1	1			2	1		19		
	U.S. DOMESTIC COMMUNICATION		2	2		2	2		2	1	1	2	2	2	2	2	2	2	2	29		
	FOREIGN DOMESTIC COMMUNICATION	4	1		1	2	3		2	6	2	2			4	5	2	1	2	37		
	NAVIGATION AND TRAFFIC CONTROL	1				1	2		1	1		1		1		1		1		10		
	SYNCHRONOUS METEOROLOGICAL			2		1	.	1	1	1	1	1	1	1	1	1	1	1	1	15		
	SYNCHRONOUS EARTH RESOURCES													4			4			8	118	180

PART "C" (OPEN LITERATURE) PART "B" (FLEMING MODEL, OCTOBER 1971)

Satellite Distributions. Satellite location criteria were established for each category and mission type contained in the above traffic models. These criteria were based chiefly on geometry considerations for earth viewing and communications access as illustrated in Figure 1. The insert shows the band of permissible locations for satellites requiring access to the contiguous United States (such as the U.S. astronomy satellites) where direct data links to the U.S. ground stations are preferred. Other location bands are shown for the individual satellite types within each category. Six zones, as shown in the figure, were defined within this pattern of location bands to aid in establishing satellite distributions. Zone 1 covers Europe and Africa; Zone 2, Asia and Australia; Zones 3, 4, and 6, the Pacific and Atlantic Oceans; and Zone 5, North and South America.

Active and inactive satellite population histories were constructed through the 1990 time period for each zone. In addition, detailed distributions of the active satellites were established to aid in the electromagnetic interference (EMI) analyses. Figure 2 gives an example of these distributions for the

Table 2. New Traffic Model Summary

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

baseline traffic model. Different symbols are used to depict each type of satellite, and all satellites operating within the same frequency band are placed in the same row. Only those satellites operating on common frequencies pose a potential EMI problem.

Geosynchronous Orbit Saturation. The detailed satellite distributions were analyzed for both physical spacing and EMI contention problems. A physical spacing requirement of at least 0.4-degree longitude between adjacent satellites was defined as a "safe" margin. This was based principally on satellite stationkeeping tolerances. EMI contention was more restrictive. A simplified interference noise model was constructed on the basis of the international limit of 1000 picowatts of noise power (psophometrically weighted). Unwanted signals from a system of eleven adjacent satellites, all operating at the same frequency (C-band), were combined into a single value of noise power. Satellite spacing and ground station antenna diameter were treated parametrically. With 60-foot-diameter ground antennas, such as those currently being considered for domestic communications satellites, normal operations could be safely conducted with 4.6-degrees spacing between satellites.

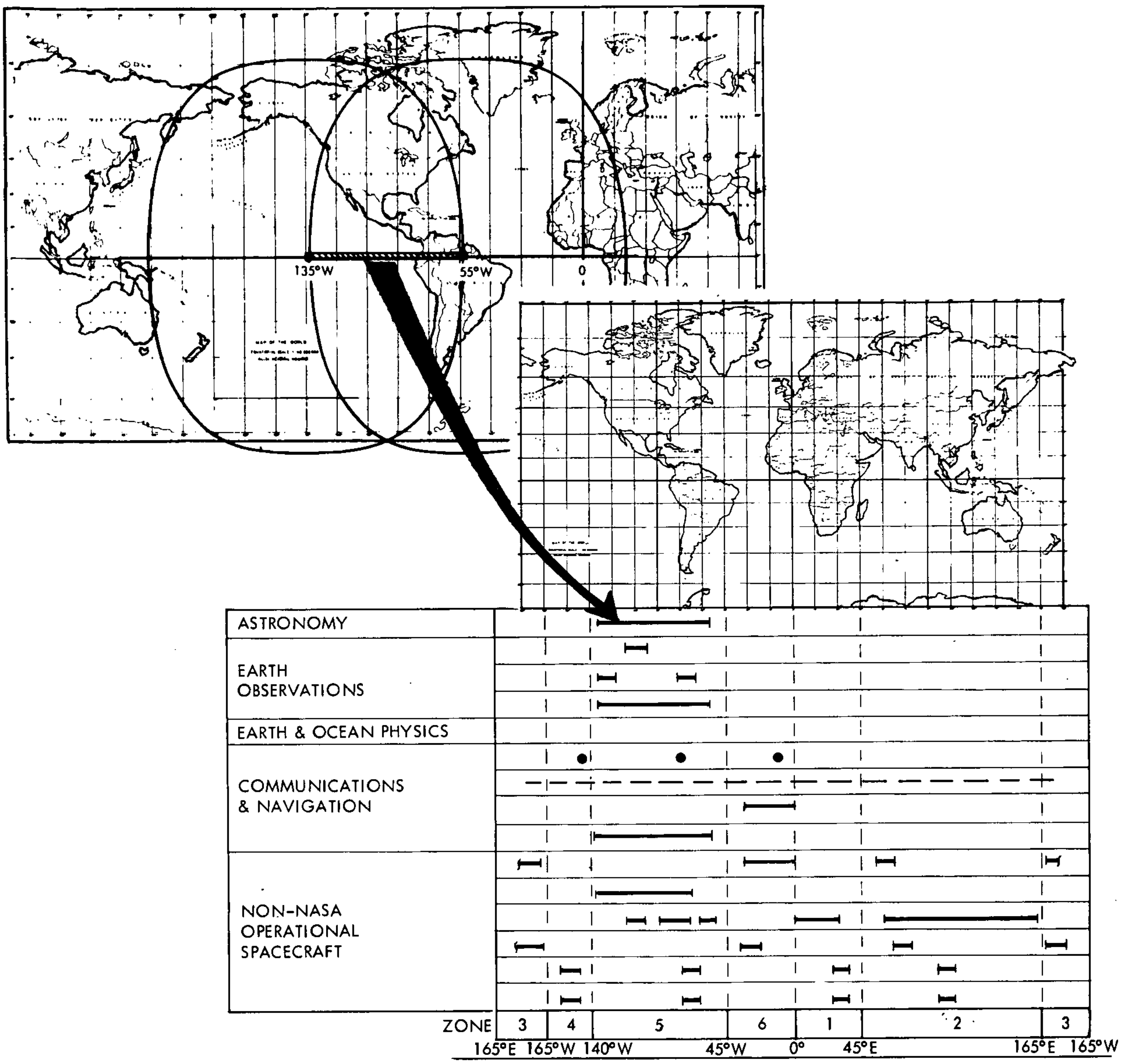

Figure 1. Preferred Satellite Locations

The application of these spacing criteria to both traffic models revealed no violations of the 0.4-degree physical spacing criteria. However, severe C-band EMI was identified in the new traffic model. This resulted from all communications relay traffic being confined to the use of C-band frequencies--a constraint applied to the construction of the new traffic model for easier comparison with the baseline traffic. Future systems must use additional bandwidths from the available spectrum (K-band) to avoid interference.

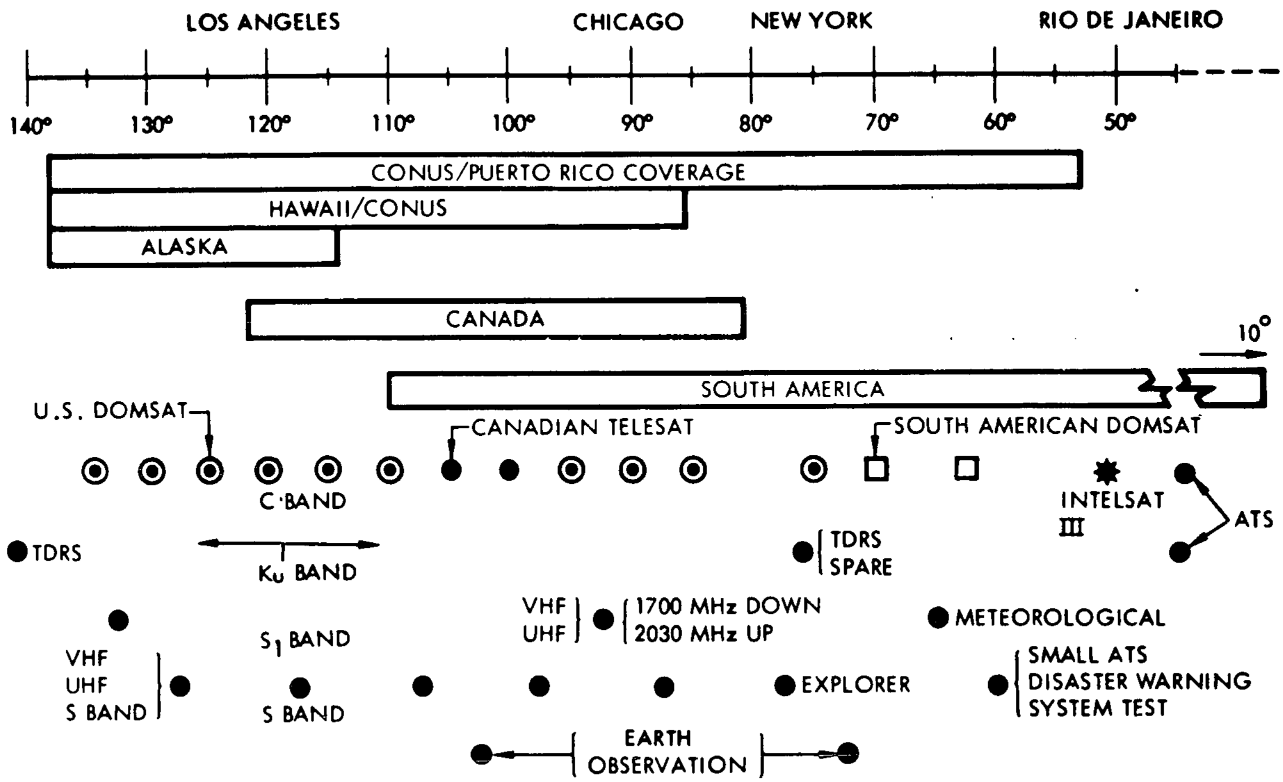

Figure 2. Detailed Satellite Distribution for the Baseline Traffic Model (Zone 5)

It was also determined that S-band interference is likely for both traffic models. S-band is used by both NASA and DOD in their STDN and SGLS networks for operation of deep space and low earth orbit missions as well as for geosynchronous operations. Although the scope of this study was limited to geosynchronous missions, the geometric interrelationships with S-band users in other orbits were recognized as likely to produce some degree of interference. Coordination and cooperation between NASA and DOD will be required in both the planning and "real time" control of these missions.

Minimum Platform Population. A six-zone pattern of geosynchronous satellite distributions (see Figure 1) was convenient for analyzing satellite population densities and interference problems. These six zones were restructured to the minimum number of global regions providing the necessary coverage. It was determined that mission functions requiring global surveillance capability must be separated into four major regions (Figure 3). These are the result of competing earth coverage requirements for land mass viewing, for monitoring

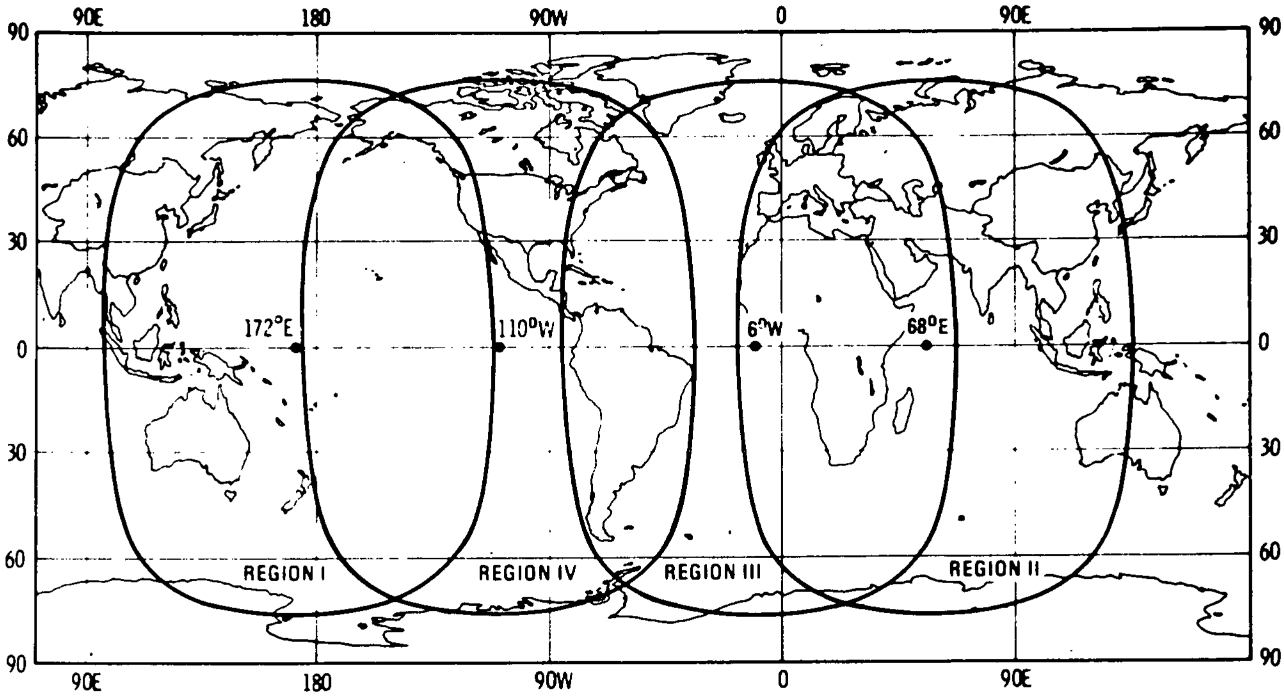

Figure 3. Global Coverage Regions

major weather cells, and for communications bridges between countries and across oceans. Four regions are the minimum number that provides high latitude coverage of the populated regions. They also afford the multipath capability necessary to preclude political blockades of international communications. With minor adjustments to best fit these constraints, the six zones correlate to the four regions as follows: Region I generally replaces Zones 3 and 4; Region III generally replaces Zones 1 and 6; Regions II and IV approximately correspond to Zones 2 and 5.

In addition to the distribution of geosynchronous payloads in four basic regions for total world coverage, other compatibility factors were considered in grouping payloads within each region. One factor is solar noise outage, which periodically interrupts communications between a given satellite/ground station pair. Thus, separation of communications payloads within a region is required to maintain continuity of essential services. Data relay from low-orbit satellites to a single earth facility (TDRS function) requires unique positioning with respect to the ground facility. Also, with only one unit needed in each of three regions, integration with other appropriate regional payloads would require two platform sizes--one standard for terrestial communications relay and one oversize with combined terrestrial communications and TDRS functions.

Further it was determined that combinations of inertial astronomy sensors with earth-pointing communications equipment were not feasible. The astronomy sensors require much more precise pointing than do those serving communication functions; communication antenna motions would introduce disturbances to astronomy operations. The relative envelope created by simultaneous inertial and local-vertical pointing would introduce major design complexities.

Earth resource sensors, with their large and varied antenna installations, also represent major design complexities. These complexities are caused by requirements for noninterfering equipment installations and sensor scanning operations involving the articulation of massive sensor elements. Thus, it would be impractical to combine earth resource sensors with other payloads.

Certain other payloads were identified in the baseline traffic model as developmental. Two factors contributed to keeping these payloads separate from others: (1) their specific characteristics are unknown at this time, and (2) there is a risk to revenue-bearing commercial-type platforms associated with relatively frequent servicing operations that may be required for R&D/experimental-type payloads. However, it is likely that many of these developmental payloads could be supported by space platforms designed for other payload groups once their characteristics and requirements are defined.

The resulting minimum platform inventory and accompanying rationale are shown in Table 3 for the baseline traffic model. A total of 16 platforms divided among four types is required. Similar analyses for the new traffic model resulted in the need for 64 platforms divided among five types. (See Table 3). The fifth type in the new traffic model was imposed by the introduction of an advanced concept for navigation and traffic control (ships and aircraft) that required elements in highly inclined, elliptical orbits. In the baseline traffic model, a more limited navigation and traffic control concept was grouped with the communications relay platform functions and thus did not appear as a separate type.

Table 3. Minimum Platform Inventory for the Baseline Traffic Model

Platform Type	Rationale	Inventory
Communications relay	Four required for global coverage (one in each region) Four additional required to preclude solar outage (one in each region)	8
Low orbit satellite data relay (TDRS)	Unique placement for single Conus ground station	3
Astrophysics	Pointing precision and viewing direction incompatible with other payload types. Four sets of astrophysics payloads require one platform plus three equipment changeouts.	1*
Earth observations	Design and integration complexities. Four required for global coverage (one in each region).	4
Totals: Four basic platform types		16

*Up to four separate platforms could be utilized instead of equipment changeouts, if continuing data from each payload set are desired.

Platform System Requirements. The utilities-support requirements for individual payloads/satellites in the traffic inventories were determined; all five platform types were serviceable by a common set of support subsystems, such as electrical power, stabilization and control, and RCS. The various sets of mission equipment differ in their integration features, but since they fall into the same general size range for support requirements, platform size is not a significant programmatic variable.

On-Orbit Servicing Requirements. On-orbit servicing includes maintenance and updating operations that may replace failed or worn equipment, change functions being performed on platforms, increase functional capacity, or apply newer state of the art. Three basic servicing approaches were assessed: (1) mechanical, remote; (2) EVA/IVA, man-attended (pressure suited); and (3) shirtsleeve, man-attended. The requirements imposed on platforms for all three modes fall into two fundamental categories: general configurational and subsystem related.

The overall size, shape, and arrangement of the platform must provide for access by the selected servicing system. For remote servicing, the platform must allow a manipulative device to grasp, unlatch, and withdraw any replaceable unit and, subsequently, to install its replacement. For the manned servicing, clearance requirements for internal access must consider the man in a suited envelope and his movement through passageways and docking ring with replaceable units, tools, etc.

The requirements imposed on the platform subsystems differ on the basis of servicing approach. Shirtsleeve servicing requires the greatest number of provisions (i.e., a pressurized enclosure, atmospheric control, lighting, voice communication, crew aids, and crew protection). EVA/IVA requires similar but less extensive provisions in that life support and environmental protection are furnished by the pressure garment assemblies. All concepts require a form of docking for rigid attachment, interface connections to the service unit, data links for checkout, and a capability to deadface or shut down systems or equipment undergoing replacement.

Safety of operations in unmanned servicing conforms essentially with the mission success of the tug-payload combination and with the shuttle-imposed safety criteria during the mission phases involving the shuttle orbiter. No unique requirements were identified for the tug with unmanned operations. However, there are special requirements for the tug, the platforms, and for the man-module with man-attended servicing. These include redundancy in critical loops or subsystems and possible alternate methods for ensuring safe return of the crew by such means as a rescue tug.

These general guidelines and their specific supporting requirements were the basis for synthesizing conceptual designs for each of the platform types.

GEOSYNCHRONOUS PLATFORM SYNTHESIS

Platform synthesis comprised three principal activities: structural/configuration trades, support subsystems definition, and mission equipment accommodations. Commonality, adaptability, and standardization were the primary objectives of all three.

Platform Configuration. Of the various platform structural configurations that were evaluated, the toroid concept with internal changeout of modules was selected as the preferred approach. The primary driver in the selection of the toroid was the capability to accommodate the three servicing modes: remote, pressure suited, and shirtsleeve. Shirtsleeve operations dictated both internal module access and a cylindrical pressurizable shape. Figure 4 illustrates the recommended configuration approach. A total of 12 standard assembly compartments is provided in the basic structure, and each compartment accommodates a 24 by 20 by 24-inch module.

Standardized packaging of assemblies simplifies servicing operations. Although some of the equipment will not require the entire module volume, a standard size permits use of a single attach/detach and manipulator end effector design. Also, the storage facility on the servicing unit can be standardized so that any replaceable module can be stored in any of the compartments. This enhances mission flexibility in that only one empty compartment is required at mission initiation. The interchange operation can be accomplished in any desirable sequence, and the sequence can even be changed in real time without the need for either dual manipulators or a temporary holding port.

The selected configuration allows the development of a servicing approach that will evolve from an auto-remote system to the man-attended systems. Provisions for all three servicing modes could be constructed into the initial platforms to give them the flexibility to operate in any servicing mode,

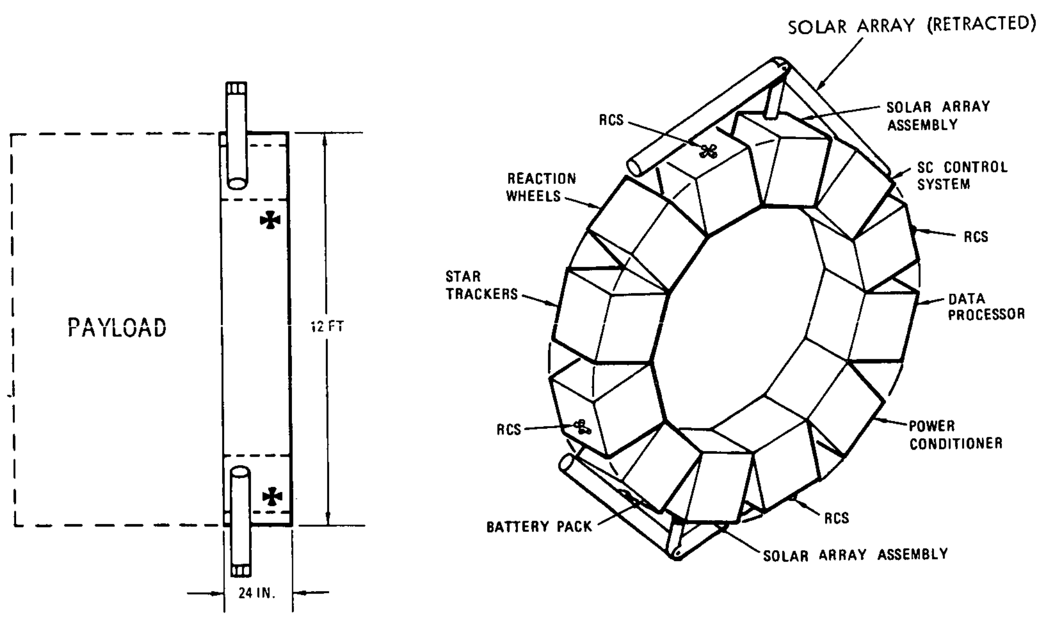

Figure 4. Toroid Configuration Concept

perhaps interchangeably from mission to mission. The nominal design penalties associated with this approach are felt to be offset by the elimination of platform obsolescence as changes in servicing modes are introduced and by reduced developmental costs associated with a single program rather than separate development programs for each servicing approach.

Platform Subsystems. Operational and performance requirements for both individual payloads (single satellite) and grouped payloads (multifunction platforms) were evaluated to establish an integrated set of subsystem performance requirements. Table 4 summarizes the most stringent requirements and identifies the platform type that sets the requirement.

Table 4. Subsystem Support Requirements

Function	Requirement	Driver
Electrical power	2.0 kilowatts	Earth observations
Pointing	0.1 arc second	Astrophysics
Stability	0.05 arc second/second	Astrophysics
Data handling	50 megabits/second	Earth observations
Impulse/propulsion	19,000 lb-sec (e.g., 88 lb hydrazine)	Astrophysics

Subsystem design concepts were evaluated to establish singular concepts that would accommodate all payloads defined for geosynchronous operations. Table 5 lists the selected subsystem approaches.

Some payloads do not require the full capabilities of the standardized support levels, and further detailed economic analyses of a finalized geosynchronous program with specified mission equipment may indicate that use of the standard subsystems is not desirable. However, the modular concept developed in this study will readily accommodate an assortment of subsystem assemblies that reflect various performance plateaus. Present indications are that this approach should produce significant cost savings over designs tailored for each mission.

Mission Equipment Accommodations. Individual design and conceptual layouts, such as those shown in Figure 5, were prepared for each platform type to illustrate the accommodation features for the complements of mission equipment. General brief definitions postulated for the principal hardware associated with the remote and manned-servicing modes are presented in Figure 6.

A comparison of the satellite and platform inventories for the two traffic models used in the study is presented in Table 6. Table 6 excludes pre-1980 satellites because they occur before the planned availability of the shuttle and the platform. Post-1980 technology/development satellites are also excluded because they have not been well defined. The reduced number of platforms, in comparison to satellites, results from functional grouping and from the inclusion of on-orbit servicing, which permits new payloads to be exchanged for obsolete or expired equipment on a given platform without increasing the inventory. Platform weights within this inventory ranged from 2651 to 8499 pounds.

Table 5. Selected Subsystem Approach

Function	Subsystem Approach	Capability
Electrical power	Solar array--battery	2 kilowatts continuous for 10 years
Pointing	Charge-coupled device star tracker	10 arc seconds[1]
Cyclic torque compensation	Reaction wheels	1.0 arc second/second[1] stability
Data handling	PSK modulation; K-band carrier frequency	50 megabits/second
Secular torque compensation and maneuvers	Four independent quads; four 1-pound-thrust engines/quad; hydrazine	39,000 lb-sec impulse[2]
Thermal control	Heat pipes to radiator	100 watts/module[3]

1. Capability reflects centralized control system concept. Tighter tolerances are achieved by direct inputs to the control system from payload sensors.
2. Packaging concepts resulted in the use of 10 of the 12 compartments of the common support structure. Two propulsion modules were added to extend the north-south stationkeeping capability of data relay platforms to approximately 2.5 years.
3. For modules that dissipate more than 100 watts, a thermal grease packet must be incorporated between the module and the cold plate to ensure adequate heat transfer.

TRANSPORTATION INTERFACES

After platform requirements and designs had been established and applied to various program options, additional analyses were conducted on transportation interfaces. These were added to the study to provide greater depth in identifying the requirements, interfaces, and operations which must be provided by the transportation system to support platform programs. Also, the applicability of solar electric propulsion to platform programs was investigated.

Principal Interfaces. Physical, functional, and operational interfaces between platforms and pertinent transportation system elements were identified for the following mission modes:

Platform placement
Auto-remote servicing

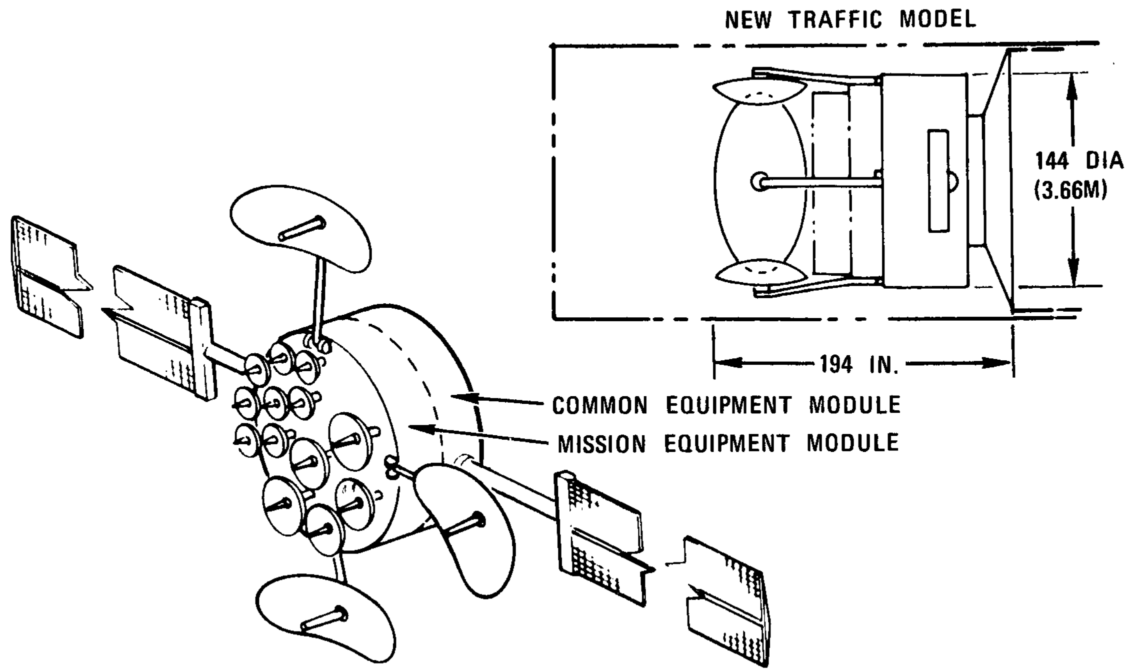

Figure 5. Typical Communications Relay Platform Configuration

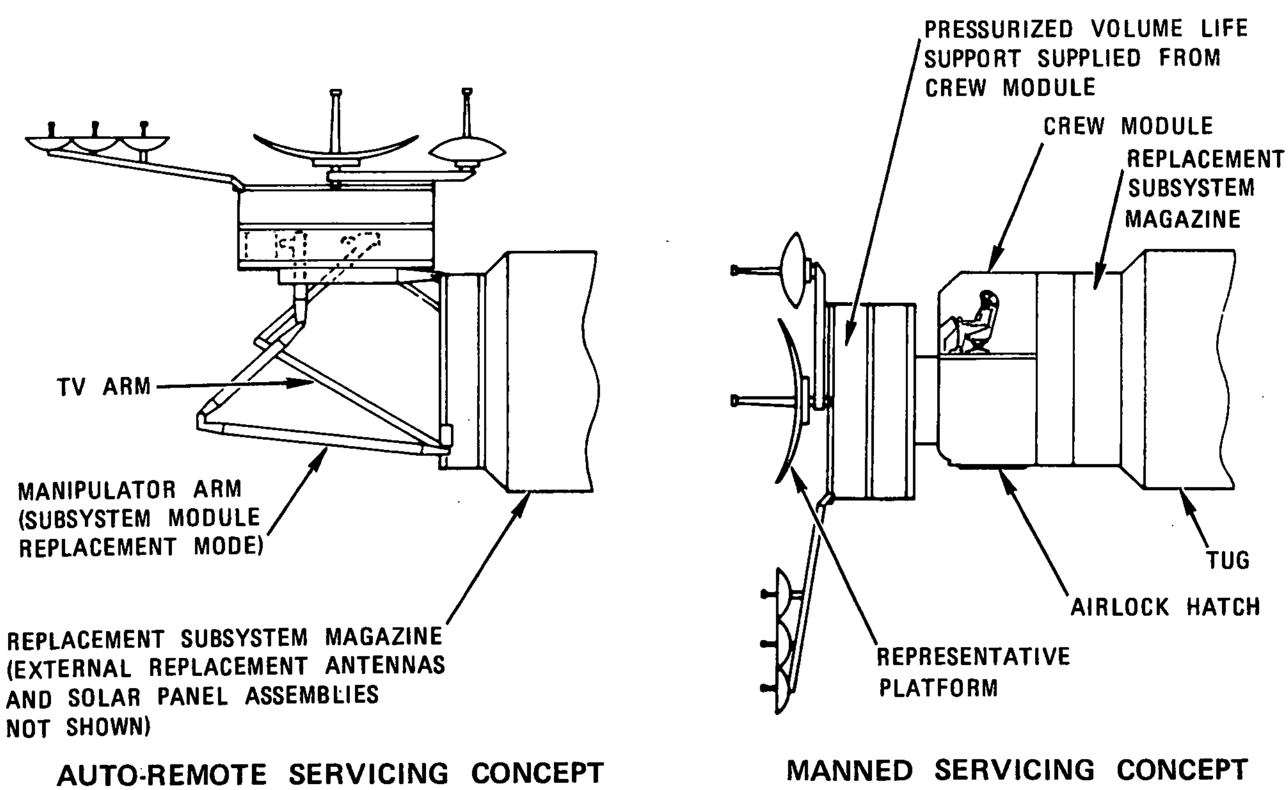

Figure 6. Servicing Hardware Configurations

Placement plus auto-remote servicing of additional platforms
Manned servicing
Placement plus manned servicing of additional platforms

Basic support capabilities for these interfaces were obtained from current sources (the shuttle configuration defined at the time of the Preliminary Requirements Review and the high-technology tug defined for the Tug Operations and Payload Support Study). Next, mission profiles and detailed timelines were constructed for each of the mission modes, with emphasis on platform-related operations, such as deployment, activation, checkout, and servicing. Interface requirements were identified and compared to the basic support capabilities provided by the defined transportation systems to determine the necessary changes to the transportation system. Trade studies were conducted to select the preferred method of interface implementation, and conceptual designs of these interface features were synthesized.

Table 6. Comparison of Inventories

Type of Payload	Baseline Traffic Model		New Traffic Model	
	Satellites	Platforms	Satellites	Platforms
Intelsat, Domsat	50	8	212	23
Navigation and traffic control	6	0*	36	20
TDRS	6	3	28	14
Earth observations	18	4	8	4
Astrophysics	4	1	13	3
Totals	84	16	297	64

*Navigation and traffic control functions are included on Intelsat/Domsat platforms.

Key areas of interface impact are identified by X's in Table 7 for both unmanned and manned mission modes. Flight interfaces associated with guidance and control and deployment dynamics provided by the defined transportation system were generally adequate for platform programs. However, changes and/or supplements to most of the physical and functional interfaces are required primarily for on-orbit servicing operations.

Solar Electric Propulsion (SEP) Applicability. The applicability of SEP to geosynchronous platform programs was investigated. Payload performance, mission operations, and potential program cost impacts were evaluated in reference to the SEP stage configuration defined in the recent SEP Feasibility Study. The best use of SEP for geosynchronous missions is in conjunction with both the shuttle and tug. The tug carries the SEP stage (called Geoseps) and payload to an intermediate orbit above the Van Allen radiation belts. From there the Geoseps operates in an interorbital mode, carrying payloads to and from geosynchronous orbit. Payload exchange operations are conducted with the tug on each trip.

Table 7. Areas of Platform Impact on Transportation System Support

Interface	Orbital Transport System Support Capability	Unmanned Mission Impact	Manned Mission Impact
Physical			
Docking/separation	Probe and drogue	X	X
Electrical connector	Power only	X	X
Docking aids	Laser and TV (visual)	X	X
Operational			
Deployment	±25 nm alt, ±0.1° incl 0.1 g accel, 1°/sec tipoff		
Stability and pointing	0.1°/sec, 0.2 degree		
Rendezvous - 100 nm	Autonomously or ground track		
Terminal rendezvous	Laser radar		
Predocking assessment	Data to ground and TV or visual inspection		
Docking	TV or visual - laser alternate		
Atmosphere control	Standard provisions for man		X
Functional			
Power and energy	Unmanned 700 w, 40 kwh	X	
	Manned 830 w, 15 kwh		X
Communications	None	X	X
Servicing interface to platform	None		X
Contamination	Preventive measures	X	X

The use of Geoseps for geosynchronous platform programs is feasible. It offers payload delivery capabilities in excess of 10,000 pounds, and its long mission life makes possible servicing missions for widely-spaced platforms. These result in significant cost savings, but operational complexities are introduced by the payload exchange operations and long trip times.

PROGRAM EVALUATIONS AND CONCLUSIONS

Program Evaluation. The study involved examing 16 programs that reflected variations in platform concepts. Within these programs, various levels and frequencies of on-orbit servicing for auto-remote and manned servicing modes were parametrically treated. The programs covered four single-function platform options (single payloads) and twelve multifunction platform options. Also, the characteristics of two conventional programs with expendable satellites were developed to the extent necessary for comparison with platform programs. The conventional satellite programs were structured directly from the baseline and new traffic models defined previously. The time span from 1981 to 1990 was assumed because the space shuttle would be available then and platforms could also be developed by that time. In addition, the high traffic levels of concern in the study would be experienced during the period.

The key to the alternate program definitions was the number of shuttle/tug launches required to support each option. Delivery schedules, constructed for each option, incorporated best use of the shuttle/tug, with multi-delivery and/or servicing missions being performed where possible and as required within the traffic schedules. In all alternate programs, equivalent geosynchronous on-orbit mission capability was maintained in accordance with the two reference traffic models.

The number and types of hardware elements required to meet the mission and servicing needs of the 16 programs were determined and costed. The costs of these elements were combined with recurring costs for shuttle/tug operations to produce total program costs. Shuttle/tug RDT&E costs were not included, since they represent a fixed and equal addition to all programs considered in the study, and hence, would not affect the program comparisons.

Conclusions. The resulting program comparisons are summarized in Tables 8 and 9 for the baseline and new traffic models. The shuttle/tug usage characteristics, peak flights per year, spacecraft regional distributions, hardware end items, and total program costs are shown. Emphasis was on analysis of servicing variations for multifunction platforms where maximum benefits were anticipated. A representative case for remote and manned servicing of single function platforms was constructed for comparison. From these data and from the earlier traffic analysis and platform synthesis activities, the following principal conclusions were derived. In general, these key study findings are listed in descending order of significance.

- Selected groupings of functions/payloads on platforms are feasible and desirable.
- For each major function, single platform designs capable of operating with any of three servicing modes (remote, EVA, shirtsleeve) appear feasible.
- Both remote-serviced and man-attended programs with multifunction platforms offer significant cost savings over conventional programs with expendable satellites, even with the high servicing levels assumed.
- Platforms are cost effective because of hardware commonality and reduced inventories.

Table 8. Baseline Traffic Model Program Comparison Summary

PROGRAM CHARACTERISTIC	PLATFORM PROGRAMS: SINGLE FUNCTION PLATFORMS (25% PER YR)		MULTIFUNCTION PLATFORMS: REMOTE			MULTIFUNCTION PLATFORMS: MANNED			EXPENDABLE SATELLITE
	REMOTE	MANNED	25 PERCENT PER YEAR	50 PERCENT PER YEAR	50 PERCENT PER 2 YR	25 PERCENT PER YEAR	50 PERCENT PER YEAR	50 PERCENT PER 2 YR	
SHUTTLE/TUG FLIGHTS									
DELIVERY ONLY	16	21	11	11	14	15	15	16	44
DELIVERY + SERVICE	34	46	7	8	6	6	6	4	-
SERVICING ONLY	125	136	71	76	36	96	152	72	-
TOTAL	175	203	89	95	56	117	173	92	44
PEAK SHUTTLE FLIGHTS/YEAR	22	25	11	11	10	14	21	17	6
SPACECRAFT DENSITY									
REGION IV	32		7						64
REGION III	15	→	4	→	→	→	→	→	24
REGION II	8		3						12
REGION I	8		4						13
TOTAL	63	63	18*	18	18	18	18	18	113**
TOTAL HARDWARE END ITEMS									
CSM	63	63	18	18	18	18	18	18	-
SSM	128	128	53	53	53	53	53	53	-
RSU	9	-	3	3	2	-	-	-	-
SSM	6	-	6	6	4	-	-	-	-
CM	-	9	-	-	-	3	3	2	-
SSM	-	6	-	-	-	9	9	6	-
COSTS ($M)									
NONRECURRING	1105.0	1157.9	1105.0	1105.0	1105.0	1157.9	1157.9	1157.9	2515.3
RECURRING	3975.8	4435.2	2121.2	2354.9	1679.2	2513.2	3371.9	2157.2	2403.8
TOTAL	5080.8	5593.1	3226.2	3459.9	2784.2	3671.1	4529.8	3315.1	4919.1

*INCLUDES TWO PLATFORMS FOR TECHNOLOGY DEVELOPMENT PAYLOADS.
**EXCLUDES TRAFFIC THROUGH 1980.

Table 9. New Traffic Model Program Comparison Summary

PROGRAM CHARACTERISTIC	PLATFORM PROGRAMS: SINGLE FUNCTION PLATFORMS (25% PER YR)		MULTIFUNCTION PLATFORMS: REMOTE			MULTIFUNCTION PLATFORMS: MANNED			EXPENDABLE SATELLITE
	REMOTE	MANNED	25 PERCENT PER YEAR	50 PERCENT PER YEAR	50 PERCENT PER 2 YR	25 PERCENT PER YEAR	50 PERCENT PER YEAR	50 PERCENT PER 2 YR	
SHUTTLE/TUG FLIGHTS									
DELIVERY ONLY	36	47	30	32	36	43	42	41	122
DELIVERY + SERVICE	76	104	19	23	16	17	17	10	-
SERVICING ONLY	281	307	194	218	94	276	427	183	-
TOTAL	393	458	243	273	146	336	486	234	122
PEAK SHUTTLE FLIGHTS/YEAR	85	99	36	41	19	50	73	31	23
SPACECRAFT DENSITY									
REGION IV	49		16						70
REGION III	23	→	13	→	→	→	→	→	39
REGION II	66		14						86
REGION I	101		23						121
TOTAL	239	239	66*	66	66	66	66	66	316**
TOTAL HARDWARE END ITEMS									
CSM	239	239	66	66	66	66	66	66	-
SSM	478	478	159	159	159	159	159	159	-
RSU	17	-	7	7	3	-	-	-	-
SSM	16	-	14	14	6	-	-	-	-
CM	-	17	-	-	-	7	7	3	-
SSM	-	15	-	-	-	21	21	9	-
COSTS ($M)									
NONRECURRING	732.0	784.9	825.0	825.0	825.0	877.9	877.9	877.9	1,550.0
RECURRING	9,557.2	10,567.6	5,789.3	6,588.6	4,494.8	7,049.6	9,348.9	5,636.8	5,972.2
TOTAL	10,289.2	11,352.5	6,614.3	7,413.6	5,319.8	7,927.5	10,226.8	6,514.7	7,522.2

*INCLUDES TWO PLATFORMS FOR TECHNOLOGY DEVELOPMENT PAYLOADS.
**EXCLUDES TRAFFIC THROUGH 1980.

- Standardized packaging is feasible for all platform subsystems and most mission equipment.

- With appropriate functional grouping, a single utilities support module design can economically support all defined geosynchronous payloads. It also offers the likely capability of supporting development and technology payloads that are yet to be defined.

- The new traffic model is more representative of the full potential for geosynchronous operations than the baseline model. It is based on global demands, and provides increased utilitarian benefits to mankind.

- Satellite physical contention is not likely to be a critical problem through the 1990 time period, even without retrieval.

- Geosynchronous EMI contention will likely occur before 1990 if wider spectrum usage is not employed by communications relay systems. Platforms using both C- and K-bands would eliminate this problem.

- S-band EMI problems currently exist among users in all orbits and will be compounded by increased space traffic. Geosynchronous platforms would aid in reducing these problems by lowering the number of traffic elements.

- Cooperation and planning will be required on both national and international levels to preclude physical and EMI contention.

- With relatively minor modifications, the baseline shuttle and tug capabilities* can meet the transportation needs of the geosynchronous programs defined during the study.

- Application of a solar electric propulsion stage to geosynchronous platform programs is feasible and offers increased payloads, but only at the expense of operational complexities associated with payload exchange operations and long trip times.

*Shuttle payload is 65,000 pounds. Tug round trip payload to geosynchronous orbit is 3225 pounds.

RECOMMENDATIONS

RECOMMENDED GEOSYNCHRONOUS PROGRAM APPROACH

The more significant conclusions of the study are that grouping of functions or payloads is feasible and that on-orbit servicing offers potential gains in shuttle/tug utilization efficiency, and further, that it is possible to design platforms offering the flexibility of operating with all three servicing modes, mechanical-remote, EVA/IVA man-attended (pressure suited), and shirtsleeve man-attended. Thus, a program approach which emphasizes selected groupings of payloads, tailored to standardized support levels and related hardware packaging, and which offers the flexibility for accommodating various servicing modes is recommended. This holds open the option for future decisions on preferred servicing modes based on added experience in both serviceable spacecraft design and actual servicing operations. The inherent capabilities of man in situ may prove to be the dominant factor in establishing the preferred servicing concept.

The pre-Phase A study shows only the basic characteristics of the desired program approach. Future efforts are required to translate this general approach into specific development activities. Geosynchronous traffic and related mission equipment must be better defined, payload grouping options must be refined and further developed, common support requirements must be sized to match the improved traffic definition and the new grouping options, on-orbit servicing techniques must be developed, and the corresponding modularized hardware designs must be synthesized.

SUPPORTING RESEARCH AND TECHNOLOGY/ADVANCED RESEARCH AND TECHNOLOGY

Research and development relevant to geosynchronous programs are shown in Table 10.

Table 10. SRT/ART Requirements Summary - Geosynchronous Platform

Subsystem	Functional Requirement	State of Art	Known Current Work	Needed SRT/ART	Criticality
Electronics and Control					
Attitude Control	Accurate attitude determination and reference within 10 arc-seconds	Attitude determination systems operating at low earth orbit in unmanned spacecraft (OAO) with $\cong$ 15 arc-sec accuracy	Image dissector, slow-scan vidicon and slow-scan charge coupled devices for star tracking presently in laboratory research	Develop 10 arc-second attitude determination system for geosynch operation	Affects attitude control accuracy and provision for continuous attitude update
Communications . Use of microwave/ millimeter waves	Increase communications capacity of data relay spaceborne systems to meet future traffic forecast requirements--by a factor of 10 to 20	12 to 40 MHz channels operating at C-band (4/6 GHz) on Intelsat and Domsat systems	24 to 40 MHz channels in C-band under development for Intelsat V and Domsats using orthogonal polarization	Need to develop use of higher frequency bands presently allocated by WARC - 11/14 GHz band - 20/30 GHz band	1985/1990 data relay capability will be affected
. Use of RF switching	Improve data relay channel, utilization flexibility	Intelsat/Domsat use fixed broad beam ground coverage-fixed channels	Intelsat V has channel switching among several narrow beamwidth transmissions under development; ground microwave systems currently utilizing TDMA* techniques	Need to develop use of TDMA techniques and RF switching at higher frequencies (especially 20/30 GHz band)	Affects capability to provide flexibility of channel allocation as a function of link traffic demand
. Use of multibeam antenna systems	Increase communications capacity of data relay systems by providing multiple simultaneous spaceborne antenna beams	Domsat/Intelsat use two to three fixed beams with dual feed antennas and separate antennas at C-band	ATS--plans multibeam, single reflector antenna systems test	Develop multibeam, single reflector antenna systems Develop use of multibeam phased array techniques combined with TDMA	Affects capability to provide flexibility of channel allocation as a function of link traffic demand Phased arrays will provide passive beam steering, thus reduced disturbance torques
Materials and Structures					
Thermal Control	Thermal protection for random orientation at up to 50:1 turn-down ratios	Apollo/Skylab with active liquid heat transport; passive systems off the shelf at up to 10:1 ratios with orientation restrictions	Variable conductance heatpipe radiators with 20:1 turn-down ratio and orientation restrictions in laboratory	Develop passive radiator system to operate with 50:1 turn-down ratio and no orientation restriction	Affects mission flexibility to provide operational capability for all orientations
Module Interfaces	Remote capability for electrical quick connect/ disconnect, especially for waveguide microwave connections	Electrical and coaxial connectors presently used Waveguide connections available with manual operation No connect/disconnect has been performed in space environment	Skylab has applied manual connect/disconnect No known remote space applications are under development	Development of mechanism to provide for precision connector mating and associated material problems	Affects capability to perform on-orbit maintenance and servicing

*TDMA - Time division multiple access