NASA TECHNICAL MEMORANDUM

NASA TM X - 64847

ORBITAL OPERATION FOR LARGE AUTOMATED SATELLITES

(NASA-TM-X-64847) ORBITAL OPERATION FOR LARGE AUTOMATED SATELLITES (NASA)

N74-26323

Unclas

G3/31 39952

MISSION OPERATIONS OFFICE

May, 1974

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

MSFC - Form 3190 (Rev June 1971)

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. TM X - 64847	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE ORBITAL OPERATION FOR LARGE AUTOMATED SATELLITES		5. REPORT DATE MAY 1974 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) J. L. LUSK AND V. BIRO*		8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812		10. WORK UNIT NO. 11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D.C. 20546		13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This preliminary study presents orbital operations concepts for the shuttle launched Large Automated Satellites (LAS). It includes the orbital operations elements and the major options for accomplishing each element.

This study is based on the preliminary payload information available in Level I and II documents and on orbital operations methods used on past programs, both manned and unmanned. It includes a definition of detailed trade studies which need to be performed as satellite design details and organization responsibilities are defined.

The major objectives of this study were to define operational methods and requirements for the long duration LAS missions which are effective and primarily economical to implement.

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17. KEY WORDS ORBITAL OPERATIONS AUTOMATED SATELLITES	18. DISTRIBUTION STATEMENT UNCLASSIFIED - UNLIMITED W. G. Clarke
19. SECURITY CLASSIF. (of this report) UNCLASSIFIED	20. SECURITY CLASSIF. (of this page) UNCLASSIFIED

MSFC - Form 3292 (Rev December 1972) For sale by National Technical Information Service, Springfield, Virginia 22151

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1.0 INTRODUCTION

1.1 GENERAL

This report presents the results of a conceptual study for orbital operation of the Large Automated Satellites (LAS) to be flown on the Space Shuttle. The Large Automated Satellites are defined as "Free Flyers", payloads capable of operating independent of the Shuttle; "Large", payloads requiring the majority of the Shuttle carrying capacity (weight and volume); and "Multi-purpose", payloads which incorporate a group of experiment equipment for a field of scientific study rather than a special purpose experiment package normally carried on the Small Automated Satellites. The LAS grouping includes payloads in the astronomy, physics, earth observations, and space technology category. The major orbital operations elements for these classes of satellites is presented in this report with potential options for their accomplishment. A summary is included which lists those studies necessary to better understand each element as it relates to the overall operations planning.

1.2 LAS DESCRIPTION

A brief description of the specific LAS payloads follows, with additional details shown in Tables 1 and 2. The operations interface complexity categories in Table 2 are based solely on an estimate of the systems complexity and the required operational functions to be performed. Figure 1 shows the launch and revisit schedule of these specific payloads.

The payload data used in this study were the Level I and II Payload Data Sheets, the 1973 NASA Payload Model and the Space Shuttle Traffic Model which were available in January 1974.

A. Earth Observatory Satellites (EOS) will obtain Earth data for mapping, soil and crop data and terrestrial observations. Experiment subsystems are thematic mapper, high resolution imager, data collection system, radar imager, and meteorological package.

B. Large High Energy Observatory (HEAO) will survey gamma ray sources in the 20 to 10^5 MeV range. Major experiment subsystems are the gamma ray survey assembly and support electronics.

Table 1. PAYLOAD OPERATIONAL CHARACTERISTICS

	EOS (EO-3)	HEAO (AST-5B)	LST (AST-6)	LSO (AST-7)	LRO (AST-8)	LXRT (AST-9B)	PHY (PHY-5)	LDEF (ST-1A)
MAXIMUM NUMBER SIMULTANEOUS OPERATION	2	2	1	1	1	2	1	1
APOGEE (KM) PERIGEE (KM) INCLINATION DEG	914.1 914.1 99.15	371 371 28.5	611 611 28.8	350 350 30	71,600 71,600 28.5	463 463 15	371 371 28.5	500 500 28.5
LENGTH (M) DIAMETER (M) WEIGHT (Kg)	11.0 3.1 2951	5.2 4.6 9,518	12.7 4.3 11,379	17.7 4.6 10,000	5.2 3.3 1,300	16.0 4.6 11,350	8.5 4.3 18,600	9.3 4.3 3,860
ON ORBIT SERVICE	YES	YES	YES	YES	YES	YES	YES	N/A
OPERATIONS INTERFACE COMPLEXITY CLASS*	3.2	3.2	3.5	3.5	3.0	3.2	3.1	0
TYPE OF EXPERIMENT DATA	DIGITAL IMAGES -- RELAY GROUND DATA -- 200 MBIT DOWNLINK	DIGITAL IMAGES 4.2 MBIT PER FRAME	DIGITAL IMAGES 0.8 TO 80 MBIT PER FRAME	DIGITAL IMAGES	RELAY DEEP SPACE SIGNALS	DIGITAL IMAGES 8.3 MBIT PER FRAME	DIGITAL IMAGES	SAMPLES RETURN WITH PAYLOAD

*Refer to Table 2.

TABLE 2: LEVELS OF LAS SYSTEMS/OPERATIONS INTERFACE COMPLEXITY

SYSTEM	EOS (EO-3)	HEAO (AST-5B)	LST (AST-6)	LSO (AST-7)	LRO (AST-8)	LXRT (AST-9B)	PHY (PHY-5)	LDEF (ST-1A)
THERMAL CONTROL	2	3	3	3	3	3	3	NONE
ATTITUDE AND POINTING CONTROL	4	4	4	4	2-4	4	4	NONE
ELECTRICAL POWER	3	3	3	3	3	3	3	USER SUPPLIED
DATA SYSTEM	4	3	3-4	4	3	3-4	3	NONE
CONSUMABLES & CONTAMINATION MANAGEMENT	2	2	3	3	2	2	2	NONE
EXPERIMENT OPERATION	4	4	4	4	3	4	4	PASSIVE
ON-ORBIT MAINTENANCE	1 YR	1-2 YRS	2-3 YRS	1 YR	2 YRS	1 YR	1 YR	N/A
RETRIEVE/ REFURBISH	4 YRS	4 YRS	3-5 YRS	6 YRS	6+Yrs	5 YRS	5+YRS	6 MOS
SUMMARY (COMPLEXITY CLASS)	3.2	3.2	3.5	3.5	3.0	3.2	3.1	0

1 - MONITOR ONLY

2 - GROUND CONTINGENCY ACTION ONLY

3 - GROUND MONITOR & SIMPLE SYSTEMS MANAGEMENT

4 - GROUND MONITOR AND COMPLEX SYSTEMS MANAGEMENT

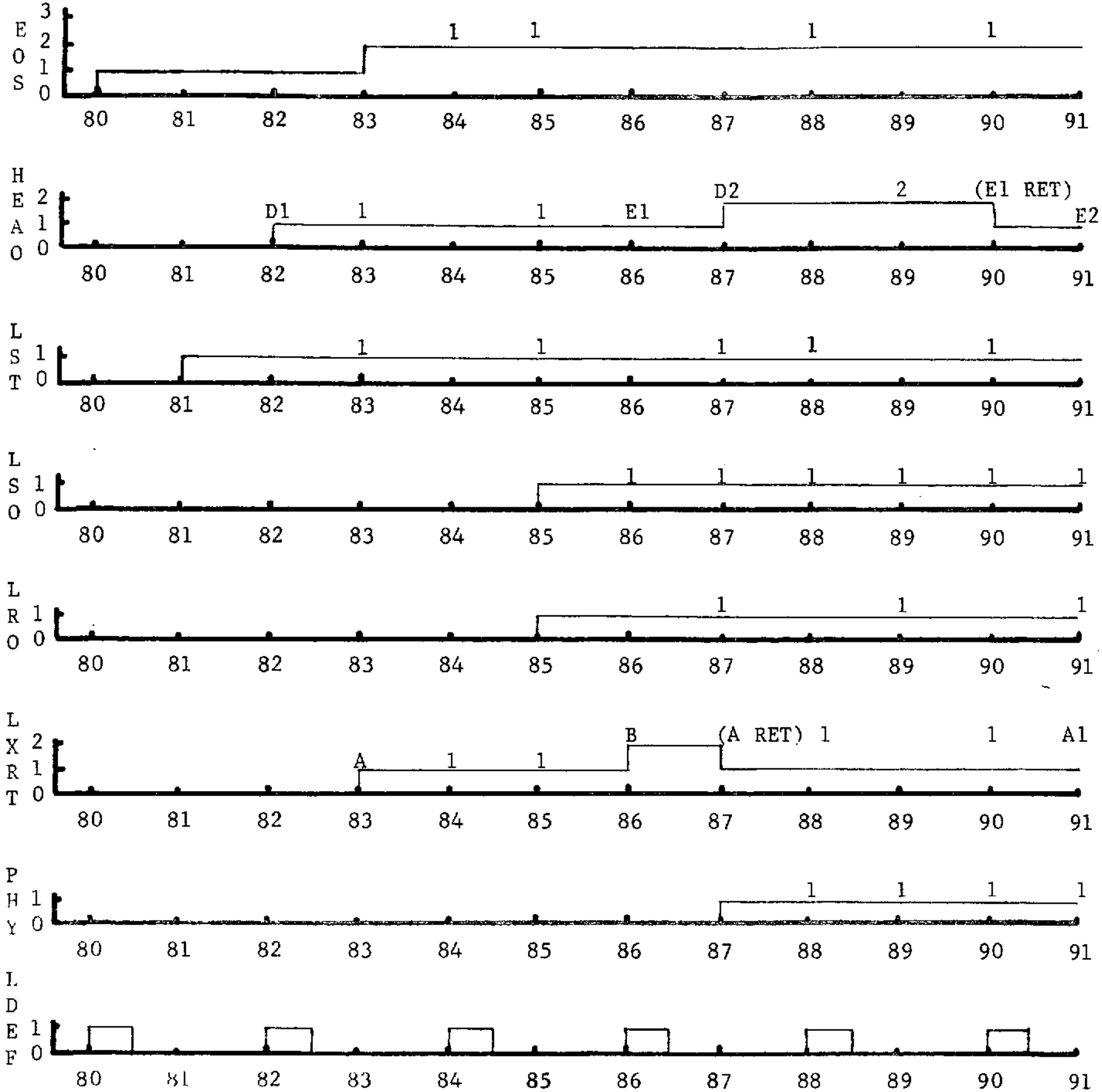

FIGURE 1: LARGE AUTOMATED SATELLITE FLIGHT AND REVISIT SCHEDULE

C. Large Space Telescope (LST) will observe stars, planets, and other stellar objects, particularly in the ultraviolet and infrared regions. It will complement ground based instruments. Major experiment subsystems are an optical telescope assembly, scientific instrument package, and support systems module.

D. Large Solar Observatory (LSO) will make multispectral observations and solar measurements such as coronal brightness, spectral resolution images of the Sun, map the Sun's emissions, locate flares, map X-ray emissions versus energy and make several X-ray measurements. It contains 16 separate experiments.

E. Large Radio Observatory (LRO) will measure low frequency spectra of discrete cosmic radio sources and obtain good angular resolution of these sources. Major systems consist of a central core and four subsatellites forming a 10 km x 4 km rhombic antenna.

F. Large X-Ray Telescope Facility (LXRT) will make high resolution imaging, spectral and polarimetric X-ray measurements. Major experiment subsystems are reflecting mirrors, proportional counter (spectrometer), large diameter grazing incidence telescope, and control electronics.

G. Cosmic Ray (PHY) will study and survey spatial and spectral distribution of cosmic background radiation field. The data presently available in Level I and II documents concerning the Physics class is very limited.

H. Long Duration Exposure Facility (LDEF) is a passive payload which will carry many self-contained specimens to measure effects of space environment. It will consist of meteoroid, microbiology and macrobiology, and technology experiments.

1.3 GUIDELINES AND ASSUMPTIONS

The following guideslines and assumptions were used in the preparation of this study.

A. The development center will be responsible for the payload hardware from design through orbital attainment of all scientific objectives.

B. Ground operations including test, checkout, launch, and refurbish are a development center responsibility which will be supported by the operations center only as required. There will be minimal discussion of ground operations in this study.

C. This study will concentrate on routine multiyear LAS orbital operations requirements and the support necessary to fulfill those requirements.

D. Economy and annual operating costs will be a major consideration in this study due to the multiyear operating lifetime of the LAS payloads.

E. Continuity of engineering expertise will be required at the development center for replacement experiment design and payload refurbish activities.

F. Operations center support to the scientific community will be similar to that provided by large ground based observatories.

2.0 PAYLOAD CONTROL

2.1 GENERAL

Control and operations monitoring will be performed at a Payload Operations Center (POC). For the payloads considered in this study, this activity is required, to some extent, from prelaunch checkout through retrieval from orbit. The individual phases and the operations involvement during each of these phases are briefly discussed in the following paragraphs.

The majority of the payload control and operations monitoring activity is required during the orbital phase which spans many years for the LAS payloads. The orbital phase activities are the major subject of this report and will be addressed in detail in the remaining sections of this study.

2.2 PRELAUNCH CHECKOUT

The POC will be activated during LAS prelaunch checkout. Payload checkout is the responsibility of the development center; the POC will be operated in a support mode during this phase. The major POC activities during prelaunch checkout will be to verify POC operational capability, perform end-to-end testing of the data handling system, simulate payload operations for personnel training and to support the development center in payload checkout as required.

2.3 LAUNCH PHASE

From launch until the initiation of on-orbit activation, there will be limited communication with the payload systems via Shuttle monitoring. For all classes of payloads, it may be necessary to monitor the contamination levels and the environment in the Shuttle payload bay during the ascent phase for protection of the experiment systems. Several payloads include cryogenics and high pressure gas bottles which require monitoring and launch abort safing procedures. During this phase, payload monitoring for safety is the responsibility of the Shuttle crew; the POC will be operated in a monitoring and support mode.

2.4 ACTIVATION

Procedures for activation, including checkout and deployment of the payloads from the Shuttle payload bay, will be developed for each payload. The two modes of activation are automatic and manual. From these there are further breakouts which concern the expertise required with the mode selected.

A. Automated Activation -- The payload is activated and checked out from the Shuttle through pre-programmed equipment. Manual or ground command override capability would be designed into the automated systems. The most significant advantage of automated activation is that the potential of human error is reduced when complex payloads require setup in a predetermined way. The payloads for which automatic activation would be feasible are the LDEF and some of the Physics and Astronomy payloads.

B. Manual Activation -- This requires manually initiated commands from a ground based control center or the Shuttle crew to the payload. Present plans from the Shuttle Mission Control Center require that a payload specialist(s) be added to the crew for manual activation control.

2.5 PAYLOAD CHECKOUT

Systems parameters of the electrical, thermal, instrumentation and communication, and attitude disciplines will be displayed at the POC during this phase. The LDEF, which is passive with regard to ground control, has no identified on-orbit checkout requirements.

All of the LAS payloads require electrical power for their operation. The majority of the payloads will require electrical checkout in the Shuttle payload bay. Deployment of these payloads includes physical size changes which increase the complexity and time required for retrieval. Monitoring capability for the Shuttle crew and the POC will be required while the payload is in the Shuttle payload bay and when the payload is attached to the Shuttle manipulator arms. Following payload release from the Shuttle, deployment and complete payload checkout will occur. The Shuttle will remain in orbit, near the payload, should any major malfunctions occur during this phase. The POC will have primary responsibility for final payload checkout prior to Shuttle departure.

For some LAS payloads, Tug placement to the desired orbit will be necessary due to payload weight and orbital altitude requirements. These interfaces and requirements of the Shuttle crew, Shuttle mission control center, Tug control center, and the Payload operations center will require that detailed procedures and operating agreements be developed. These will be based on (1) safety, both personnel and equipment; (2) complete checkout while retrieval from orbit is still readily available; and (3) economics, reduce duplication of control and monitoring equipment and technical expertise to the maximum extent possible. Intercenter communications methods would be used where possible to reduce personnel travel while maintaining effective payload control during the activation and checkout phase.

2.6 ORBITAL OPERATIONS

Orbital Operations of the LAS payloads is addressed in Section 3 and subsequent sections of this study.

2.7 PAYLOAD SERVICING

Several of the LAS payloads include on-orbit servicing provisions. Routine reservicing is planned at 1 to 3 year intervals dependent on payload requirements. Experiment and systems status will be monitored by the operations team to facilitate management decisions concerning scheduled and unscheduled maintenance, consumables replenishment and experiment changeout.

In addition to on-orbit servicing, all LAS payloads will be retrieved from orbit for periodic refurbish and experiment changeout. These retrieval intervals range from six months for the LDEF to six years for the LRO. Payload deactivation, safing and configuration changes required for Payload stowage in the Shuttle payload bay will be monitored by the POC. For some of the LAS payloads, special contamination protection procedures will be required to protect experiment optics during the retrieval and return activities. Refurbish and reconfiguration following payload retrieval is assumed to be a development center responsibility and is not addressed in this study.

3.0 ORBITAL OPERATIONS

3.1 GENERAL

Orbital operations must be considered early in payload design to ensure that operational control requirements can be effectively accomplished by the hardware design. Refer to Figure 2 for a typical LAS operations flow plan. Operational considerations, particularly in command control and data systems, must be included as a part of this basic design philosophy. Basic systems management functions for monitoring and control have to be considered with emphasis on the science aspects of the mission. These considerations can prevent future operational problems, result in improved monitoring and control capabilities and improve cost effectiveness. In addition, flight operations plans and procedures must be developed and these procedures exercised prelaunch through simulations and training to prepare the ground and flight crew and the software for the actual mission.

Orbital operations for the LAS payloads is required 24 hours per day, seven days per week, for up to 15 years mission lifetime.

Orbital operations will include payload systems and experiment monitoring, mission planning, support to the guest observers to ensure maximum science return, data handling, and many other support functions.

Monitoring of the basic systems management functions is required dependent on the degree of automation designed into each payload. It is assumed that override requirements exist for critical onboard functions. Systems and experiment consumables will be monitored for input to reservice scheduling.

Guest observers will participate in orbital operations, analyzing quick-look data for feedback into observing program optimization. They will be supported with detailed mission planning to meet their individual observing requirements. As guest observers change througout the lifetime of the LAS, they must be informed of changes in payload capability and constraints.

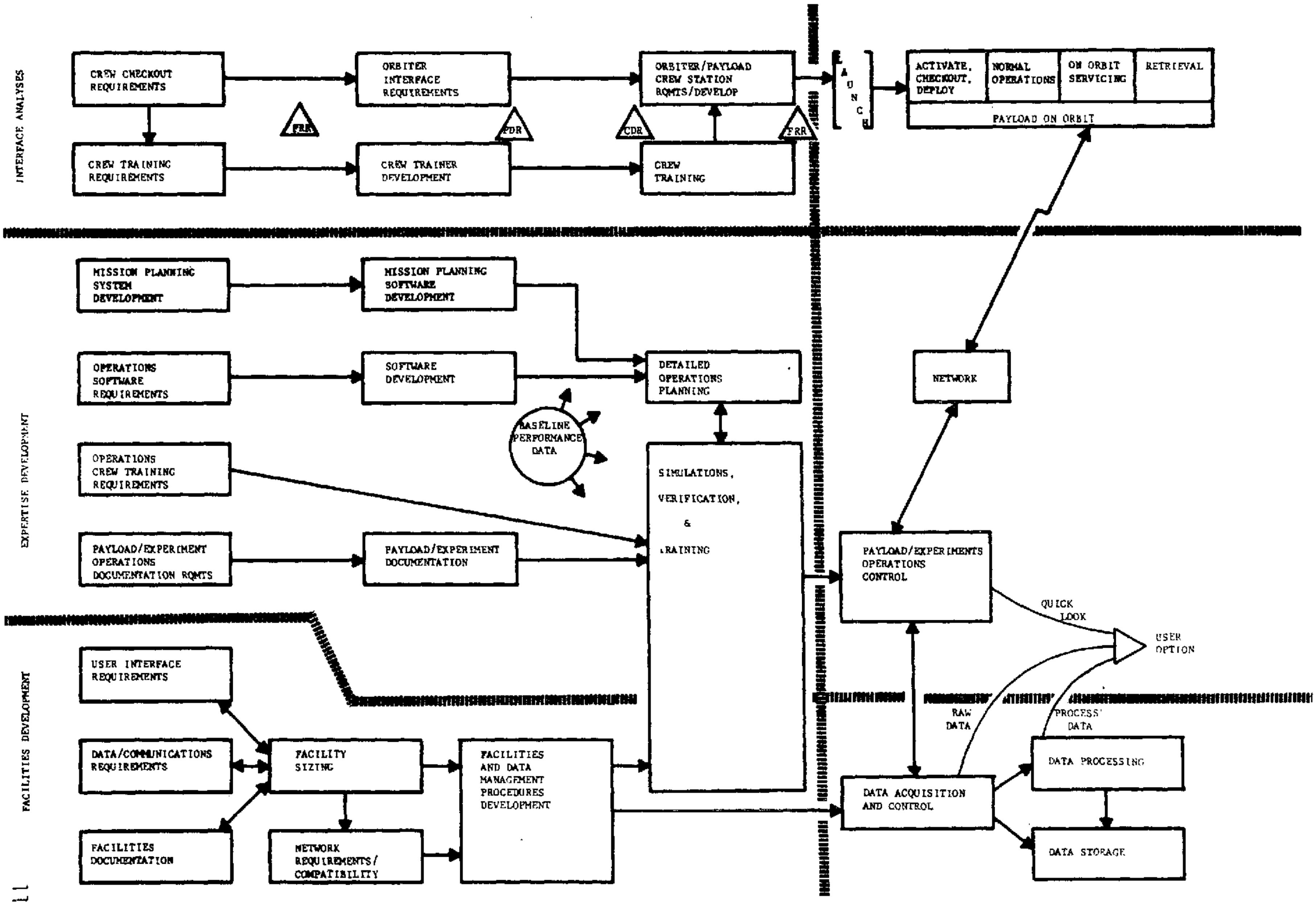

Figure 2: Typical LAS Operations Flow Plan

3.2 PLANNING AND CONTROL

3.2.1 MISSION PLANNING

Mission planning for the LAS will follow a routine schedule with the majority of the planning accomplished days or weeks in advance of the operation. It is assumed that minimum real-time rescheduling will be required that would greatly impact the timeline. Refer to Figure 3 for a typical flow timeline. The development center will provide the basic science program input to the planning team, coordinating all experiments housed within their payload and resolving any conflicts between experimenters.

To effectively perform the mission planning function for the long lifetime LAS mission, continual contact with the control team and the guest observers is necessary. Mission planning will require one individual on each shift with additional personnel during the day shift. The floating shift personnel may be deleted on the non-science operating shifts. Personnel reduction would depend on specific payload requirements and activities.

The day shift personnel would perform the majority of the planning and requirements coordination with the development center and guest observer personnel. Detailed activity plans would be computer generated from inputs developed by the planning team. Command lists controlling attitude changes, power usage and consumables management could also be generated by this system. Each mission plan will be coordinated with the payload project/science representative before implementation.

3.2.2 COMMAND CONTROL

The transmission of the mission plan to the payload will be accomplished by a command controller. The commands will be computer generated and verified by mini to small size computers. Command link contact with the payload will vary between a few minutes each orbit to a method where 24 to 48 hours of planning information is uplinked and stored onboard the payload for future use. The degree of payload autonomy, planning complexity and guest observer requirements will determine the method and equipment required for each payload.

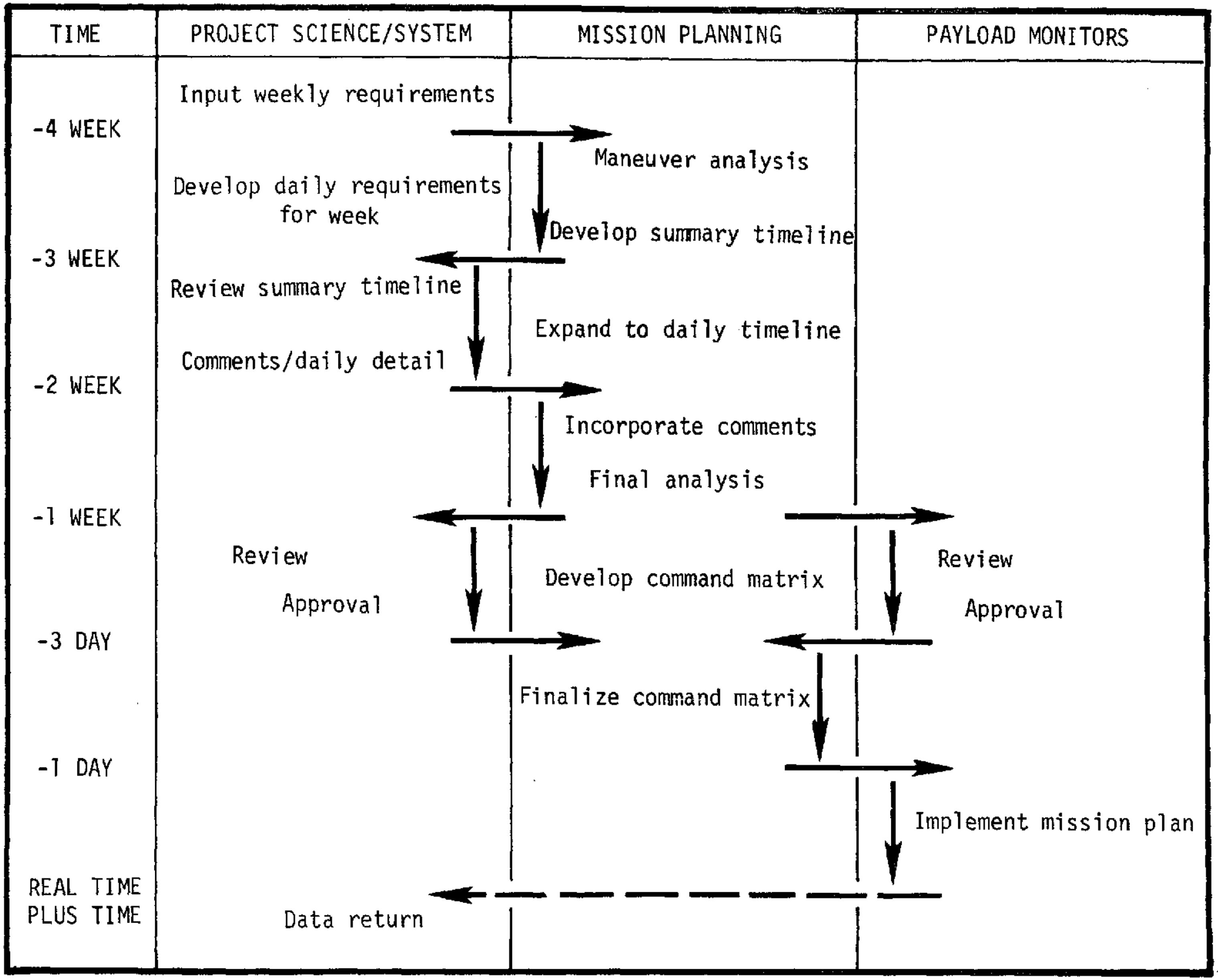

Figure 3: MISSION PLAN FLOW

3.3 PAYLOAD MONITORING

3.3.1 PAYLOAD SYSTEMS

Basic systems management functions for orbital monitoring and control are presented here. Several options exist dependent upon the degree of automation designed into each satellite. The assumption is made that override requirements will exist for critical functions onboard the vehicle, which necessitates systems status monitoring. System Functions are summarized in Table 3, based on Skylab ATM, and are identified as follows:

A. The Electrical Power Systems (EPS) parameters will be monitored in order to determine status for power management. Monitoring requirements for each satellite with power management capabilities are approximately 70 prime and 100 secondary measurements. Solar Array and battery systems are assumed for all except the Technology (LDEF) Satellite. It is assumed that any LDEF experiment requiring electrical power will have self contained batteries. Satellites with solar arrays and one or more batteries capable of providing at least one experiment with sufficient electrical power to operate will have ground management capability. Solar Array articulation is not assumed for the Large Solar Observatory.

   Orbital inclination implies that orbital day/night cycles will be involved in the power profile planning/management scheme. The software required for EPS control will include battery characteristics and depth of discharge, solar array output and degradation, solar array articulation (where required), maneuver predictions, Beta angle effects, load predictions, etc. Energy consumable analysis is also a consideration for the battery system of the LDEF.

B. The Instrumentation and Communication (I&C) parameters which indicate the status of the system consists of about 85 prime and 36 secondary measurements for each LAS which will be monitored to ensure data flow and accuracy. Instrumentation and Communications system management functions are stored data dump, antenna pointing control and systems monitoring. The complexity of Instrumentation and Communication management will vary with the type of ground data

Table 3: ORBITAL PHASE SYSTEMS MONITORING REQUIREMENTS

	EOS	HEAO	LST	LSO	LRO	LXRT	PHY	LDEF
THERMAL CONTROL SYSTEM								
ACTIVE CONTROL/O'RIDE	NO	NO	YES	YES	YES	YES	YES	NO
*MONITOR								
PRIME	25	25	25	25	25	25	25	NONE
SEC	38	38	38	38	38	38	38	NONE
ELECTRICAL POWER SYSTEM								
MANAGEMENT/CONTROL	YES	YES	YES	YES	YES	YES	YES	NO
*MONITOR								
PRIME	70	70	70	62	70	70	70	NONE
SEC	100	100	100	96	100	100	100	NONE
INSTRUMENTATION AND COMMUNICATIONS								
STORED DATA DUMP	YES	YES	YES	YES	YES	YES	YES	NO
ANTENNA CONTROL	YES	YES	YES	YES	YES	YES	YES	NO
*MONITOR Prime	85	85	85	85	85	85	85	NONE
Sec	36	36	36	36	36	36	36	NONE
ATTITUDE CONTROL SYSTEM								
GROUND PROGRAM	YES	YES	YES	YES	YES	YES	YES	NO
MOMENTUM MANAGEMENT	NO	NO	YES	NO	NO	NO	YES	NO
NAV UPDATES	YES	YES	YES	YES	YES	YES	YES	NO
*MONITOR								
PRIME	74	74	74	74	74	74	74	NONE
SEC	85	85	85	85	85	85	85	NONE

*Estimated Quantities based on Skylab ATM.

INFORMATION CONTAINED IN THIS TABLE IS BASED ON SYSTEMS REQUIREMENTS IN LEVEL I AND LEVEL II DATA SHEETS.

receiving system. The receiving system with multiple stations, short duration contacts, and data gaps between contacts increases data storage/playback and antenna pointing control. For the long duration missions, data system management will be software controlled. It will primarily be included in the mission planning system. Data rates are discussed in the data management portion of this study and include both scientific data and system status/housekeeping data. All remote data acquisition and control is assumed to be performed at the POC.

C. The Attitude Control System (ACS) parameters, consisting of about 74 prime and 85 secondary measurements for each payload, will be monitored to ensure that pointing is accomplished within acceptable limits. Attitude control and pointing functions are based on existing design specifications. Control moment gyros are assumed to require momentum management functions and ground programs, and inertial measuring units were assumed to require periodic updates. It is also assumed that all pointing payloads require complete ground control and override capabilities of the attitude system. The ACS software will not only be used for payload control and maneuver predictions, but will also provide a primary input to reservice and retrieval planning. Consumables (cold gas thrusters) may affect schedules and orbital ephemeris data will be required by the Shuttle for reservice/retrieval maneuvering.

D. Anticipated operational temperatures, in the absence of systems design data, are utilized in determining Thermal Control System management functions. If the required temperature control range of the payload is less than 17 degrees K, it is assumed that a liquid coolant system with ground management capability will be used. For temperature control ranges greater than 17 degrees K, adequate control can be maintained with louver control, if the satellite is not looking at the Earth. In addition, preliminary data for several of the payloads indicate the use of heaters and cryogenic cooling for experiments, primarily for thermal control of optics.

E. The payload experiments monitoring requirements, based on Skylab data, are shown in Table 4. The quantity of measurements for each satellite is dependent upon the number of experiments aboard the LAS, and the degree of sophistication of the experi-

TABLE 4: ORBITAL PHASE EXPERIMENTS MONITORING REQUIREMENTS

PAYLOAD NAME/EXPERIMENTS	SIMILAR TO SKYLAB EXPERIMENT	SUPPORT MEAS		SCIENTIFIC DATA	
		PRI	SEC	TM	FILM
LARGE SOLAR OBSERVATORY					
SOFT X-RAY SPECTROMETER/SPECTROHELIO.	S056	8	8	1	
EXTERNALLY OCCULTED CORONAGRAPH	S052	10	20	1	
100-CM PHOTO-HELIOGRAPH	S082A	2	34	1	
UV SPECTROGRAPH	S055A	37	24	1	
XUV SPECTROHELIOMETER	S082B	2	43	1	
SPECTROMETER/SPECTROHELIOGRAPH	S082B	2	43	1	
HIGH SPECTRAL PURITY SPECTROHELIOGRAPH	S082A	2	34	1	
GRID-COLLIMATOR ACQUISITION PHOTOMETER	T027	5	10	10	
MODULATION COLLIMATOR		10	20	1	
X-RAY TELESCOPE	S054	13	54	1	YES
SOLID STATE FLARE DETECTOR		10	20	1	
X-RAY BURST DETECTOR	S054	13	54	1	
X-RAY/GAMMA RAY SPECTROMETER	S054	13	54	1	
GAMMA RAY SPECTROMETER	S054	13	54	1	
SOLAR X-RAY POLARIMETER	T027	5	10	10	
BRAGG REFLECTION CRYSTAL POLARIMETER	T027	5	10	10	
SOLAR NEUTRON EXPERIMENT	Hα	14	3	1	
HIGH ENERGY GAMMA RAY AND NEUTRON DET.	S056	8	8	1	
SOLAR GAMMA RAY DETECTOR	Hα	14	3	1	
LARGE HIGH ENERGY OBSERVATORY					
LARGE HIGH ENERGY X-RAY SURVEY	S056	8	8	1	NO
LARGE SPACE TELESCOPE					
OPTICAL TELESCOPE	S191+TV	10	--	1	
FAINT OBJECT SPECTROMETERS (4) INSTR.	SOSSA(x4)	148	96		NO
TWO ECHELLE HIGH RESOLUTION SPECTRO.	SOSSA(x2)	74	48		
LARGE X-RAY TELESCOPE FACILITY					
IMAGING DETECTOR	S192	31	--	22	
SPECTROMETER	S191/S054	10/13	0/54	1	NO
POLARIMETER	T027	5	10	10	
STELLAR ASPECT SENSOR	Hα	14	3	1	
EARTH OBSERVATORY SATELLITE					
THERMATIC MAPPER	S192	31	--	22	
HIGH RESOLUTION IMAGER	S192	31	--	22	YES
RADAR IMAGER	S193	88	--	39	
METEOROLOGICAL PACKAGE	S194	15	--	11	
LARGE RADIO OBSERVATORY					
TELESCOPE	S194	15	--	11	
DETECTOR ARRAY	S193+S194	103	--	50	
RADIOMETER	S194	15	--	11	NC
SPECTROMETER	S191/S054	13	154	1	
PHYSICS					
COSMIC RAY	TBD	TBD	TBD	TBD	TBD

ments. There are between two and 148 primary measurements, and between zero and 96 secondary measurements for systems support of each experiment. Systems status will be monitored to ensure scientific data quality is maintained and to allow detection and correction of those items affecting pointing, calibration and alignment. In addition, scientific data will be monitored periodically by payload specialists at the POC to maintain maximum science return from the payload.

3.3.2 SYSTEMS MONITORING

Payload systems monitoring is used herein as that activity necessary to assure that the payload is operating and controlled in a manner that permits it to gather the desired scientific data.

Monitoring will span 24 hours per day, seven days a week for the payload's orbital lifetime (up to six years between retrieval intervals). For this study, equal staffing is assumed for each shift. Certain economies may be feasible by reducing staffing requirements on night shifts or weekend shifts. This economy would depend entirely on the scientific requirements of the payload and would require indepth study of each payload. Economy may be achieved by incorporating some form of computerized limit scanning to reduce personnel requirements. This method could provide a useful tool to the monitor and support reduced manning during non-scientific data gathering periods. Reliance on a computer scanning system would require full staffing on all shifts for the initial weeks of the mission, until software debugging, stable limit assignment and desired operation is assured. It would further require that payload system specialists be available, on call, should any limit violations occur. This monitoring and control of the payload will follow limits, constraints and rules developed by the payload development center.

In the case where the host POC provides the monitors, for possibly only the off hour shifts, the monitors would coordinate any problems or non-routine performance with the payload systems specialists. The monitors will perform indepth analysis only to the extent necessary to continue the mission or to safe the payload for Shuttle retrieval. Payload hardware responsibility remains with the development center.

Monitoring of payload systems and experiment system performance requires a control room with consoles and display equipment which is computer supported. The sizing of the facility and equipment will depend on payload complexity and the data volume to be handled. Table 5 presents an estimate of the consoles and equipment required for monitoring.

3.3.3 COMPUTERIZED SYSTEMS MONITORING

Monitoring systems performance for many years could become a very boring task if performed manually. Manual performance would also be very expensive as qualified personnel with detailed systems knowledge are required. One approach that may be practical is computerized monitoring. This system would be based on engineering criteria, redlines and normal operating limits provided by the development center. To be practical, the system would need multiple levels of criteria, applied by several sensing routines. The most probable sensing routines would include single limits, multiple limits, discrete events, slope changes, rate of change curves, cyclic changes, multiple measurement calculations, and many other potentials. The system would need to be developed as general routines, then tailored into a payload peculiar system. The system should be thoroughly tested prior to initial payload flight and should be operated in parallel with engineering monitors during the initial weeks of the mission. During this time the engineers would not only monitor payload performance manually, but would monitor all criteria set into the system. The system could then be upgraded with actual performance data. As confidence in the computer system grew, the engineer would return to his assigned tasks. He would remain on call to support any detailed analysis required by the computer system findings. The operating mode could then evolve into engineering monitors on duty during high activity periods, leaving the computerized system as prime during night, weekend, and low activity periods. Limited direct engineering support with other specialists on call would be required whenever the computer system was prime.

Although the development and implementation costs of a computerized system would be fairly large, a potential manpower savings of approximately 40% could be achieved over the entire payload mission duration without decreasing payload monitoring capability. This 40% savings is based on reducing manual monitoring coverage to:

- 100% - day shift on weekdays; this is assumed to be the primary scientific operating shift
- 60% - evening shift on weekdays and day shift on weekends; this is assumed to be the secondary scientific operating shift
- 30% - midnight shift, 7 days a week and evening shift on weekends; this is assumed to require minimal scientific coverage.

Table 5: ESTIMATED SUPPORT REQUIREMENTS

	EOS	HEAO	LST	LSO	LRO	LXRT	PHY	LDEF
SYSTEMS SUPPORT								
CONSOLES								
CONTROL	11	10	11	12	10	11	11	0
SUPPORT	6	5	6	6	5	6	6	0
COMPUTERS								
COMMAND	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	SMALL	NONE
DISPLAYS	MEDIUM	MEDIUM	SMALL-MED	SMALL-MED	MEDIUM	SMALL-MED	SMALL-MED	NONE
OFF-LINE SUPPORT **	LARGE	LARGE	LARGE	LARGE	LARGE	LARGE	LARGE	NONE
TV	YES	NO	NO	YES	YES	NO	NO	NO
EXPERIMENTS SUPPORT								
CONSOLES								
CONTROL	4	4	4	4	4	4	4	0
SUPPORT	4	4	4	4	4	4	4	0
COMPUTERS								
SCIENTIFIC DATA	*	*	*	*	*	*	*	NONE

* HIGH STORAGE CAPACITY, MEDIUM COMPUTATION CAPABILITY
** INCLUDES MISSION PLANNING SYSTEM

Converting the 40% savings to costs over the LAS mission durations leads to:

5	monitoring positions per payload (assumed for typical LAS)
x 4.2	factor for 7 day, 24 hours per day payload monitoring coverage
x 15%	vacation and illness lost time factor
x 66	number of LAS payload operating years, 1980 - 1991 (refer again to Figure 1).
1594	manyears required to monitor LAS payloads

The 40% potential savings of 1594 manyears is 638 manyears or 25.5 million based on a 40K per annum rate. This savings would be used to offset the software development costs of a computerized monitoring system.

The feasibility of such a system has been tried and used with varying success, on several past programs or tasks. The LAS program, due to its long duration requirements, offers a unique opportunity to apply the better parts of past systems and develop a fully functional system. Another factor is that development and test time still exists for an LAS monitoring system. Lack of time for a thorough development and test program has probably been the largest factor in reduced performance of earlier systems.

3.3.4 SYSTEMS MODELING

Systems models are normally developed by the design engineers early in the payload development cycle. These design models are historically much more detailed than necessary for operations purposes. The design models provide an excellent base for the operations model but reductions in complexity are required. This reduction is necessary to allow rapid model performance for data output to the operations personnel. To effectively modify the design model into an operations model requires that operational methods are thoroughly understood and factored into the model while sufficient test time is still available.

3.4 DATA SUPPORT

3.4.1 DATA MANAGEMENT

The data management team coordinates with all data requesters in defining a composite set of payload data handling requirements. They need to be involved very early in program development. Data usage requirements can affect payload design, particularly in the payload data system. These activities include planning and developing the software for the coordination and control of data acquisition, processing, and dissemination. Each payload or program will have specific needs for data personnel located in the POC and in other geographic locations.

The major difference in data management of LAS data versus earlier programs is in the large volume of data. The majority of the LAS payloads will downlink counting array and digital image scientific data, at rates presently identified, of up to 200 Mbits/second with a daily volume of up to 2×10^{13} bits per day. Although this is the extreme case, the average downlink rates are high when compared to previous programs. Of the eight identified LAS classes of payloads, one (LDEF) has no downlink data system. Six of the seven remaining classes have payloads with a 1.0 Mbit/second or greater downlink system for either realtime data, near realtime data or for both systems. Handling of this volume emphasizes the need to initiate a data management system early in the program.

3.4.2 DATA HANDLING

Payload data will be returned to the POC via RF transmission systems and processed for the users into a prescribed format. The majority of the payload science data will not be processed at the POC beyond formatting to user specifications. The handling and preparation of this data into a form suitable for use is defined as three categories: (1) operations data, (2) data reduction, and (3) data analysis.

A. Operations Data -- The term, Operations Data, is used to denote that data which is used in direct support of the mission. In general, it will consist of payload systems data, experiment data, and a subset of the science data depending on the amount of ground interaction with the scientific objectives. The operations data flow to a POC is in either real time (direct transmission) or in near realtime (recorded and dumped). Realtime data supports ground based action on time critical functions, while near realtime data is used in support of long term analysis and generally the management of the mission objectives. For the payload data flow analyzed to date, the operations real and near realtime requirements will be approximately ten percent of the total data generated by the payload.

B. Data Reduction -- This category encompasses the processing of data to user specifications. This level of processing may include decommutation, engineering unit conversion, formatting for a user's computers, and merging with ancillary data. Data processing is a function which NASA provides to the guest observers. It is normally performed offline and follows data receipt by a predetermined time schedule.

C. Data Analysis -- This category encompasses the analysis and reduction of the data to obtain its scientific content. It is performed by the guest observers in their own facility or at facilities contracted to the observer. This category is not a NASA responsibility and will not be addressed in this study.

3.4.3 DATA FLOW

Figure 4 presents a top level schematic of a data flow system. This system is functionally defined in detail normally by the time of the Critical Design Review, at which time implementation begins with detailed cost trades. In providing data to multiple users, duplication in the development of similar types of processing software may occur. Software functions common to a significant number of experiments will be investigated to determine the savings associated with providing standardized software and processing.

Monitoring of data quality needs to occur throughout the data flow. This effort would be primarily software with manual spot checks due to the large volume of data. This type of effort has always been important and is even more important for the digital image data generated by the LAS payloads. As an example, the LST AS140 optical instrument will provide an image composed of up to 80 megabits. Transmitted by a 1.0 Mb/s data system will require error free transmission, handling and

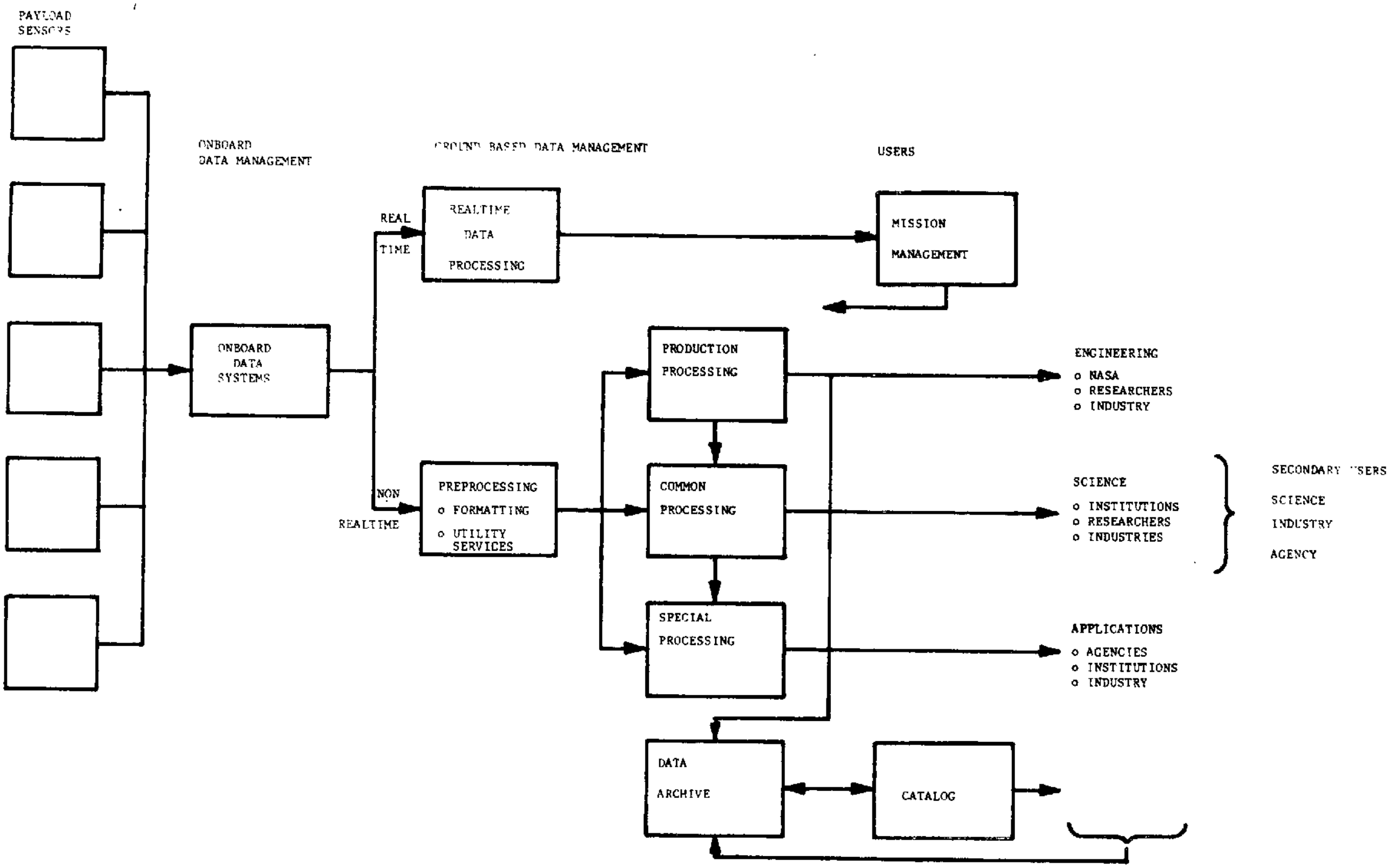

FIGURE 4: LAS DATA FLOW SOURCE-TO-USER

processing of an 80 second data burst for each image received. Any data bit dropped or noise bit added could impair the data validity.

Users receive data by obtaining it at a NASA facility, by having it mailed to them, or by having it transmitted to them electronically. Delivery of data must be receipted and quality verified by the user. The experimenter may need his own final processing equipment.

Payload film, retrieved samples, and other forms of onboard stored data will be returned by the Shuttle. Environment critical data will be brought back and located for immediate access. Such critical data will be removed immediately after Shuttle landing to satisfy the perishability constraints. Other onboard data will be removed at the earliest convenient point in the post-landing operations flow. Following removal from the Orbiter, returned data must be safeguarded with appropriately controlled environment until dissemination can be made to the user.

Experience has shown that only a percentage of the data collected is actually analyzed. Historically, all the data has gone through the data management system in order that the useful data can be identified. Techniques must be developed by which the useful information content can be identified early in the collection process, and subsequent data handling restricted to that which is of value. It can be implemented by hardware and software designs and its goal is to permit some intelligence (man and/or machine) to review and edit the data as it is being collected. This review will result in decisions along the data flow that will eliminate or allow data to flow to the next processing step. The closer the data is reviewed to the sensor, the greater the benefits. These techniques could complicate onboard systems by adding more complex software. By paying these costs, the ground processing costs can be reduced with a net reduction in the total cost per information bit collected. It could also make the process of satisfying scientific objectives more efficient and provide greater scientific yield per mission. This consideration would need to be reflected in basic design, and would need to be studied very early in the program.

NASA has the requirement that all data funded by the government be available to the general public once a scientist's proprietary right to the analysis of that data has expired (generally one year after data receipt by the scientist).

Archives will be established to accomplish this. Data acquired through private user funds would not be publicly available unless a release is given by the user. New archiving procedures will be established to recognize these types of data. It is assumed that data archiving would not be a POC responsibility, that it would remain with the National Space Science Data Center (NSSDC). The subject is addressed here only to the extent that proprietary rights and archive requirements will impact POC data handling procedures.

A. Communications Network Data Flow -- Two communications networks are being analyzed within NASA for future program utilization. One of these is the Satellite Tracking and Data Network (STDN) which is a combination of the manned and unmanned networks which were used during the Apollo Program era. It will be in use through the late 1970's. The Tracking and Data Relay Satellite System (TDRSS) is presently under study as an addition to the STDN in the 1980's. Should this system be adopted by NASA, then the number of STDN sites will be reduced to those necessary for launch support and deep space support. Two synchronous orbit satellites will relay data to White Sands (WHS). It will be routed from WHS to the POC via either high speed data lines or a domestic satellite (DOMSAT), refer to Figures 5 and 6. The data from the STDN is transmitted from the remote sites to GSFC via high speed data lines and is then routed to the POC. The data line capability is expected to be 1.334 Mbs in the Continental United States and 60 Kbs from the remote sites.

B. Network Impact -- The decision on which system (TDRSS or STDN) will be available during the LAS mission time period will impact LAS operations somewhat. The impact will be primarily in the data storage and playback area due to short duration STDN contact times and data gaps between contacts. Segmented data of this type also impacts data handling efficiency. The effects of this impact can be minimized by close coordination between the mission planning group and the guest observers to obtain the maximum scientific return with the contact time available.

C. LAS Requirements -- As greater numbers of payloads with large data volumes are orbited, schedule constraints

- STANDARDIZATION OF SUPPORT CAPABILITY AT ALL NETWORK SITES AND TDRSS FOR TRACKING, COMMANDING AND ACQUISITION OF DATA FROM SHUTTLE AND PAYLOADS AT S-BAND FREQUENCIES
- STANDARDIZATION OF SUPPORT CAPABILITY AT A LIMITED NUMBER OF STDN STATIONS AT KU-BAND FOR ACQUISITION OF WIDEBAND DATA
- TRANSMIT AND RECEIVE AT KU-BAND FOR SINGLE ACCESS (WIDEBAND) USERS THRU TDRSS
- DATA PROCESSING AND TRANSMITTING DATA TO CONTHOL CENTERS IN A REAL-TIME OR NEAR REAL-TIME MODE
- FREQUENCY BAND SUPPORT CAPABILITY

BAND	USER RETURN LINK	USER FORWARD LINK
S	2200-2300 MHz	2025-2120 MHz
Ku	13.4-14.0 GHz	14.6-15.2 GHz

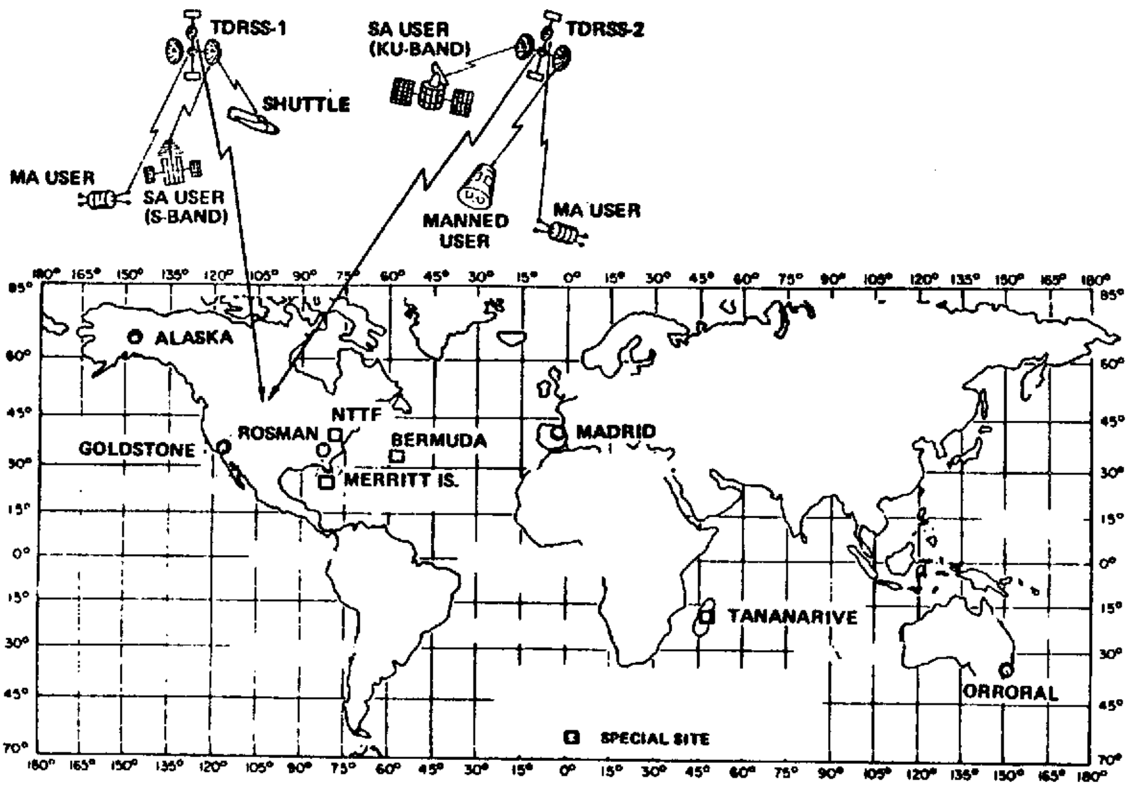

Figure 5: Planned STDN System Capabilities 1979 - 1985

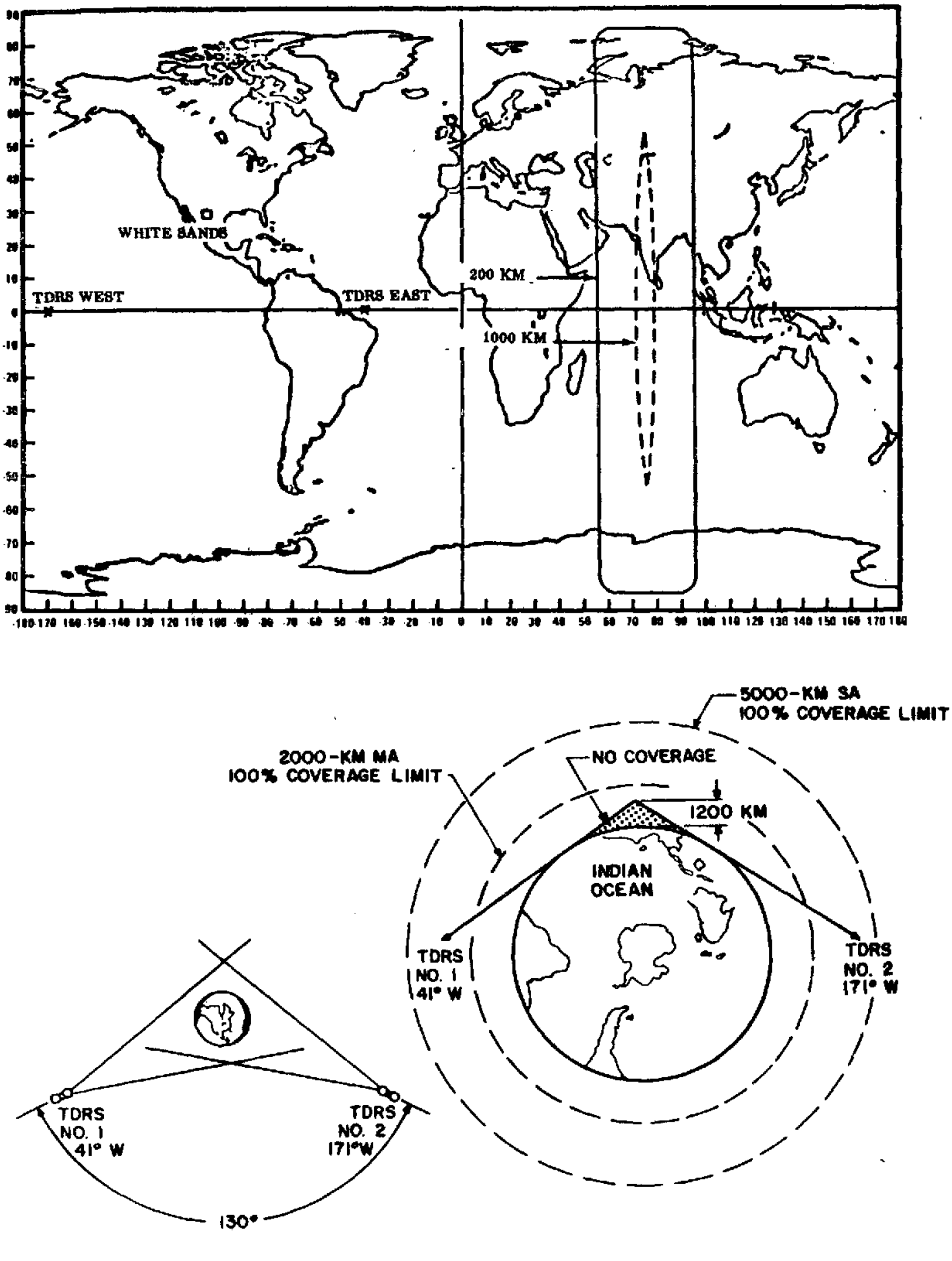

Figure 6: TDRSS User Coverage Capability

with the TDRSS will also create data gaps. The single access (SA) channels in the Ku band are required for digital image transmission, due to the high transmission rates. The present definition of the TDRSS will provide only two SA channels for each satellite. Of the eight identified classes of LAS payloads, six will require the data handling capability of the TDRSS single access channels. In these six classes (EOS, HEAO, LST, LSO, LXRT, and PHY), there will be nine payloads in simultaneous orbit in the 1986 - 1989 time period (refer again to Figure 1). These payloads will be required to time share the two single access channels on each TDRSS for downlinking their scientific data. Systems data from the payloads could be routed through the TDRSS multiple access channels and provide near continuous coverage for each payload.

The two LAS class of payloads that will not use the TDRSS are the LDEF and the LRO. As mentioned earlier, the LDEF does not have an RF data system. The LRO has an RF data system, but it will be orbiting above the TDRSS coverage area of 5,000 km. The LRO orbital altitude of 71,600 km will require contact with the STDN sites.

3.5 PERSONNEL TRAINING

Premission training is required for all Payload Operations personnel to ensure that a competent, smoothly functioning team is on duty during all orbital operations. Establishing the training program requires consideration of the sustained operations for the LAS payloads, that several teams would be needed for any 24 hour day, seven day week operation, that all skills would have to be maintained and upgraded during the years of operations planned for the LAS Programs; and for the specific operating requirements of each individual satellite. Due to the duration of the LAS Program, consideration must also be given to backup personnel in the event of illness, family emergency, and vacations, and for personnel turnover.

Operations training can be separated into several categories:

A. Technical Training -- That training where all operating personnel become familiar with the peculiarities of the individual satellite systems and experiments and with the overall operating methods and data return by the guest observers and development center personnel.

B. Equipment Training -- That training required for personnel who would be operating the consoles or other communications equipment such as computer terminals, to ensure that all operating personnel fully understand the tools they will be working with.

C. Procedural Training -- That training required so that each individual understands what is required of him and how he interfaces with other POC and development center personnel. This will ensure a smooth flow of information, facilitate orbital operations control and provide for maximum scientific return from the payload.

D. Simulations -- This activity would follow the individual training sessions discussed earlier and has the single purpose of molding the individuals into functional teams, verifying that each member understands his function and can support it under routine or off nominal conditions.

E. The training sessions should be scheduled such that all primary individual training is completed six months before a LAS payload launch. This would necessitate completion of supporting computer programs, facilities, and data flow systems by that same time. The final six months would then be dedicated to simulation activities, specific technical training update and POC support to payload final checkout and integrated systems tests.

Training will be minimized by simplified and standardized operating procedures for all payloads. Any payload specific training will be limited to required personnel and will be specified by the payload development center. Crew training for special payload handling or servicing would be the responsibility of the development center, not the POC. It would normally be performed on specialized mockups and for zero-G operations, in a neutral buoyancy facility such as the one located at MSFC.

4.0 PAYLOAD OPERATIONS CONCEPT

4.1 GENERAL

A POC will be used to control the LAS during its orbital mission lifetime. It will assume control of the payload from the Shuttle Mission Control Center at the time of activation/checkout. The POC will also be involved in ground test and checkout activities, launch activities and on-orbit payload servicing activities.

The POC will operate as a user service facility, providing necessary support to the experimenters. Refer to Figure 7 for a typical operations information flow scheme.

The concept of providing services to the user is necessary to facilitate the accomplishment of the payload science program. LAS science users (guest observers) will be sharing experiment hardware to gather information for their specific field of endeavor. In general, these services will include:

A. Interpretation of the LAS capability for the guest observer's objectives. This service, although required in the initial phase of the mission, becomes increasingly important as new users enter or return to the program and as the potential for hardware degradation or additional systems constraints increase. The payload capabilities will vary, dependent on the users involved and on the period of time in the "up to six years refurbish interval", or "up to 15 year payload mission."

B. Provision of a mission planning system, including integrated timelines, maneuver analysis, resource allocation, etc.

C. Provision of "round-the-clock" systems monitors and command technicians for science program execution.

D. Provision of quick-look data feedback to determine that the data is of the quality and nature expected by the guest observer and for observing program optimization.

E. Provision of a work environment for payload operations, including communications, display equipment, facilities, computation support, administrative support, etc.

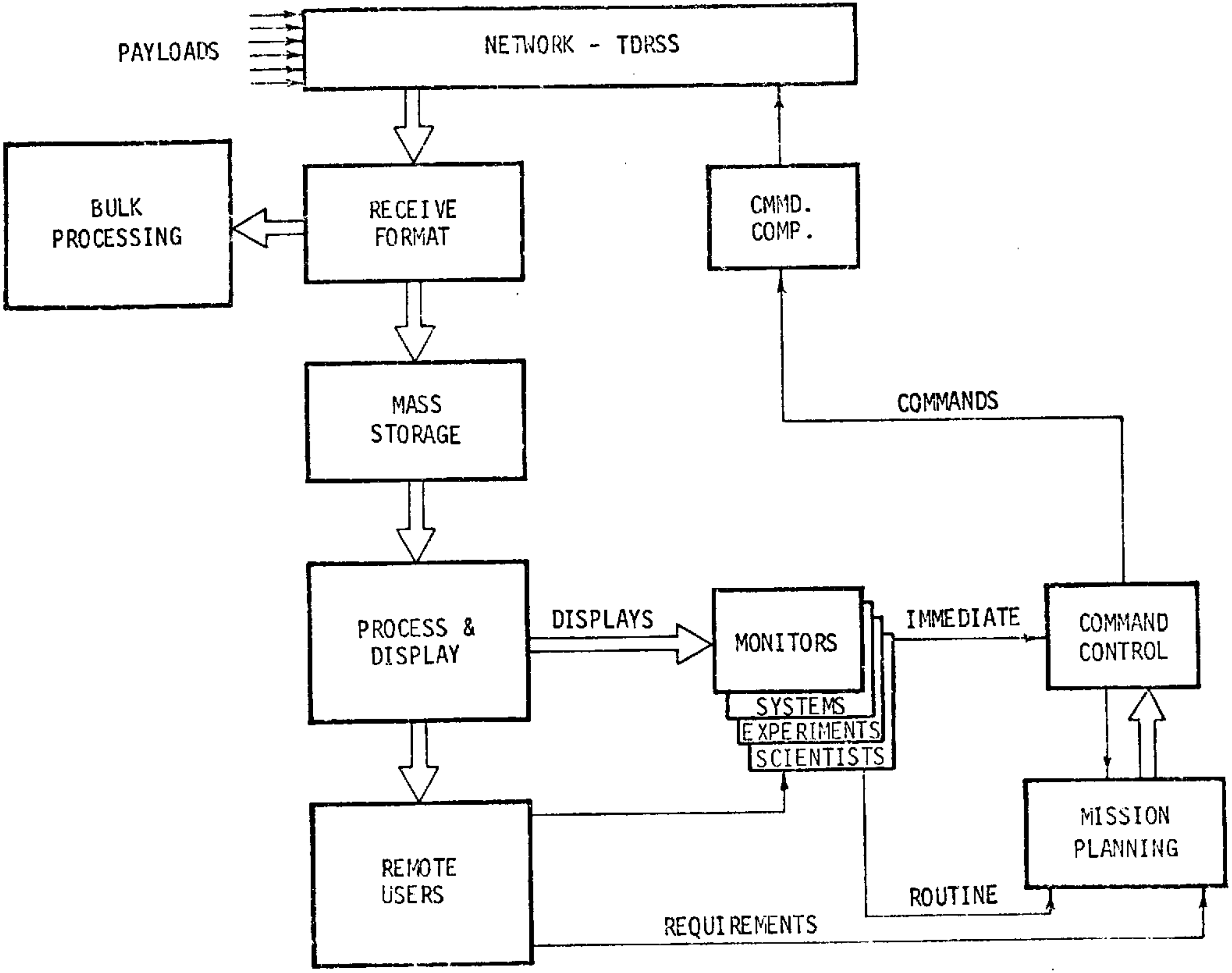

Figure 7: OPERATIONS INFORMATION FLOW

4.2 OPERATIONS CENTER OPTIONS

4.2.1 GENERAL

Operations centers are presently developed for a specific mission or payload and may or may not be geographically located at the development center. Options for POCs are (1) to maintain an individual operations control center for each payload; (2) to group operations of several LAS according to similarity of operations or some other means of grouping, yet have several operations centers, and (3) to have all the LAS operations performed from a single location. The single operations center (Option 3) is the current mode of unmanned low earth satellite operations. In all options it is assumed the development center retains hardware and project responsibility for the payload.

The primary reason for the conceptual study of these three options is found in the NASA 1973 Payload model and the Space Shuttle Traffic Model, TMX 64751, Revision 2. The number of payloads in orbit during the Shuttle era is much larger than current operations. A summary of the large and small unmanned earth orbital satellites is presented in Figure 8. In addition to the larger number of satellites in operation, the shuttle retrieval capability will require that design continuity and sustaining engineering be maintained for longer mission lifetimes and the refurbishment of payloads will result in new experiment hardware and an upgrading of the payload systems.

The similarity in support requirements and the long duration aspect of the LAS payloads leads to the concept of combining the POC to support several payloads and providing the support at a development center.

4.2.2 INDIVIDUAL CONTROL CENTERS

This option requires that each payload project establish its own control center at the development center. The POC, including all its facilities and personnel, would be dedicated to a single payload.

Location at the development center allows major economies in usage of project engineering personnel. It precludes relocation of development center personnel to a remote POC,

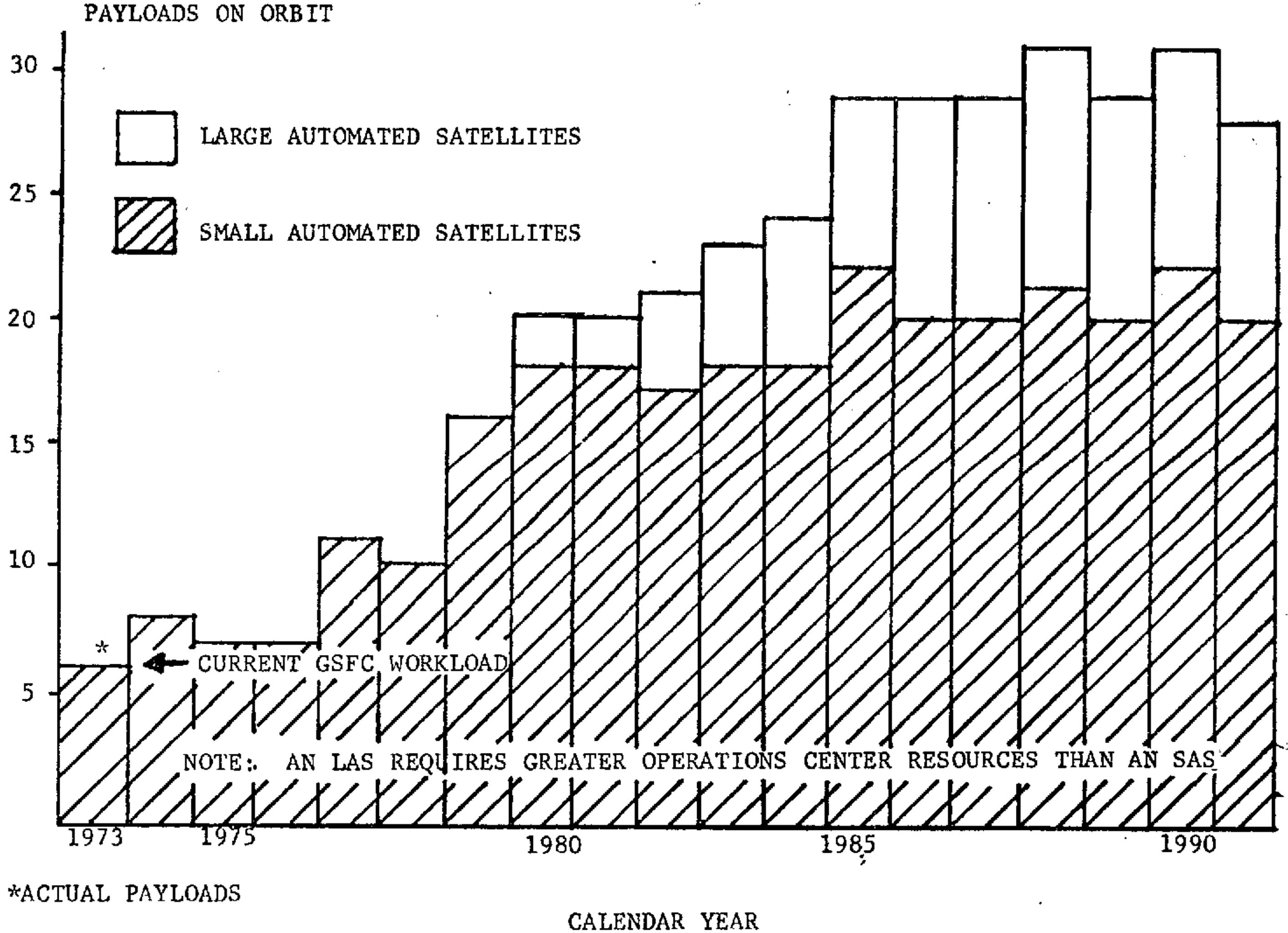

FIGURE 8: NASA AUTOMATED SATELLITE SUMMARY

with the resulting hardships on personnel and their families, as well as the cost to the government for travel and other expenses. It also allows engineering personnel who are not dedicated to operations to perform other duties and still remain available on call, should problems develop requiring their expertise.

A further advantage is the maintenance of technical continuity and operations awareness for engineering personnel who are to continue systems development efforts for the one to three year reservice cycle and the three to six year refurbish cycle.

To summarize, by using existing facilities at each development center which are adaptable to POCs, more effective use can be made of manpower and facilities, requiring less new construction and personnel relocation. Personnel at the existing facilities would be available to support a POC as well as being a part of the development center buildup. A potential disadvantage to this approach is that there would be less efficient utilization of operations facilities, equipment, and personnel as each operations center would be specialized for its own payload. This disadvantage would be negated if the development center was responsible for several payloads, as discussed in paragraph 4.2.3.

4.2.3 MULTIPLE CONTROL CENTERS

This option establishes an operations center at the major development centers, that is, those development centers which develop several payloads.

There are two major differences between this option and the "individual control center" option. (1) The operations center would be established to operate in a partially shared manner to affect the economies available, and (2) the operations center would operate all payloads developed at that center and similar payloads from other centers that develop very few payloads. Also, payloads developed at other centers which require minimal engineering support and do not warrant the expense of establishing a control center, would be considered under this option. After analysis of facilities, expertise, and total manpower and costs, a development center may determine it would be to their advantage not to develop a POC locally, but to use a POC at another location.

As in the individual control center option, this approach allows for reduced travel costs and maintenance of engineering continuity and support to operations while performing other duties. Separate control teams are required for each payload with a dedicated control room/console area. This is considered necessary for project integration and efficient payload operation. The shared approach allows for economizing in areas such as facility floor space, conference rooms, a backup emergency power system, etc. The major ecomony comes from sharing all common support services. This includes, but is not limited to:

A. Computer operating personnel and computation equipment for data receipt, routing, preprocessing, display, analysis and for mission planning and command generation. Sharing or dedicated equipment would depend on data volume, handling requirements and the capacity of the computer equipment and requires a separate study of specific requirements to determine the most feasible approach.

B. Software programmers and software routines may be shared dependent on payload commonality such as similar solar array/battery systems.

C. Communications equipment and personnel.

D. Display equipment and personnel.

E. Mission planning personnel and software. Certain skill types such as orbit determination, maneuver analysis, etc., could be shared while others would be dedicated to the payload.

F. Command control personnel and command generation matrices may be shared between two or three payloads. Most of the LAS have defined requirements of approximately ten minutes per orbit average or a 10 to 15 percent time usage factor.

G. Network control personnel.

H. Administrative support personnel.

I. Facility maintenance personnel.

J. Data management skills, including requirements, dissemination, archives, status, etc.

Operating a POC in a shared manner requires a management scheme that allows the operations team to become involved early in program development of each LAS. This is necessary to ensure incorporation of all program requirements and the development of a flexible team receptive to each program's priorities during the operational period.

An added consideration is the grouping of similar payloads at these multiple operations centers. By use of grouping criteria, based on specific payload requirements, it is possible to take full advantage of the available technical expertise. The combined expertise available at a location will be a prime factor in determining an optimum grouping for the payloads. This expertise also includes personnel required for support, communications, facilities, and related services.

In summary, the multiple operations center option offers many of the same benefits as the individual operations center option. It also offers added benefits in shared functions. Grouping of the payloads into these multiple centers needs to be carefully considered to obtain full benefits without incurring other disadvantages by combining too much, as discussed in paragraph 4.2.4.

4.2.4 SINGLE CONTROL CENTER

In this option, which is the current operating mode, all unmanned earth orbital payloads are operated from a single control center location. The development center still maintains control of the payload at this centralized center. If a central POC is chosen, major modifications to the facilities will probably be required, as well as new equipment buys, in order to handle the volume of operation (Refer to Figure 8). The physical space requirements to operate the number of payloads in orbit during the Shuttle era exceed the existing facilities at the current control centers. The building of new facilities at the single center presents a greater cost than modification of existing facilities at several centers to obtain the required space.

The major impact on the development center(s) by this option is the potential loss of engineering continuity and the addition of travel costs and personnel relocation for missions of up to

15 years duration. The development and operations center would be duplicating talents in some cases to maintain operations technical expertise and continuing engineering development for payload refurbishment at different geographic locations.

The advantages of sharing common facilities, equipment and personnel discussed in the multiple control center option also apply to the single control center option. However, overcentralization can be a major problem. During the 1986 - 1989 time period, the annual operations effort will include approximately nine large and 20 small automated satellites and approximately 27 Spacelab payloads. By combining too much, project control can easily get bogged down due to the complexity and control of the increased number of interfaces. Each project would have its own management setup as would the POC. If these are different organizations, the project responsibilities and related interfaces may affect the LAS operations. This would be in addition to the management structure required at each development center, which would still maintain responsibility for its payload. This meshing of the management organizations will require that detailed procedures and criteria be established.

In summary, use of a single control area to control all unmanned earth orbiting payloads is feasible, although almost all conflicts, particularly schedule conflicts, will result in operational compromises and could reduce science return from the payloads. Since scientific data return is the primary purpose for the payload, this would be undesirable.

4.3 OPERATION CENTER OPTION SUMMARY

In addition to the three options presented, (1) individual control centers, (2) multiple control centers, and (3) a single control center , there is a suboption to consider.

This suboption involves the technical personnel who operate and control the payload and whether they are provided by the development center project or the host operations center.

This suboption will depend entirely on the complexity of the payload and the cost of duplicating skills for payload control. There are varying degrees of this suboption, which are briefly addressed in operations functions, but since it is so closely related to the specific payload, this study assumes a dedicated control team provided by the development center project.

In the three major options presented:

A. Options (1) and (2) provide economy and efficiency in reduced travel, continuity of design expertise, and use of existing facilities.

B. Options (2) and (3) provide economy and efficiency in shared usage of common facilities and personnel.

C. Option (2) provides the advantages of both Options (1) and (3), and negates the disadvantages of both options.

Therefore, the summary conclusion of this study is that multiple operations centers be established at the major development centers and that those operations centers be operated in a shared manner. The operations functions and the methods and concepts necessary to perform those functions will be addressed in the remainder of the study.

5.0 PAYLOAD CONTROL FOR A SINGLE LAS

This section presents specific operations requirements for a typical, single LAS payload. For comparative purposes, Section 6 presents the same information for multiple payloads.

5.1 ORGANIZATION

The organization involved in operating an LAS includes many diverse talents. Figure 9 shows a typical organization. The individual elements of the Mission Operations group, engineering support to operations and guest observer interfaces will be discussed in detail in the following paragraphs.

This organization must be established during the payload development phase to (1) ensure that operational considerations are included in payload design, (2) ensure the payload design constraints are included in software development, and (3) ensure that a smoothly functioning organization is ready at the start of the mission. This team will continue to operate on a 24 hour day, seven day week schedule for the "up to 15 years" lifetime of the payload.

This organization is responsible to the development center Project Manager for the operation of the payload and to the user community for gathering of the desired scientific data. In addition, there is an organizational interface with the ground and Shuttle operations groups for schedules and requirements concerning reservicing and refurbishing the payload.

5.1.1 CONTROL TEAM

The control team is responsible for monitoring and controlling payload systems and experiment systems performance. This team is dedicated to payload operations and is equally staffed on each shift for round-the-clock operation.

For the typical LAS, the control team is composed of five engineers on each of four teams (20 total). Each team includes an operations director, an avionics engineer, an electrical engineer, a mechanical engineer, and an experiment systems engineer.

The control team is primarily responsible for routine operations and payload safety. They perform quick look analysis on data received continuously from the payload. In the event of problems

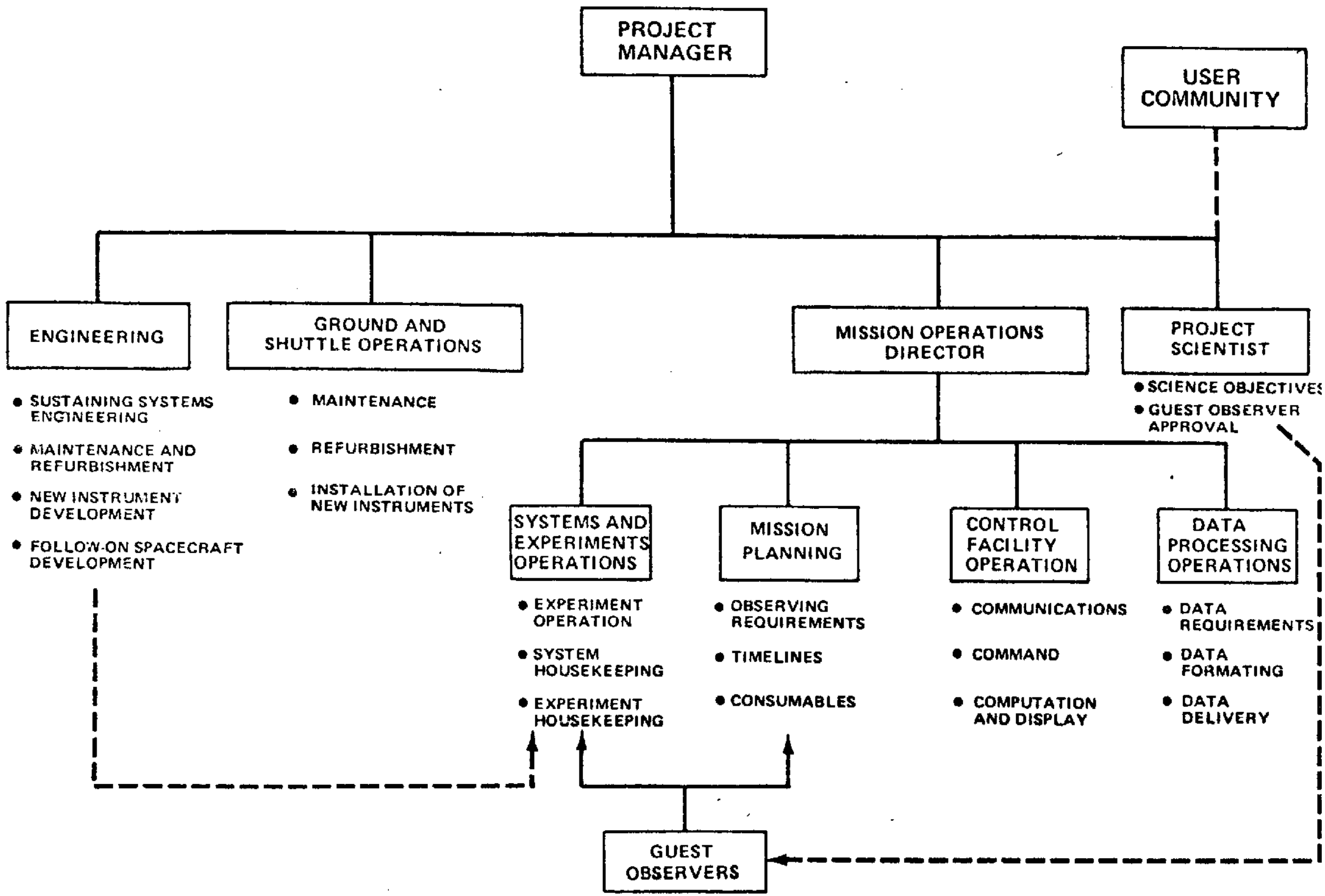

FIGURE 9: TYPICAL LAS PROJECT ORGANIZATION (OPERATIONAL PHASE)

or performance anomalies which are not routine, they call on project specialists to perform indepth analysis and to support contingency actions. For the typical LAS, a level of ten project engineers are included in the organization.

The project engineers will maintain cognizance of the day-to-day payload performance, but they are not assigned to an operating shift. They spend the majority of their time in furthering the designs for payload refurbish and other project functions. They remain on call to support the operations as necessary.

5.1.2 MISSION PLANNING

The mission planning team is responsible for developing a payload operating plan which will provide the target opportunities and scientific data desired by the guest observers and is within the systems capability of the payload. To accomplish this function, they coordinate their activities with the guest observers, the project scientist, the control team, and where necessary, with project specialists and network controllers who determine communications contact times with the payload.

The mission planning team is composed of one coordinator on each of the four operating teams and five personnel on the day shift,seven days a week (11 total). The day shift personnel (seven total) would operate with varying off days to maintain the five positions, seven days a week. The skill requirements for the mission planning team includes maneuver analysis, experiment requirements, timelining and consumables analysis.

The mission plans will be developed using a computerized mission planning system. They will be developed in a routine manner several weeks before they are actually implemented to allow thorough review and coordination with the scientific and engineering participants in the program. Realtime changes will be held to a minimum, but will be incorporated as necessary to incorporate new systems constraints and guest observer requirements.

5.1.3 FACILITY OPERATIONS

The facility operations group includes all of the support personnel necessary to allow the control, planning, project and observer personnel to perform their functions. This group is composed of 18 positions on each of the four operating shifts (72 total), and includes the following:

A. Command Specialist -- One position responsible for the generation and verification of all commands transmitted to the payload. This position is supported by a mini to small class of computer, dependent on the complexity of the command system and the volume of commands to be generated. The LAS command uplink rates vary between 200 and 4096 b/s. Command link contact with the typical LAS payload is assumed to be an average of ten minutes per orbit or approximately 11 percent of the time.

B. Controllers -- Three positions are Network, Facility, and Display. (1) The network controller is responsible for scheduling of all data contact requirements with the payload and for the data flow from the network to the POC. (2) The Facility Controller is responsible for the maintenance and operation of the facility. (3) The Display Controller is responsible for maintaining all console and display equipment to support the monitoring personnel.

C. Computer Operation -- This consists of seven positions composed of computer operators and technicians and one software programmer. These personnel are responsible for the routine operation of the receiving, formatting, processing, and planning computation equipment. In addition, the programmer is responsible for realtime maintenance of the software used by the operations team; this position is supported by the software development group who would be on call if major software problems were encountered.

   An additional two computer operation positions on each operating shift will be required for the LAS if a special purpose computer is added to process digital images for the guest observers quick-look analysis.

   As the majority of the LAS payloads obtain some of their scientific data in digital image form, these additional two positions are considered necessary for the typical LAS. This results in a total of nine computer operations positions on each of the four operating shifts.

D. Communications -- Three positions are required for communications internal to the POC and for contact with external sources. The responsibilities of these positions include operation and maintenance of all TV and communications equipment and operation of an internal PABX system.

E. Administrative Support -- Two positions to support the variety of services necessary for payload operation including library maintenance, reproduction, typing and filing, personnel locating, etc.

5.1.4 SUPERVISORY AND OVERHEAD

In addition to the positions listed, there are additional personnel requirements which fall into two general categories. These are the various supervisory positions and clerical support required for each of the areas and primarily, the positions required for fill in for vacations, illness, and overtime. Each of the operating positions is listed as four operating teams. One of those teams would be required to work an additional shift each week or a fifth team would be required for 24 hours per day, seven days a week coverage.

To cover these requirements, a standard factor of 30 percent is applied and results in the following total:

Control Team	5 positions x 4 teams	20 total
Engineering Support	On Call	10 total
Mission planning	1 position x 4 teams	11 total
	5 positions x 1.4 teams	
Facility Operations	18 positions x 4 teams	72 total
Subtotal		113
Supervisory and Overhead	30%	34
Total		147

5.2 FACILITIES

5.2.1 GENERAL

The facility used for operating long lifetime payloads needs to be efficiently organized. It needs to include space not only for the controllers and operations support personnel, but also for guest observer personnel. Figure 10 presents a typical facility layout which could be used for LAS payload operations.

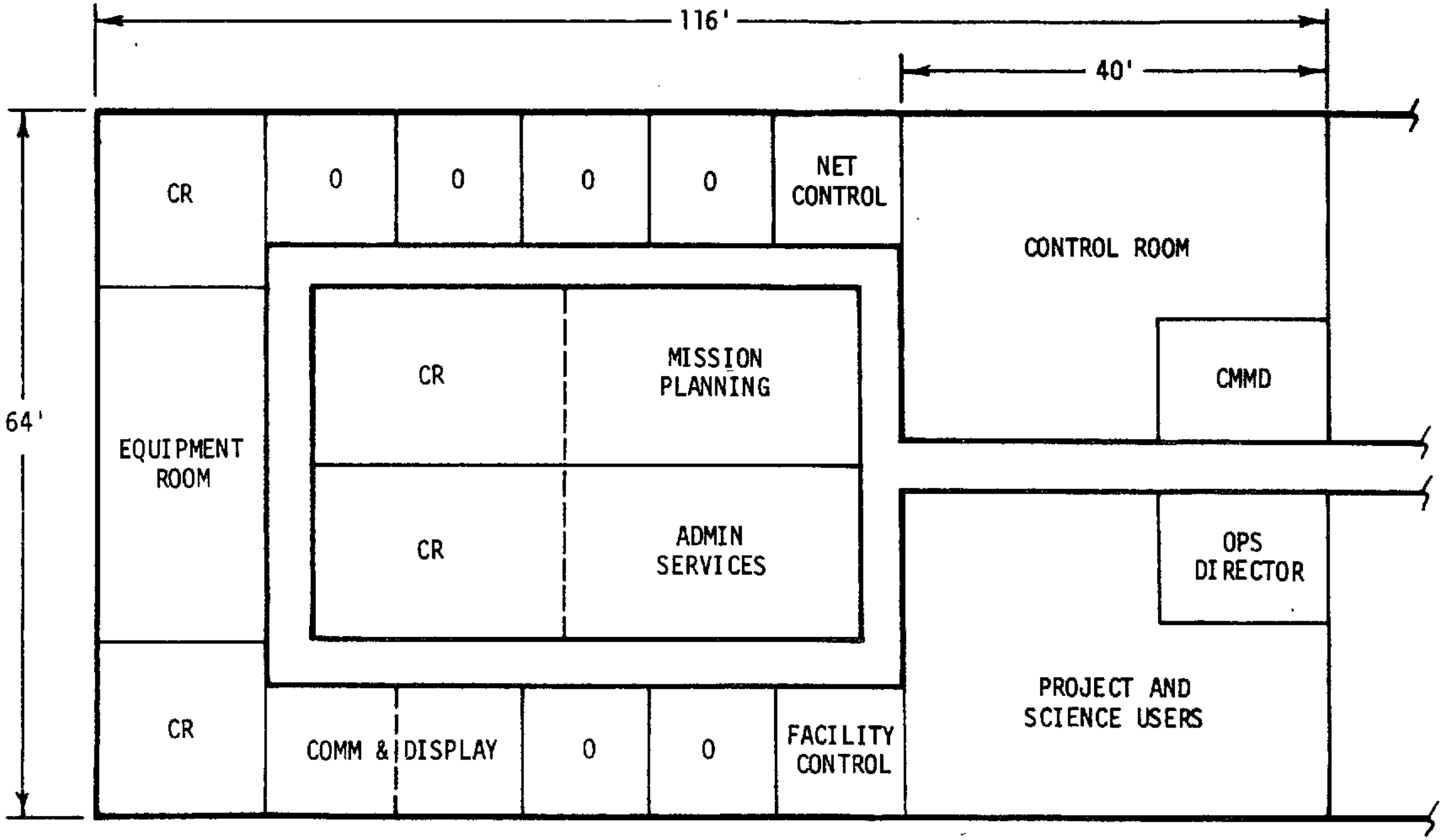

FIGURE 10: TYPICAL LAS OPERATIONS FACILITY
(SINGLE PAYLOAD)

Communications within the POC and between the POC and the development center and guest observer personnel need to be available. This communications includes not only dial circuits, it includes direct lines for conferences to other areas, a dedicated intra-POC communications system for controller use, closed circuit TV and TV displays and data transmission/reception lines.

Individual project teams, discipline groups, experimenters and support functions will require conference, work areas, and status areas to satisfy specific needs and to support operations. Facility space in some cases could be shared but for others, it would have to be dedicated to the group.

5.2.2 OPERATIONS FACILITY

The operations facility provides a control room for the consoles and an adjacent area for project and guest observer personnel. These two areas will require raised floors for cabling and cooling ducts. The adjacent support functions, offices and conference facilities are provided to support whatever activity is necessary. The operations facility encompasses approximately 7,500 square feet.

5.2.3 COMPUTER FACILITY

The computer facility will include the receiving and formatting, processing, and mission planning computer equipment. It also includes the special purpose computer for processing digital images. The physical layout of the computer facility will be based on type and volume of equipment required for the specific payload. This area will also require raised floors.

For the typical LAS computer requirements, the computer facility will require approximately 7,500 square feet of floor space.

5.3 RESOURCE REQUIREMENTS

5.3.1 GENERAL

The resource requirement for operating an LAS payload are similar to those required for any mission operation. They fall into two broad categories of capital outlay and operating expenses. All costs are estimated for a typical LAS and are based on 1974 dollars.

5.3.2 CAPITAL COSTS

The capital costs for operating an LAS are necessary to provide facilities, equipment, and communications.

A. Building Modification -- The costs for a facility are based on modification of an existing facility.

Portions of the facility will require minimal modification; all computer and console equipment area will require raised floor modification.

For the single LAS structure (subsection 5.2), the facility will include 5,000 square feet of non-raised floor area and 10,000 square feet of raised floor area. In addition, no-fail utilities will have to be installed to assure uninterrupted operations.

The building modification costs for a single LAS facility are:

Non-raised floor	5,000 sq. ft.	0.1 M
Raised floor	10,000 sq. ft.	0.4 M
No fail Utilities	---	0.2 M
TOTAL:		0.7 Million Dollars

B. Equipment -- The costs for equipment include the following computation equipment and software:

Data Receiving, computation, and display	2.0 M
Special purpose digital image processor	1.5 M
Command System	0.6 M
Data Storage	
7 days systems data	1.2 M
1 day science data	1.2 M
Redundancy	3.6 M
Software Development	20.0 M
TOTAL EQUIPMENT:	30.1 Million Dollars

C. Total -- Total capital costs for a single LAS control center are:

Facilities	0.7 M
Equipment	30.1 M
TOTAL	30.8 Million Dollars

5.3.3 OPERATING COSTS

A. Communications -- Communications costs fall into three categories:

Local distribution or communications internal to the operations center are 0.2M,

Longlines for receipt of payload data at rates of 1.0 Mb/s and for command transmission are 1.3M,

Fascimile and support communications for communicating with the other centers and the guest observers are 0.2M.

Total annual operating costs for communications are 1.7 million dollars.

B. Manpower -- Manpower requirements are described in subsection 5.1. Manpower costs are based on an estimate of $40,000 annually.

Manpower	147 Man Years	5.9 Million Dollars

C. Maintenance and Supplies -- Costs for facility and equipment maintenance and supplies is estimated at 1.0M annually.

D. Total -- Total Operating Costs for operating a single LAS payload are:

Communications	1.7 M
Manpower	5.9 M
Maintenance and Supplies	1.0 M
TOTAL:	8.6 Million Dollars Annually

6.0 PAYLOAD CONTROL FOR MULTIPLE LAS

6.1 ORGANIZATION

The organization for operating multiple LAS from a single POC differs slightly from that discussed in subsection 5.1, the responsibilities of the organizational elements is identical. The majority of the differences involves sharing of common functions between payloads and a subsequent reduction in manpower. Each of the organizational elements will be addressed in the following paragraphs.

For the purpose of this study, multiple payloads is defined as up to six payloads being operated from a single POC. At that point, organizational interfaces and facility sizes start to become constraining factors.

Each payload, regardless of the number, will have an organizational structure as shown in subsection 5.1, figure 9. The project maintains full responsibility for the payload.

6.1.1 CONTROL TEAM

The control team for each payload is dedicated to that payload. There is minimal potential for savings by having one engineer monitoring multiple payloads due to systems and experiments complexity.

Therefore, the personnel requirements for multiple payload control will be a control team of 20 and a project engineering staff of 10 for each payload controlled from the POC.

There is one potential for economizing which is payload dependent, not typical. This potential depends upon the degree of payload autonomy, the depth of computerized systems monitoring (discussed earlier in this study) and the number of non-critical shifts. A reduced number of control personnel could possibly be assigned to certain shifts with the right circumstances. As this potential is considered payload peculiar, it will not be used in this study, as an economy factor, it would need to be addressed by each project.

6.1.2 MISSION PLANNING

The mission planning responsibilities are the same as discussed in subsection 5.1.2. In performing these responsibilities for multiple payloads, certain common functions can be time shared.

The basic mission planning team for a typical LAS is eleven personnel. For the second and each subsequent payload, an additional eight personnel would be added. The reduction of three for each subsequent payload is possible in specific skill areas such as maneuver analysis, timelining, consumable analysis and by combining duties of the shift coordinator during non-critical shifts. Refer to paragraph 3.2.1 for a description of the mission planning team shift assignments.

For the case where multiple payloads are controlled from a POC, it is assumed that premission planning will have resolved or defined criteria for potential conflicts between payloads. The main areas of concern are schedules for shared operations support, priorities for contingency support and conflicts in data delivery schedules within the POC or with payloads controlled by other POCs.

Each LAS payload will have different operating considerations that would need to be incorporated in their mission plans. Although the specifics are different, the types are common and could be incorporated into a common planning scheme. Some common points are orbital position, communication gaps, experiment opportunities, discipline management controls, operating modes, etc.

The development of the computerized mission planning system would need to include the requirements for each of the payloads. Wherever possible, common routines would be used to reduce specialized programming for each payload. This concept would reduce the cost to each payload and allow for development of a more efficient operating system. However, the cost of the combined system would be greater than that encountered by any single payload. The time required for software development and testing would also be greater due to the larger number of interfaces.

To achieve this reduction will require added development effort. However, this added effort should produce a more efficient planning function for each payload. The reduction in personnel, 14 percent for two payloads up to 23 percent for six payloads, will be a gain for each year of the payload lifetime. The following manning would be used for each year of payload operations.

OPERATING POSITIONS

Number of Payloads	Shift Coordinator	Day Shift Team	Total Planning Team
1	4	7	11
2	7	12	19
3	10	17	27
4	13	22	35
5	16	27	43
6	19	32	51

As the number of payloads increase, the complexities and variety of interfaces will cause ever increasing management problems. The specific requirements of each individual payload will require detail study to determine the most efficient mode for routine mission planning.

6.1.3 FACILITY OPERATIONS

The facility operations group has the same responsibilities for multiple payloads as it does for a single payload (see subsection 5.1.3). This group offers the greatest potential for sharing of common functions. This is due to the fact that many operations support functions are required to be available whenever operations are in progress but they are not necessarily occupied full time. The following are estimated to be the potential sharing in a maximum combination mode for multiple LAS operations.

A. Command Specialist -- In addition to one position per shift, a total of two specialists per payload would be required. The reduction of two personnel per added payload is possible by reduced coverage on non-critical shifts and by the estimated average of ten minutes contact time required per payload orbit or 11 percent contact time per payload. The number of command personnel would therefore range from four for the single payload to 14 for six payloads.

This combination factor would need to be considered during the development phase as a larger computer, capable of generating and verifying commands to two or more payloads will be required. Using a single larger computing unit instead of several small units may also provide added economy.

B. Controllers -- In addition to the three positions on each operating shift, a total of three controllers per payload would be required. These additional personnel would operate during the day shift, handling the majority of the facility problems and adding support to the network controller. The number of controller personnel would therefore range from 12 for the single payload to 27 for six payloads.

C. Computer Operations -- This group provides the least savings potential by grouping of payloads. The savings that is possible is created by using larger computers for the combined receiving, formatting, processing, and mission planning systems, rather than adding computers for each system for each payload. In addition to the nine operating positions for each shift for the single payload, six added operating positions per shift would be required for each added payload as an average. This would reduce a total of 12 persons needed for each added payload.

To effectively accomplish this level of personnel savings, and potentially economizing in total computation equipment capital, requires a thorough study of the details of each payload's data handling requirements. It may be necessary to install a larger capacity mainframe for one payload to allow the expansion capability for two payloads. This would cause an apparent increase in capital outlay for one project until the second project became operational to share the costs. In addition, if the capital outlay was spread between computer manufacturers, a potential interaction in software commonality might exist.

The potential reduction in this type of sharing would be a total of 60 man years of effort per year of payload mission life for the six payload operations center. This amount of savings should warrant the study effort required to achieve it. The number of computer operations personnel range from 36 for a single payload to 156 for six payloads.

D. Communications -- In addition to the three positions per operating shift required for a single payload, two personnel will be added for each added payload. A larger PABX system would be used to handle the increased volume of communications traffic. The added personnel would work during the critical operating shifts to ensure rapid efficient service is available to all payloads. The number of communications personnel would range from 12 for a single payload to 22 for six payloads.

E. Administrative Support -- In addition to the two positions per operating shift required for the single payload, one person total should be added for each subsequent payload for project peculiar effort. These added personnel would form a nucleus of added personnel during the critical operating shifts. The number of administrative support personnel would range from eight for a single payload to 13 for six payloads.

F. FACILITY OPERATIONS MANNING SUMMARY

Total Personnel	NUMBER OF PAYLOADS 1	2	3	4	5	6
Command Specialist	4	6	8	10	12	14
Controllers	12	15	18	21	24	27
Computer Operations	36	60	84	108	132	156
Communications	12	14	16	18	20	22
Administrative Supt	8	9	10	11	12	13
TOTAL FACILITY	72	104	136	168	200	232
Average per Payload	72	52	46	42	40	39

6.1.4 SUPERVISORY AND OVERHEAD

The same percentage (30%) would be applied for a multiple LAS operations center as for the single LAS operations center.

The total manning required for the multiple LAS operations center for a given number of payloads is as follows:

Total Personnel	NUMBER OF PAYLOADS 1	2	3	4	5	6
Control Team	20	40	60	80	100	120
Engineering Support	10	20	30	40	50	60
Mission Planning	11	19	27	35	43	51
Facility Operations	72	104	136	168	200	232
SUBTOTAL	113	183	253	323	393	463
Supervisory and Overhead	34	55	76	97	118	139
TOTAL	147	238	329	420	511	602
Average per Payload	147	119	110	105	103	101

6.2 FACILITIES

6.2.1 GENERAL

The facilities for multiple LAS payload control must provide for the same functions as the single payload but allow for some facility sharing. Approaching the LAS programs from a unified POC concept allows for economizing in many areas including facility floor space, conference rooms, a backup emergency power system for operations equipment, etc. Figure 11 provides

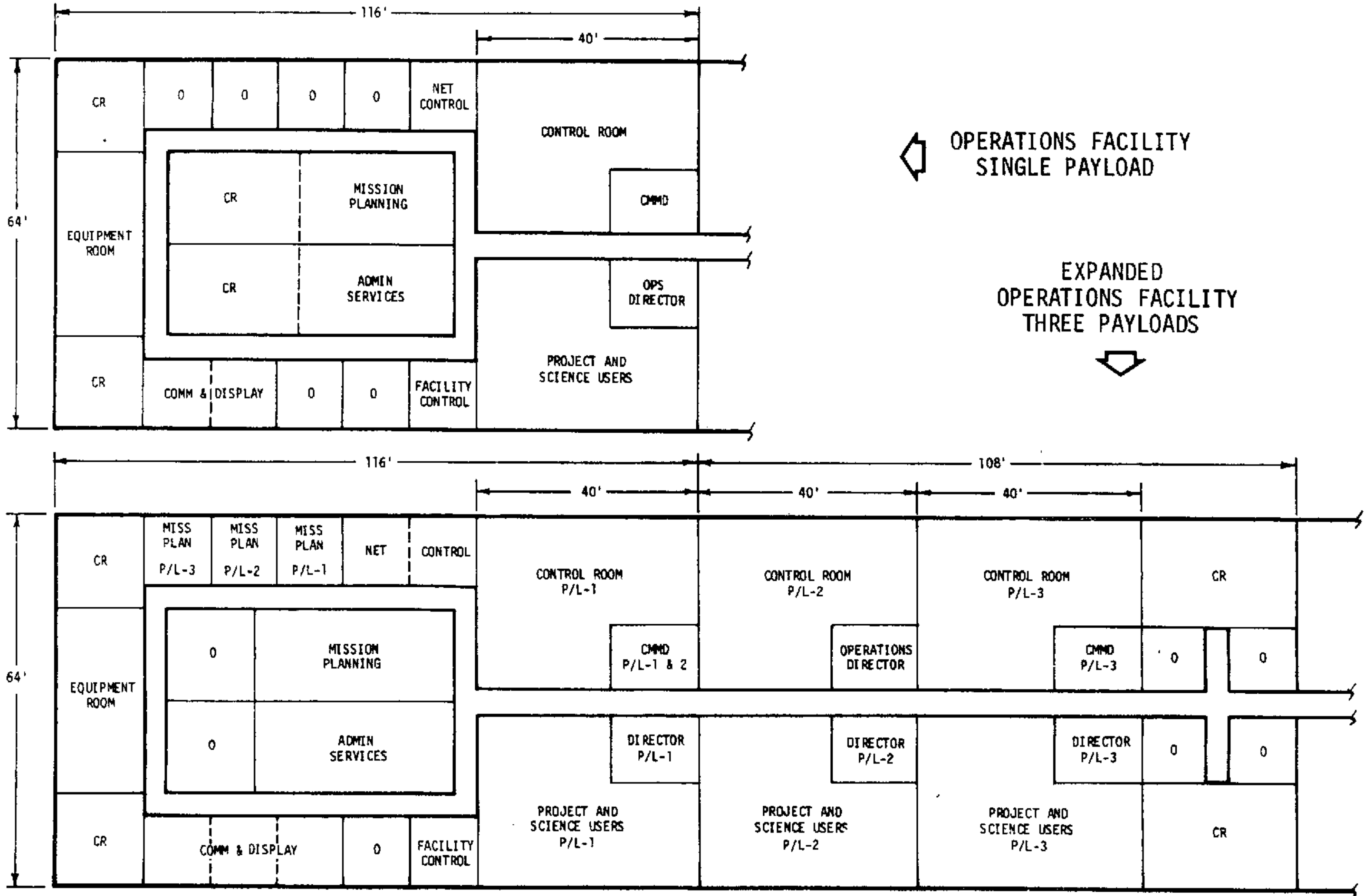

FIGURE 11: TYPICAL LAS OPERATIONS FACILITY
(MULTIPLE PAYLOADS)

a typical control center layout for a single payload and shows the same layout expanded for control of three payloads. The facility is organized to allow expansion without disrupting ongoing missions. This expansion, with control and user personnel sharing common facilities and support services, would allow triple the number of payloads to be operated with an additional 93 percent of floor space.

6.2.2 OPERATIONS FACILITIES

The operations facilities for multiple payloads include separate, dedicated control rooms and Project/guest observer areas for each payload to insure efficient payload control and maximized science return.

The facilities for the remainder of the operations functions are shared by the three payloads as discussed in the organization subsection. This layout for three payloads requires approximately 15,000 square feet. For efficiency of operation, a facility layout for six payloads will be exactly double the depicted layout.

6.2.3 COMPUTER FACILITIES

Assuming that larger capacity computers will be used for the multiple payload data volume, the computation equipment for three payloads will require approximately 18,000 square feet of floor space. If individual computation equipment is used for each of the three payloads, the floor space would be approximately 22,000 square feet. The computer facility for six payloads would be approximately double the three payload area as additional combination of computer functions will occur.

6.3 RESOURCE REQUIREMENTS

6.3.1 GENERAL

The resource requirements for operating multiple LAS from a single facility provide some economics by sharing common facility areas. These are briefly discussed in the following paragraphs for a six payload configuration.

6.3.2 CAPITAL COSTS

A. Building Modification -- The multiple LAS facility is described in subsection 6.2 and is also based on modifying an existing facility. It would require 15,000 square feet of non-raised floor and 15,000 square feet of raised floor for the operations facilities and 36,000 square feet of raised floor for the computer facility area. No fail utilities will also be required.

The building modification costs for a multiple LAS control center with space for six payloads are:

Non-Raised Floor	15,000 sq. ft.	0.2 M
Raised Floor	51,000 sq. ft.	1.8 M
No fail Utilities	--	0.5 M
TOTAL		2.5 Million Dollars
Average per LAS Payload		0.4 Million Dollars

B. Equipment -- The multiple LAS control center will allow for some economy by sharing of certain equipment and software. The capital costs for six LAS payloads is estimated as :

Data Receiving, Computation, and Display — 10.0 M
(Some larger capacity computers operating at higher speeds will be used rather than smaller individual payload units. Reduction is 2.0 M).

Special Purpose Digital Image Processor — 7.5 M
(Scheduling will allow some reduction, five units are provided for the six payloads. Reduction is 1.5M).

Command System — 2.4 M
(Three larger units are used instead of six small units to handle the command volume. Reduction is 1.2M).

Data Storage

7 days Systems Data	7.2 M
1 day Science Data	7.2 M

(No sharing potential is considered for data storage, each payload has its own individual experiment).

Redundancy 4.2 M
(Separate redundant units for each payload is not required for total backup capability to each payload. Reduction from six individual redundancy arrangements is 17.4M).

Software development 95.0 M
(Commonality in executive routines and to some extent in mission planning, data receiving and display is estimated as 5.0M for each subsequent payload. Reduction is 25.0M).

TOTAL EQUIPMENT (SIX PAYLOADS)	133.5 Million Dollars
Average per payload	22.3 Million Dollars

C. Total -- Total capital costs and average costs per payload for a six payload LAS control center are:

Facilities	2.5 M
Equipment	133.5 M
	136.0 Million Dollars
Average per Payload	22.7 Million Dollars

6.3.3 OPERATING COSTS

A. Communications -- Communications costs for the multiple LAS payload control center are:

Local distribution costs are based on using a single large system which allows some economy (reduction 0.5 M), cost is 0.7 M.

Longlines would be required to handle approximately 6.0 Mbs data rates for the six payloads combined. This rate would possibly warrant a Domestic Satellite communications link rather than multiple longlines. As such, this subject warrants a separate indepth study based on specific payload data rates, considering scheduled contact times and data interleaving on the lines. For the purposes of this study, no reduction will be considered. Cost is 6 x 1.3M = 7.8M.

Fascimile and support communications will be shared to some extent (reduction 0.5M). Cost 0.7M.

Total operating costs for communications for six payloads is 9.2 million dollars or an average of 1.5 million dollars per payload.

B. Manpower -- Manpower requirements for the multiple LAS configuration is described in subsection 6.1. Manpower costs are based on $40,000 annually and are:

Manpower for six LAS Payloads, 602 Man Years	24.1 M
Average per payload, 101 Man Years	4.0 M

C. Maintenance and Supplies -- There is some cost reduction in the multiple LAS control center for facilities and equipment maintenance and in supplies for a reduced number of personnel. However, a large portion of the supplies cost is for computer supplies for payload data which is not reduced by combination. (Reduction is 1.0 M). Cost is 5.0 M.

D. Total -- Total and average operating costs for operating a six payload multiple LAS control center are:

Communications	9.2 M
Manpower	24.1 M
Maintenance and Supplies	5.0 M
TOTAL	38.3 Million Dollars
Average Per Payload	6.4 Million Dollars

6.4 SUMMARY

6.4.1 LAS PAYLOAD SHARING

The comparison of resource requirements for a single LAS payload control center and for a multiple LAS control center of six payloads shows a considerable savings is possible.

	SINGLE LAS	AVERAGE MULTIPLE LAS
Facilities	0.7 M	0.4 M
Equipment	30.1 M	22.3 M
TOTAL CAPITAL COSTS	30.8 M	22.7 M
Communications	1.7 M	1.53 M
Manpower	5.9 M	4.0 M
Maintenance and Supplies	1.0 M	0.83 M
TOTAL ANNUAL OPERATING COSTS	8.6 M	6.4 M

The reduction in capital costs of 8.1M is relatively significant but is a single cost. The major reduction is in operating costs where the 2.2M annual reduction will be experienced for the entire mission lifetime of up to 15 years.

6.4.2 OPERATIONS CENTER SHARING WITH OTHER PROJECTS

During this conceptual study, operations center sharing was considered between the LAS class of payloads and other earth orbital payloads, such as the small automated satellites and the Spacelab.

The SAS requirements are similar to the LAS but they are less complex to operate. Therefore, considering a typical SAS, its requirements and functions could be shared with an LAS control center with probably the same percentage of savings.

Spacelab control involves man-in-space and therefore will have more strict realtime response requirements. To fulfill the manned safety aspect will require total dedication of operations personnel during the time Spacelab is in orbit. Any attempt to share personnel during its orbital phase would place the unmanned satellite in the potential posture of losing capability and scientific gain. Since Spacelab flights are presently baselined at seven to 30 days, there is some potential for sharing between missions.

The major areas which seem to present a potential for sharing are listed below:

A. Facilities -- Dependent on the size of the facility that is available for the operations center, certain savings could be attained. These are:

   (1) No fail utilities
   (2) Internal communications equipment space
   (3) Conference rooms
   (4) Personnel support facilities (restrooms, canteen, elevators, etc.)
   (5) Common Computer Area
   (6) Common Repair Shops

B. Equipment -- Some of the operations support equipment and all control room consoles will be dedicated to the individual project. The types of operations support equipment which can be shared are:

   (1) Communications switching and distribution could be shared by installing a larger central unit.
   (2) More efficient use of computation equipment by averaging workloads since peak loads are likely to occur at different times.
   (3) Redundant computation equipment, necessary for guaranteed operations support could be reduced. Equipment used for non-critical functions could be used to backup critical functions between projects dependent on equipment capacities.
   (4) Spares inventories could be reduced.

   Note: In items (2) and (3), the tradeoff between economy and providing sufficient computation capacity to prevent lengthy delays in processing scientific data needs to be considered.

C. Personnel -- Some classifications of support personnel could share time between the projects and are listed below. All control team personnel would be dedicated to their assigned project.

(1) Mission Planning -- Spacelab planning personnel will be involved in the next mission's plans between mission times, therefore, there is little sharing potential. Sharing between SAS and LAS is similar to the LAS discussion (reference paragraph 6.1.2).
(2) Clerical and administrative support personnel could operate in a shared manner with some positions dedicated to each project.
(3) Computation equipment operators would be assigned to specific equipment and would be shared in the same manner as the equipment.
(4) Facilities, display, maintenance, and communications technicians could operate in a combined group, providing greater capability and expertise to each project.
(5) Backup personnel required for position fill-in could possibly be shared between projects which would provide a small percentage decrease in overall numbers of personnel.

D. Software -- Software development costs provide a potential for economy by sharing due to commonality of many functions. This potential is dependent on development schedules, whether serial or parallel, on commonality of computation equipment and on the commonality of the computer languages used in preparing the software. Specific areas which provide potential are:

(1) Executive routines, if the equipment is common.
(2) Mission planning system which would include many subroutines which are common to a degree; timelining, consumables analysis, maneuver analysis, etc. Thorough information interchange between projects would be required during the development phase to ensure that each project obtained an effective system.

(3) Computerized monitoring limit sensing; each subroutine could be shared if development included individual control, quality verification and input formatting programs.

(4) Network coordination and telemetry receiving and routing software development provides a potential for economy dependent on the similarity in orbital data systems.

In summary, the operations requirements and the operations equipment needs are nearly identical for all projects. They differ only in volume, size or capacity. When the operations center is initially developed, all payloads which might be operated at that geographic location should be considered and sizing should be established accordingly.

There are sufficient economy potentials available in sharing an operations center between Spacelab, Tug, SAS, and the LAS class of satellites to warrant indepth study of the specifics involved. Establishing a Payload Operations Center, capable of supporting several payloads requires that a dedicated nucleous of operations personnel be established early in the development phase. This group of people will define and develop the operations center, receptive to the needs of each of the projects. Their primary purpose will be to determine the most economical system to support current projects with growth potential for future projects.

7.0 SUMMARY

7.1 PRINCIPAL CONCLUSIONS AND RECOMMENDATIONS

Several conclusions can be drawn from this initial orbital operations study. Many detail areas require that individual, indepth trade studies be performed. They are listed below as individual points and are not organized by priority or program impact.

A. POCs should be grouped to handle more than one payload to efficiently utilize facilities and personnel, particularly due to extended mission durations.

B. Total LAS program assignment would probably tax existing personnel, facility and computer capacity at any one NASA center. More than one POC should be chosen (Multiple POC Option).

C. It is necessary to maintain continuity in communications with the scientific community from program inception, throughout the orbital operations phase, to dissemination of scientific results to the general public.

D. The Operations Center should allow scientists to conduct their experiments with:

(1) minimum mission preparation time,
(2) maximum productive science return,
(3) direct participation by experiment personnel,
(4) efficient facility and data support, and
(5) minimum cost.

E. The subject of Data Management is of extreme importance in the LAS programs. It needs to be involved in acquisition, flow, requirements, processing, dissemination, and archiving from the inception of the program to its conclusion.

F. Software development needs the same management emphasis as hardware development and needs to be initiated early in the program to assure thorough testing prior to mission start.

G. Operation Center planning and implementation occurs in parallel with payload design and development and includes participation in premission testing and verification.

7.2 STUDY SUBJECTS

Areas requiring further study for developing the operations requirements/procedures of the LAS are:

A. Conduct detailed trade studies of advantages and disadvantages of POC options and payload grouping. This study will be based on additional payload system definition as it becomes available. It will address the specific operations requirements of the payload in the areas of facilities, operating modes, etc. This study would be developed in consonance with the applicable payload project organizations.

B. Expand LAS study to cover other payloads. The next twenty years of space operations will see continued operation of existing satellites, the LAS, and many other smaller payloads. Operations studies must not be limited to only the LAS, but must include all the payloads and how they will affect the operations of one another, the overall operations requirements, data management, and other interrelations.

C. Study data handling capabilities and requirements. The present STDN is capable of receiving downlink data at a rate of 1×10^6 bits per second. The LAS require from 1×10^6 bits per second to 200×10^6 bits per second. This means that the STDN is inadequate to handle the entire LAS requirement without consideration for other programs which are operating simultaneously. The proposed TDRSS will have the capability of handling 100×10^6 bits per second in multiple circuits which will adequately handle all the LAS systems data plus other programs which may be operating simultaneously. LAS scientific image data will require scheduled use of the TDRSS single access channels. Considering that several of the LAS may be operational before TDRSS, studies must be made to determine the most effective means of communication with those LAS together with other operational satellites during the time between first LAS launch and TDRSS operation.

D. Determine the feasibility and application of a computerized payload monitoring system. This study would be based on specific measurements and systems requirements of each payload. An offshoot of the study would be a design feedback of operations considerations into the measurement system. The primary result of this study will be determining the types of computer routines required and developing them into a workable system early in the program.

E. Determine the most effective methods of meeting experimenter requirements. Inherent in all NASA programs, there are scientists who have certain requirements pertaining to those experiments. In order to satisfy these experimenters, a study needs to be made to determine the kinds and quantity of requirements and devise a method of procedure for handling them. This can best be done by looking at the problems and successes of the Apollo, Skylab, and all unmanned NASA programs where experimenters have had specific requirements, and the results of each as they could be applied to the LAS program.

F. Perform a trade study to determine the feasibility of reducing onboard data transmission rates and onboard data storage requirements. Candidate methods to be considered are:

   (1) Delta PCM transmission of image type data
   (2) Orbital computer monitoring and results transmission of systems data
   (3) Orbital data compression to remove identical redundant points in science and systems data
   (4) Incorporating a programable instrumentation system to vary measurement sample rates and accuracy.

   In addition, determine the effect on ground data handling and software requirements for each of the categories studied.

There are numerous design trade-offs which directly affect operations complexity and must be considered. These include such items as common versus unique; structures, electrical systems, thermal systems, and instrumentation systems.

8.0 ACRONYMS AND ABBREVIATIONS

ACS	Attitude Control System
ATM	Apollo Telescope Mount (Skylab Program)
b/s	Bits per second
BAT	Battery
CDR	Critical Design Review
CGT	Cold Gas Thrusters
CMG	Control Moment Gyro
CMMD	Command
DC	Development Center
DOMSAT	Domestic Satellite
DTV	Digital Television
EOS	Earth Observations Satellite
EPS	Electrical Power Systems
EVA	Extravehicular Activities
FRR	Flight Readiness Review
HEAO	High Energy Astronomincal Observatory
HOSC	Huntsville Operations Support Center
I&C	Instrumentation and Communications
Kb/s	Kilobits per second
LAS	Large Automated Satellites
LDEF	Long Duration Exposure Facility
LIEF	Launch Information Exchange Facility
LRO	Large Radio Observatory
LSO	Large Solar Observatory
LST	Large Space Telescope
LXRT	Large X-Ray Telescope
Mb/s	Megabits per second
MHz	Mega Hertz
NM	Nautical Mile
NRT	Near Real Time
NSSDC	National Space Science Data Center
O'RIDE	Override
PDR	Preliminary Design Review
PHY	Physics
P/L	Payload
POC	Payloads Operations Center
PRR	Preliminary Requirements Review
RF	Radio Frequency
RT	Real Time
SA	Solar Array
SAS	Small Automated Satellites
SEC	Secondary
STDN	Spacecraft Tracking and Data Network
TBD	To Be Determined
TDRSS	Tracking Data Relay Satellite System

TV	Television
UV	Ultra Violet
V	Voice
WHS	White Sands
XUV	Extreme Ultra Violet

APPROVAL

ORBITAL OPERATIONS FOR LARGE AUTOMATED SATELLITES

OPERATIONS ENGINEERING OFFICE

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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