STARLAB GROUND SYSTEM GUIDELINES DOCUMENT

FINAL

JANUARY 1984

National Aeronautics and
Space Administration

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

This document was prepared by:

Dr. Frederick J. Hawkins
and the
Data and Operations Sub-committee (DOS)

EXECUTIVE SUMMARY

In accordance with a letter of intent among Australia, Canada and the United States, the United States will supply a Starlab Ground System to support required mission planning, pre-launch, launch, normal, and contingency operations phases and post-flight data preprocessing and processing, and data archival. This Starlab Ground System will support at least two six months missions on a Space Platform/Station. The Starlab Ground System augmented with Experimenter Ground Support Equipment (EGSE) will provide required capability for investigators from the three participating countries and possibly guest observers for these missions. A Data Analysis Facility (DAF) is planned and will be sized to provide science data processing capability for U.S. investigators and guest observers. It is also anticipated that Australia and/or Canada will develop similar capability using appropriate commonality to support their national investigators and guest investigators. The Starlab Ground System will provide the necessary interfaces and data products to support the DAF and other national facilities.

The Starlab Ground System will provide all data streams required for quicklook analysis of high rate science data to the Payload Operations Control Center (POCC) and EGSE. These streams will be configured to enable data systems communications transparency, wherever possible. Off-line analysis capability will be provided by the DAF. The image analysis capability provided by the EGSE will be required to bridge the gap between realtime (same orbit) response and that which can be reasonably expected from an off-line facility. The data preprocessing and processing functions will provide science data, appropriately calibrated, appended with necessary ancillary data, and with required instrument signature removal to support science data processing functions. Various data types and products produced by the preprocessing and processing functions will be archived by the Starlab Ground System. This archive will provide a complete storage of necessary Starlab derived data and data products. Access requirements will be sized to support the science data analysis needs of U.S. investigators and guest observers and the retrieval needs of Australian and Canadian investigators.

It is important that serious consideration be given to the development of preliminary requirements and to the conceptualization of the required Starlab Ground System at this stage to avoid some of the problems that have been experienced in the development of other ground systems. This document provides a compilation of preliminary requirements and guidelines for a ground system to meet currently identified Starlab needs. Section 6 summarizes these requirements and will provide the nucleus for the subsequent requirements document. Both Shuttle sortie and Space Platform/Station type missions have been addressed. At the time this document was prepared the initial Starlab flight(s) were to be in the Shuttle sortie mode. **However, at the November 1983, tripartite meeting the decision was made to delete the sortie mode and to use as a baseline, a six month mission on the Space Platform/Station.**

Several sources of information have been utilized in the preparation of this document, but in particular the support of the Starlab Data and Operations Sub-committee (DOS) is appreciated.

TABLE OF CONTENTS

TABLE OF CONTENTS (concluded)

LIST OF FIGURES

LIST OF TABLES

LIST OF ABREVIATIONS AND ACRONYMS

Term	Explanation
AFD	Aft Flight Deck
AM	Accumulating Memory
BCH	Bose-Chaudhuri-Hocquenguem (Cyclic Codes)
BCU	Bus Coupler Unit
C&DH	Command & Data Handling
CAPS	Crew Activity Planning System
CCT	Computer Compatible Tape
CCTV	Closed Circuit Television
CDMS	Command & Data Management System
CU	Central Unit
CVZ	Constant Viewing Zone
DAC	Direct Access Channel
DAF	Data Analysis Facility
DEC	Declination
DEP	Dedicated Experiment Processor
DI	Direct Imager
DOS	Data & Operations Sub-committee
DST	Department of Science and Technology
DQM	Data Quality Monitoring
EC	Experiment Computer
ECAS	Experiment Computer Applications Software
ECIO	Experiment Computer Input/Output
ECOS	Experiment Computer Operating System
EER	Engineering & Economics Research, Inc.
EGSE	Experimenter Ground Support Equipment
ESA	European Space Agency
EU	Electronic Unit
FDF	Flight Dynamics Facility
FFT	Fast Fourier Transform
FGS	Fine Guidance System
GSFC	Goddard Space Flight Center
GSSS	Guide Star Selection System
HDRR	High Data Rate Recorder
HRDM	High Rate Demultiplexor
HRM	High Rate Multiplexor
IC	Instrument Computer
ID	Identification
IPS	Instrument Pointing System
IUE	International Ultraviolet Explorer
JSC	Johnson Space Center
JSWG	Joint Science Working Group
KSC	Kennedy Space Center
MA	Multiple Access
MCC	Mission Control Center
MDB	Multiplex Data Bus
MDM	Multiplexor-Demultiplexor
MIPS	Mission Planning Computer System
MMS	Multi-mission Modular Spacecraft

LIST OF ABREVIATIONS AND ACRONYMS (concluded)

Term	Explanation
MMU	Mass Memory Unit
MOU	Memorandum of Understanding
MSOCC	Multi-Satellite Operations Control Center
NASA	National Aeronautics & Space Administration
NASCOM	NASA Communications
NCC	Network Control Center
NRCC	National Research Council of Canada
NSSDC	National Space Science Data Center
OBC	Onboard Computer
OCF	Orbit Computing Facility
OD	Operational Downlink
PA	Position Angle
PCM	Pulse Code Modulated
PDI	Payload Data Interleaver
PIP	Payload Integration Plan
PMP	Pre-Modulation Processor
POCC	Payload Operations Control Center
RA	Right Ascension
RAL	Rutherford Appleton Laboratory
RAU	Remote Acquisition Unit
RCS	Reaction Control System
RIU	Remote Interface Unit
ROM	Rough Order of Magnitude
SA	Single Access
SAA	South Atlantic Anomaly
SC	Subsystem Computer
SCIO	Subsystem Computer Input/Output
SDPF	Sensor Data Processing Facility
SLC	Starlab Computer
SLDPF	Spacelab Data Processing Facility
SMM	Solar Maximum Mission
SPIF	Shuttle/POCC Interface Facility
SPSS	Science Planning & Scheduling System
ST	Space Telescope
STACC	Standard Telemetry and Command Components
STDN	Space Tracking & Data Network
STINT	Standard Interface for Computer
STS	Space Transportation System
SWG	Science Working Group
TAGS	Text and Graphics System
TC	Telescope Computer
TDRSS	Tracking and Data Relay Satellite System
UV	Ultraviolet
ZOE	Zone of Exclusion

GLOSSARY

The following definitions are used in this document. This list is intended to clarify those terms which might be confusing to the reader and is not meant to be a complete set of definitions.

Ancillary Data - Additional, non-Starlab data which are required to facilitate the analysis and reduction of science data and/or Starlab instrument engineering data. These data include: time data, programmatic data, attitude data, empheris data, and non-Starlab instrument engineering data obtained on special request.

Data Analysis Facility - A host facility providing off-line science data analysis capability for the support of U.S. investigators and possibly guest observers. The primary DAF function is to provide the capability for the extraction of scientific knowledge from Starlab images and associated data. It also provides information necessary for feedback to the planning of subsequent observations and for developing and improving calibration procedures. The DAF provides processing customized according to the specification of individual users, where these comprise two basic classes. The first class includes observers and archival researchers who process Starlab images and spectrograms for scientific purposes; the second process Starlab images and spectrograms to help understand the Starlab instrument, to monitor its performance, and to update its calibration functions and tables.

Data Preprocessing - The function providing Starlab data capture and recording, demultiplexing and synchronization, data quality monitoring and data accounting. Following data preprocessing the resultant data are delivered to the data processing function and/or data archives.

Data Processing - The data processing function performs a number of processing steps on buffered pre-processed data received from the data preprocessing function in order to produce various data products including level 2 data. These steps include an assessment of image data quality, archival of raw images (level 0), calibration parameter determination, creation and archival of level 2 calibrated images, and maintenance of a Starlab image catalog complete with the associated calibration history.

Experimenter Ground Support Equipment (EGSE). - EGSE provide support at various phases of the ground flow and/or operations. These include instrument development and calibration, facility development and calibration, payload integration and test and Payload Operations Control Center (POCC) operations. The EGSE are investigator provided, and support various quicklook processing functions at the POCC including selected processing of the engineering data stream and data processing of high rate science data. In general, POCC facilities are not designed to handle data streams in excess of approximately 2 Mbps.

Science Data Analysis - This function provides primarily extraction of scientific knowledge from the Starlab images and associated data. It also provides the capability necessary for a feedback of information to support planning of subsequent observations and for developing and improving calibration procedures.

Starlab Ground System - The Starlab Ground System provides the required capability to support mission planning, pre-launch, launch, normal, and contingency operations phases and post-flight data preprocessing and processing, and data archival. The Starlab Ground System requires augmentation by investigator provided EGSE to provide necessary quicklook analysis functions. A DAF sized to provide science data analysis capability for U.S. investigators and observers is planned as a part of the Starlab Ground System. Australia and Canada are proposing to develop similar capability to the DAF to support their national investigators. The Starlab Ground System will provide the necessary interfaces to support these remote facilities.

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to identify preliminary requirements and guidelines to be considered in the definition of detailed requirements for the Starlab Ground System. The Starlab Ground System will be supplied by the United States in accordance with the letter of intent signed by the three national agencies under a tripartite agreement representing Australia, Canada, and the United States. These agencies are the Australian Department of Science and Technology (DST), the National Research Council of Canada (NRCC), and the National Aeronautics and Space Administration (NASA) respectively.

The letter of intent covered the first two long duration missions to be performed utilizing the Starlab facility carried upon a space platform, which would be supplied by the United States. Subsequent to this agreement, it has been proposed to perform up to two missions in an attached Shuttle sortie configuration. It is therefore necessary to consider the additional guidelines necessary to support these missions.

This document will be used as input on the Starlab Ground System necessary for the preparation of the Memorandum of Understanding (MOU) to be executed between the three participating countries. In addition, the document will provide inputs to be used in the preparation of a detailed Starlab Ground System Requirements Document. This latter document will represent the statement of ground system requirements as approved by the NASA Starlab Project at the Goddard Space Flight Center (GSFC).

1.2 SCOPE

The Starlab Ground System will provide necessary capabilities required to support mission planning, pre-launch, launch, normal, and contingency operations phases and post-flight data preprocessing, processing, and archival. These capabilities will include mission planning, science operations control, space segment operations control (as required), data management and appropriate support requirements. In this document, consideration will be given to the overall ground system for Starlab including potential facilities within Australia and Canada, however the emphasis will be on the definition of preliminary requirements and guidelines for the NASA provided Starlab Ground System. The Starlab Ground System will provide appropriate data products and the necessary interfaces to support science data processing activities within the U.S., Australia and Canada. Science data processing capability to support U.S. investigators and possibly guest observers will be provided via a Data Analysis Facility (DAF). It is likely that similar capability will be developed by Australia and Canada to support their national investigators. Commonality of systems and/or subsystems will be an important consideration in the development of these science data processing facilities.

Current NASA plans are for the development of a Space Station, which is likely to provide for both manned and unmanned elements. The unmanned element of the Space Station is therefore a possible candidate to provide the Starlab space platform capability. An alternate candidate is a Leasecraft type system and at the present time this is the preferred candidate. In each case, the platform will be in low Earth orbit and tended periodically by the Orbiter. The capabilities required for space segment operations control are dependent on the flight configuration and it is therefore necessary to consider both the attached Shuttle sortie configuration proposed for the initial up to two missions and the subsequent space platform configuration in the guidelines definition.

For both configurations, ground systems capability for space segment support will exist or will be developed to support all missions to be carried on the space segment. It is therefore necessary to consider the development of a Starlab Ground System in the context of available and planned capability.

In the case of the attached payload configuration, the command of the Orbiter flight with control of all resources and safety aspects is under the direct control of the Johnson Space Center (JSC) Mission Control Center (MCC). In addition, Spacelab elements such as the European Space Agency (ESA) supplied Instrument Pointing System (IPS) are under MCC control. The JSC Payload Operations Control Center (POCC) can support attached payloads in this operational environment, where the broad range of capability and services provided by this facility can be augmented by Experimenter Ground Support Equipment (EGSE), as required. Further, data preprocessing services for Spacelab payloads for providing data products for post-flight analysis are provided by the GSFC Spacelab Data Processing Facility (SLDPF). For the Leasecraft system, a Multi-Satellite Operations Control Center (MSOCC) type capability and the Sensor Data Processing Facility (SDPF) can support similar functions.

In this document, the guidelines for a Starlab Ground System will be developed within this overall framework for providing required capability. Guidelines for the various functional requirements and interfaces will therefore be developed. One important aspect in the definition of the guidelines will be the development of a concept to provide continuity between configurations, wherever possible.

In general, the Starlab Ground System will provide for data capture, signature removal, quality checks, and quicklook analysis for realtime control for U.S., Australian, and Canadian investigators, and possibly guest observers. Facilities for detailed analysis and data archival will be developed by each country while the DAF will host U.S. based investigators.

1.3 Applicable Documents

The following documentation has been used as input in the preparation of the Starlab Ground System guidelines defined in this document:

1. Starlab, An Australia-Canada-U.S.A. Orbiting Telescope, Project Concept and Scientific Goals, A Report of the Starlab Joint Science Working Group (JSWG), University of Virginia, Charlottesville, VA 22903, September 1982.

2. Study of Starlab Ground Segment, Issue 1, Rutherford Appleton Laboratory (RAL), Chilton, Didcot, Oxfordshire, England, August 1982.

3. Ground System Considerations for Projects, POB-30SD/0181, NASA/Goddard Space Flight Center, January 1981.

4. Payload Operations Control Centers User's Services Guide, MOD-1 PUG/0180, NASA/Goddard Space Flight Center, April 1981.

5. Spacelab Payload Accommodation Handbook, SLP/2104, Issue 1, Revision No. 5, January 31, 1981.

6. POCC Capabilities Document, Volume 1, JSC Attached POCC Capabilities Description, JSC-14433, Revision A, February 20, 1981.

7. POCC Capabilities Document, Volume 2, MCC/Remote POCC Interface Capabilities Description, JSC-14433, Revision A, March 1, 1980.

8. Starlab Mission Profile Analysis, Mount Stromlo and Siding Spring Observatories, Australian National University, January 1983.

9. Starlab Reference Specifications, JSWG, November 1983.

10. Starlab Memory Usage, A report prepared by the Data and Operations Sub-committee, March 1983.

11. Real-Time Interaction with Starlab, A discussion paper prepared by the Data and Operations Sub-committee, March 1983.

12. Summary Response to EER Priority Issues, Starlab Data and Operations Sub-committee report, September 1, 1983.

13. Starlab Shuttle Mission Profile Study, Data and Operations Sub-committee, October 1983 [Issue 1].

14. Starlab Mission Profile Analysis: 1983 Canadian Survey [J. Hesser], March 24, 1983.

15. Starlab Command and Data System Requirements Document, Code 600, NASA/GSFC, Preliminary copy, October 1983.

16. Starlab-Level 1 Scientific Requirement Document (SRD), JSWG, Draft, December 1, 1983.

2.0 OVERVIEW OF THE STARLAB SCIENCE OBJECTIVES

2.1 SCIENCE OBJECTIVES

The planned Starlab facility will consist of a one-meter space telescope having unique capabilities which will enable the pursuit of a wide variety of frontier astrophysical problems in the optical and ultraviolet spectral regions. The initial one or two flights of the facility will be in an attached mode on the Orbiter utilizing the IPS and Spacelab. Flight times of two weeks are anticipated. Subsequent flights will utilize a space platform to provide a series of missions lasting a minimum of six months each.

Starlab will provide a definitive contribution in two areas:

- Very high spatial resolution, large bandwidth imagery over a large field of view, and

- High efficiency, high spatial resolution spectroscopy of extended or point sources in applications where large spectral or spatial multiplex gains are required.

Starlab will provide an ideal complement to the powerful capabilities of the Space Telescope (ST) having the potential to survey significant areas of the sky for fundamentally new astrophysical phenomena near ST's threshold. Starlab operates in the same spectral range as ST, has a spatial resolution and spectral coverage in the same class, but will have an imagery field one hundred times larger. Its imagery field is therefore perfectly matched to the scale of many important targets, including globular star clusters, nearby galaxies, and distant clusters of galaxies.

The current Starlab design includes two each of two instrument types: Direct Imagers (DI) mounted radially and echelle spectrographs axially mounted. Among the many imagery problems to which Starlab would make definitive contributions are the following: the early evolution of galaxies, clusters of galaxies, superclusters, and quasars viewed at large look-back times; calibration of "standard candles" used in determining cosmic distances and use of new distance indicators, especially Type I supernovae to extend determination of the cosmic deceleration parameter to the largest possible distances; investigation of the "missing mass" by using globular cluster tidal radii to map the gravitational field in the halos of galaxies and by searching for the signature of decaying massive neutrinos in clusters of galaxies; stellar physics in other galaxies, including the study of very short-lived evolutionary phases, the initial mass function, and star formation in spiral arms; the spatial structure of supernova remnant shock waves; and analysis of the important ultraviolet radiation from gas and dust near stellar birthsites in our and other galaxies.

The unique power of Starlab's multimode spectrograph instruments derives from the capability for high spectral resolution coupled with superb spatial resolution over a long slit (up to 8 arc-min). The resulting multiplex gains give Starlab distinct advantages in many applications over the ST and other spectroscopic facilities in both the ultraviolet and optical regions. Important scientific problems for which these unique capabilities are essential include the following: study of the physical properties (chemical abundances, temperatures, densities, flow velocities) of extended structures in the interstellar medium such as supernova remnants, H II regions, and planetary nebulae; dynamics of stars and gas in the vicinity of galactic nuclei; physical conditions in the extended ionized gas often encountered in strong extragalactic radio sources and galaxies which appear to be accreting hot material from circumgalactic space; studies of individual stars in crowded fields (e.g., globular clusters and nearby galaxies) or variable stars; analysis of the recently-discovered hot halo gas of our own and nearby galaxies; and study of atomic and molecular emission from comets and planets.

2.2 GROUND SYSTEM CONSIDERATIONS

It is important to identify science objectives which have an impact on ground system design. Several areas requiring consideration have already been identified. These are the following:

a) The need for realtime interaction versus preprogrammed operation has been considered by the Starlab Data and Operations Sub-committee (DOS). Their recommendations are summarized for both space segment configurations in Table 2-1.

b) The capability for providing small offsets corresponding to a small fraction of the minimum width of the telescope's point-spread function is required. A 0.1 arc-sec offset with 0.016 arc-sec resolution is typical. These offsets could be necessary to eliminate the aliasing caused by the coarse sample interval of the DI detector. The recording in sequence, of a number of exposures with very small differences in the guidance null positions, corresponding to the fine sub-pixel offsets needed to give critical sampling is a technique under

Table 2-1. Ground System Considerations Derived from the Science Objectives

[Item numbers refer to sub-section numbering in the text]

Consideration	Configuration	
	Shuttle Sortie	Space Platform
a. Realtime interaction versus preprogrammed operation		
o Principal operating mode	Preprogrammed	Preprogrammed
o Percent of observations requiring realtime interaction	50	15
o Primary realtime interaction function	Commissioning of facility	Spectroscopic observations (account for approximately thirty (30) percent of all observations)
o Functions performed by realtime interaction	Updating or overriding the preplanned sequence to allow efficient optimization and diagnosis of problems in timescales of minutes. During the activation and check-out phase the realtime link will be required > 50% of the time, reducing to possibly 20% following gain of operational experience. During the observational phase, realtime interaction would normally only support spectroscopic target acquisition (with possibly crew involvement) and simple operations such as alternate filter selection.	Ground assisted target acquisition to accurately align the spectrograph slit, optimization of the instrument configuration or slew to an alternate target (branching)

Table 2-1. Ground System Considerations Derived from the Science Objectives (continued)

[Item numbers refer to sub-section numbering in the text]

Consideration	Configuration	
	Shuttle Sortie	Space Platform
o Notes	Major replanning of the scheduled preplanned timeline will be required to support facility commissioning, where a mission replanning cycle time of 12 hours is considered representative. This replanning would be designed to minimize later realtime interaction and perturbation of STS operations.	
c. Observations		
o Number per orbit	2	Minimum of 2, more typically 3
o Average number per day	25-30	40-50
d. Percent of spectroscopic observations compared with total for spectroscopy and direct imagery	25	30 with increase over time
f. Target availability duration per orbit		
o Sunlit side (minutes)	3-50 (20-25 typical)	40-50
o Dark side (minutes)	35	35
h. Slews		
o approximate size	$>100^0$ and possibly much higher for non-Continuous Viewing Zones (CVZ) observations	$>100^0$ and possibly much higher
o Average number per day	25-30	35-40

Table 2-1. Ground System Considerations Derived from the Science Objectives (continued)

[Item numbers refer to sub-section numbering in the text]

Consideration	Configuration	
	Shuttle Sortie	Space Platform
i. Average data rate		
o Bits per orbit	3.3×10^9	4×10^9
o Bits per day	5×10^{10}	6×10^{10}
o Data transmission at 16 Mbps (minutes/orbit)	3	4
k. Calibration		
o Flat fielding	Several times per day with 10-30 minutes per exposure. Applies to the DI and the spectrograph. Utilization of crew breaktimes, where possible.	TBD minutes/day, Applies to the DI and the spectrograph
o Arc lamp	5 minutes duration at least following configuration changes of the spectrograph	5 minutes duration at least following configuration changes of the spectrograph
o Observations of standard stars for astrometric and photometric calibration of the DIs and spectrophotometric calibrations of the spectrographs	Repeated observations required	Repeated observations required
o Percentage calibration time compared with total for calibration and astronomical observations	20	10

Table 2-1. Ground System Considerations Derived from the Science Objectives (continued)

[Item numbers refer to sub-section numbering in the text]

Consideration	Configuration	
	Shuttle Sortie	Space Platform
m. Astronomical target list		
o Prepared ahead of schedule	2 years	TBD
o Contingency factor to provide timelining flexibility (time requested/time available)	4	TBD
n. Optimization of orbital parameters for observational efficiency	Orbit attitude and inclination, SAA phasing, phasing of new moon, beta angle and Continuous Viewing Zones (CVZ)	Scientific requirements are one of several sets of competing requirements utilized to determine desired orbital parameters at launch. Following launch, this orbit or the actual orbit achieved determines the observing efficiency for all observations as a function of time throughout the mission. Any optimization of observing efficiency must be determined by selecting the actual observations and times scheduled accordingly.
o. Priority of payload	Starlab prime-secondary payloads do not impose restrictions	TBD
p. Replanning/interactive operational requirements		
o Mission replanning cycle (major changes) .	12 hours (designed for minimal perturbation of STS)	Not required

Table 2-1. Ground System Considerations Derived from the Science Objectives (continued)

[Item numbers refer to sub-section numbering in the text]

Consideration	Configuration	
	Shuttle Sortie	Space Platform
o Minor timeline changes response time	approx. 15 minutes	For following orbit-response time of approx. 20 minutes
o Realtime/near realtime interaction capability response time	≤ 20 seconds	≤ 20 seconds
q. Mission duration		
o Total	14 days with at least 7 days for astronomical observations	≥ 6 months
o Other activities	4.5 days-engineering verification and performance analysis 1 day - calibration (internal and external) 1 day - reentry preparation	TBD
s. Targets of opportunity		
o Number anticipated	None	One every two weeks worst case
o Percent of normal observations	0	≤ 5
t. Alternate branching		
o Utilization	Unlikely	Required
o Percent of normal observations	0	< 10 with most being spectroscopic

Table 2-1. Ground System Considerations Derived from the Science Objectives (concluded)

[Item numbers refer to sub-section numbering in the text]

Consideration	Configuration	
	Shuttle Sortie	Space Platform
v. Special pointing requirements		
o Functions supported	Alignment of spectrograph slit	Alignment of spectrograph slit, possibly ground-assisted. Guide star acquisition in difficult fields.
o Modes supported		
-- blind pointing	yes	yes
-- onboard computer controlled acquisition	yes	yes
-- crew assisted	Likely	no
-- ground assisted	Probably	yes

consideration to support this requirement. With a photon counting detector as proposed on Starlab the sample mesh can possibly be made arbitrarily smaller without degradation in overall picture quality; the penalty is the increased demand on data transmission and processing for a single field. However, technical limitations limit the mesh size adopted. Utilization of this technique would increase operational complexity, but is only proposed for the space platform configuration missions.

c) Most observations, particularly direct imaging, are expected to have a duration of approximately twenty (20) minutes or longer. Table 2-1 presents the number of observations per orbit and the average number of observations performed per day for both configurations.

d) The proportion of direct imaging observations relative to spectroscopic is a function of observational requirements. The percent of spectroscopic observations anticipated is presented in Table 2-1. Utilization of dark time for direct imaging with spectroscopic observations conducted on the sunlit side of the orbit is likely to be common.

e) Observations of variable or transient phenomena will frequently be necessary, and will result in the need for repetitive observations of the same field.

f) A significant fraction of scheduled observations will require multiple exposures at the same position and with the same instrument configuration to achieve a single long exposure. This results from the duration of target availability for a single orbit (refer to Table 2-1 for typical dark and sunlit side observation durations). It will be desirable to return to the same guide star and Position Angle (PA) to facilitate the addition and registration of the images (both imaging and spectroscopic) for these exposures.

g) Observations with high time resolution will be required for the study of objects displaying periodic or aperodic variability of short duration. The capability to store data from a small area (or sub-image) in successive areas of the Accumulating Memory (AM) will be required. The ground system will need the capability to extract data collected in this operational mode for the analysis of observed variability. An absolute time accuracy of 1 msec is required.

h) Based on the need to schedule two (2) to three (3) observations per orbit as a direct consequence of the need to avoid target occultation by the Earth, a significant number of large maneuvers will be required. Table 2-1 presents the approximate maneuver size and average number of maneuvers required per day.

i) Based on the mission profile analysis for the Shuttle sortie and space platform configurations (references 13 and 8 respectively) and the assumption that an individual exposure produces 1.3×10^9 bits per AM memory dump (9000 x 9000 pixels x 16 bits), the average data rate requirements presented in Table 2-1 were derived. The NASA tape recorder of capacity 3.8×10^{10} bits can store approximately 29 Starlab images of this size. However, it is recognized that several factors could increase these values including:

o Utilization of shorter than average exposure times.

- Inclusion of engineering data of approximately an additional ten (10) percent.

- Increased detector resolution requiring significantly increased data per exposure. For instance, an increase of a factor of two in resolution would require a fourfold increase in memory size.

- The requirement to sub-step the telescope to overcome the image sampling problem as described in item b) above would require an increased number of shorter exposures. This could increase the quantity of data required to be dumped for some observations (approximately 30% TBD) by as much as a factor of 4.

- The need to transmit additional data in a non-destructive mode during an exposure for ground monitoring purposes.

It was therefore suggested that based on these factors the derived values should be increased by a contingency factor of ten (10) for planning purposes.

j) Orientation of the Position Angle (PA) will be significant for certain observations. These include:

- For imaging, when multiple exposures of the same field are required (e.g. in different filters, or to achieve a long exposure), utilization of a "constant" roll angle will facilitate image analysis.

- For spectroscopy, the roll angle may need to be defined to align the spectrograph slit at a desired PA.

- When required due to a thermal constraint.

- To support guide star selection.

k) There is a requirement for scheduling regular calibrations of the instruments. These calibrations include measurements for flat fielding of the detectors and filters, astrometric and photometric calibrations on star fields, focussing and alignment checks, wavelength calibration of the spectrographs, spectrophotometric calibration of the spectrographs on standard stars, and determination of the intensity transfer function. The frequency of calibration measurements will be determined primarily by the repeatibility and stability of the instruments in orbit. These characteristics are not known, but the information presented in Table 2-1 is assumed to be fairly typical. In addition, the following calibration requirements are likely:

- Focussing sequences may be required for verification purposes.

- Astrometric and photometric calibration of the DIs will require collection of data from selected fields for TBD minutes per day.

- Occasional exposures on standard stars will be required for photometric calibration of the spectrographs.

l) The ability to track solar system objects with predetermined orbits is required.

m) The astronomical targets to be observed will be selected by some form of tri-national peer review procedure. The timeframe for the selection of these targets is shown in Table 2-1. In addition, it is expected that the targets selected will require a longer period of observing time to complete than the time available since this will provide for flexibility in the construction of an efficient mission timeline. The factor defining the ratio of selected observing requirements to available observing time is also shown.

n) Optimization of the orbital parameters can provide a significant improvement in the amount of observing time and also the ratio of night side to sunlit side observing time available. This results from phasing passages through the South Atlantic Anomaly (SAA) entirely outside orbital darkness, selecting the mission timeframe to coincide with the new moon to reduce background light levels, selection of the sun beta angle to maximize the amount of time spent in the Earth's shadow and the selection of the location of the CVZ to coincide to desired target areas. In addition, orbit altitude and inclination affect the plasma glow intensity (reduces with increasing altitude) and the size and intensity of the SAA (both increase with altitude). Table 2-1 summarizes this requirement.

o) The payload complement selected should allow Starlab the principal role in the selection of requirements such as optimization of orbital parameters (reference item n. above), and should avoid secondary payloads imposing restrictions on achievement of Starlab science and operational objectives (Table 2-1 summarizes this requirement).

p) The capability to perform specific replanning and interactive operations is required. This requirement is presented in Table 2-1.

q) The mission duration needs to be selected to enable adequate performance of Starlab astronomical observations. Again, Table 2-1 provides specific details.

r) Serendipity observations with the DIs should be conducted during all spectroscopic observations. In this mode, imagery of the outer field segment is obtained during the acquisition of spectroscopic data from the inner segment. This is the only approved parallel instrument operation and will most likely involve the use of the grism (for survey purposes). Utilization of this mode will involve the separation of the direct imager component and the spectrograph component from the data by the ground system.

s) A requirement to observe targets of opportunity, such as comets, supernovae, and errupting variables will be relatively infrequent. An average case would be once per two weeks, and would probably not arise during a Shuttle sortie mission. A target of opportunity would frequently require more than one observation; e.g., a supernova would be observed perhaps 15 times over the course of weeks or months. Overall however, targets of opportunity should account for less than five (5) percent of observations. Observation of targets of opportunity should be performed by replacement of a planned target in a timescale of a few orbits. Reference 16 specifies a maximum response time of 12 hours, with a goal of a 3 hour response time. This capability should use standard procedures for the updating of preplanned timelines. Table 2-1 summarizes this requirement.

t) The capability to plan and execute alternate branches within the preplanned timeline is required for the space platform configuration.

Utilization of this capability for the Shuttle sortie case is considered unlikely, since it is not proposed to request significant changes to the timeline at short notice (i.e., a new target) in this mode. The frequency of branching operations will be commensurate with the amount of realtime astronomy conducted and in practice should be less than 10% of the operational load for normal operations. This restriction is important since utilization of branching provides additional complexity requiring constaint checking, maneuver and acquisition computations, and verification of end-state for all paths. In general, branching operations will be used for spectroscopic observations.

The primary function of branching sequences will be to provide flexibility in observing poorly understood or unpredictably variable objects (e.g., cataclysmic variables). Preparation of a branching sequence will require considerable additional planning, which will need to be justified. Utilization of this capability is not considered likely for early termination of an observation because adequate signal to noise has been achieved. In this situation, the start of the following observation would not normally be able to be initiated earlier than planned. Table 2-1 summarizes this requirement.

u) Realtime, or near realtime, data processing and analysis will be required to support routine monitoring of instrument performance and data quality, diagnostics and instrument optimization, and also interactive observing sessions. For an interactive observing session (probably spectroscopic) facilities will need to be provided for ground-assisted target acquisition and also for the display of astronomical data in a form suitable for decision-making by the astronomer. This area needs further study, but it can be assumed that the facilities would be similar to those used currently with ground-based photon-counting detectors. Specifically, the spectroscopic image (or sub-image) would need to be displayed in a 2-D grey-scale format to allow quick assessment of the overall data. Via cursor control and/or keyboard command, it should be possible to extract from the display, a sky subtracted spectrum of counts versus wavelength from the object of interest. This processing is likely to be performed on the raw image i.e., prior to flat fielding, distortion removal, etc. It will be essential to have hardcopy facilities to record raw images and processed data. The response time for these type of activities is covered in item p.

v) Special pointing requirements will be required for alignment of the spectrograph slit. No decisions have been made with regard to potential spectrograph acquisition modes, but three modes are likely: namely; blind pointing, onboard computer controlled acquisition, and ground assisted (or crew assisted?) target acquisition. Performance of the latter mode would need transmission of an image obtained via the direct imaging mode of the spectrograph (an image size of 256 x 256 pixels is possible). The centroid position of a reference object in the image would need to be determined by a cursor and/or by function fitting, with offsets automatically calculated and uplinked to place the target object in the slit. A second direct image may need to be transmitted for verification purposes before beginning the spectroscopic observations. Note that precise centering will only be required in one dimension (i.e. perpendicular to the slit), unless a coronagraphic-type aperature is used.

On the space platform it is possible that ground-assisted acquisition of a guide star (rather than a target) may be required in difficult fields. This may require transmission of the pointing system sensor star-field data, or starfield data from the Fine Guidance System (FGS). Table 2-1 summarizes this requirement.

3.0 OVERVIEW OF THE STARLAB SPACE SEGMENT

The Starlab facility will be carried in an attached payload configuration on up to two Shuttle sortie missions in order to provide a sufficiently early launch date for the facility. These early flights of approximately two weeks duration each will be followed by a series of flights on a space platform such as Leasecraft or the Space Station. Utilization of these different space segment configurations provides complications especially in the Starlab facility interface, since the avionics and capabilities provided by each configuration are dissimilar. In the Shuttle sortie configuration utilization of the Spacelab is required since the IPS is an integral part of this system. For the Space Station the configuration and capabilities are largely undefined at this time, whereas Leasecraft primarily utilizes a Multi-mission Modular Spacecraft (MMS) system. The solution of this interface problem is outside the scope of this document, but the impact of the utilization of the different configurations from a ground system standpoint must be considered.

3.1 FACILITY DEFINITION

The facility consists of a 1-meter f/15 modified Ritchey-Chretien telescope, and instrument bay, and data acquisition and control systems. It will be approximately 5 meters long and 2 meters in diameter and will weigh approximately 1800 kg., including instruments. The nominal telescope optical coating for general applications will be aluminum overcoated with magnesium fluoride, usable from 1150A to the near infrared. The telescope will provide a fully baffled field. A reflective corrector will direct the telescope beam to the DI instruments, mounted radially, and enable the entire 30 arc-min diameter field of an instrument to be recorded with very little degradation of image quality. An annulus of outer diameter 0.8 degrees and inner diameter 0.5 degrees surrounding a DI field will provide a guidance field for a Fine Guidance System (FGS). An uncorrected data field in the axial position will carry the multimode echelle spectrographs designed to accommodate slits up to 8 arc-min long. It is intended that simultaneous operation of a spectrograph and a DI over a significant fraction of the DI data field will be possible (serendipity mode).

In the attached payload configuration the IPS will be used to provide crude guidance via star tracker inputs. In the space platform configuration similar pointing capability will need to be provided. Fine guidance will be accomplished by the FGS. The fine guidance sensors will be mounted in both radial and axial fields, where there will be TBD FGS sensors: TBD for the DIs and TBD for the spectrographs. It is proposed that the spectrograph FGS sensors be capable of acting as backup for the DI and vice versa, where in the latter case there would be a sacrifice in the ability to orientate the spectrograph slit. A Guide Star Selection System (GSSS) will be needed to support utilization of the FGS. Access to the ST GSSS data base and/or utilization of ST developed systems and/or expertise should be explored to support this requirement.

The FGS will provide an image stability of 0.016 arc-sec rms and a minimum probability of acquiring a suitable guide star of 95 percent without target decentering at the galactic poles. This fine guidance will be accomplished via articulation of the telescope secondary mirror.

Bright objects must be avoided during telescope pointing. The avoidance angle for the Earth will depend on whether the limb is dark or bright. However, the dark and bright Earth avoidance angles are not fixed quantities, but will be dependent on the position of the terminator, instrument used, wavelength range, target brightness, etc. Faint objects will require the darkest possible sky and observations in the far ultraviolet (UV) may require higher angles to minimize atmospheric absorption. In addition, it is anticipated that less stringent conditions will apply to the FGS, depending on the magnitude of the guide star. Typical requirements are presented in Table 6-6 in Section 6-2. However, reference should be made to Starlab requirements specifications for precise values. In addition, consideration will have to be given to moon avoidance, bright star avoidance, zodiacal light background, and avoidance of the bright or dark Orbiter surface. The sensitivity of Starlab to the ram effect is TBD at present. A cover with automatic closure within TBD degrees of the sun will be fitted, but this is a contingency safety device and should never be exercised under normal operations.

The sensitivity of the two instruments and the FGS to the South Atlantic Anomaly (SAA) may be different and the capability of modelling more than one constraint is therefore required. In addition, the model should be adaptive allowing modification when necessary. It must be possible to switch the FGS into a standby mode during passages through the SAA. Observations of bright targets or calibration exposures may be performed during outer SAA regions.

Roll pointing precision is required to be 0.25 x narrowest spectrograph slit width or 15 arc-sec rms. This precision would be provided by the IPS in the attached payload configuration.

Two instrument types will be carried in the instrument bay. Two DIs mounted radially and two spectrographs mounted axially. The DI will have a

30 arc-minute field of view and utilize two detectors to provide coverage of the ultraviolet and visible/near infrared spectral regions. A total of 24 and 24 filters are proposed for the ultraviolet and visible/near infrared detectors respectively. Two grisms (one per detector) provide spectral resolution across the entire 30 arc minute field of view for both spectral regions.

The detectors will be of the photon counting type with a diameter of 90 or 130 mm. These detectors provide 2-dimensional image registration over up to 10,000 x 10,000 pixels. The filter accommodation and detector size for the spectrographs are TBD.

Data acquisition and control functions will be provided by various onboard computers. These include the Starlab Computer (SLC), the Telescope Computer (TC), and Instrument Computer (IC). In general several baseline and non-baseline functions are likely to be provided. Table 3-1 presents a preliminary breakdown of likely functions for the various computer systems. Table 3-2 provides several additional functions which may be considered for potential inclusion.

3.2 FACILITY OPERATIONS

The multi-mode spectrographs have been designed for on-orbit operational autonomy. There are three modes of operation.

- Low dispersion: three mirror surfaces, four interchangeable fixed angle gratings used in first order. Ultraviolet cutout filters can be used in long wavelength bands. The maximum resolution is 5000, and maximum slit length 8 arc-min throughout the 1100-8000A range.

Table 3-1: Onboard Data Acquisition and Control Functions (Preliminary)

System	Function
SLC	Facility control including: -- Power distribution and management -- RAU interface management of TC and IC interfaces. -- Starlab CDMS Management (SLC/TC/IC buses, etc) including: redundancy management -- Performance of facility level functions including o command buffering, preliminary decoding, routing, etc. o telemetry buffering o DEP load buffering o Formatting and buffering DEP dumps.
TC	Telescope control including: -- Command handling (decoding, execution, verification, etc.) -- Telemetry acquisition and dispatch (and monitoring functions) -- Management of TC CDMS -- Housekeeping - control of mechanisms, power supplies, thermal control, etc. -- FGS control -- Test and diagnostics
IC	Instrument package control including: -- Commands -- Telemetry (including monitoring) -- Management -- Housekeeping -- Test -- Control of Accumulating Memory (AM) [dump, etc]

Table 3-2: Potential Onboard Functions

a) A high time resolution mode to satisfy requirements detailed in item 2.2 g)

b) Full-field image compression

c) Selectable readout of memory (selected area of pixels and selected bit depth)

d) Realtime monitoring of image buildup

e) Onboard algorithms including possibly an automatic acquisition mode for the spectrograph, sub-stepping control, and spacecraft ephemeris generation (for spectrograph doppler corrections)

- High dispersion: two mirror surfaces, four interchangeable, fixed angle cross disperser gratings used in first order and two interchangeable echelles optimized for long and short wavelengths. Ultraviolet cutout filters can be used in long wavelength bands. The maximum resolution is 10^5. Maximum slit length is 30 arc-sec without order overlap throughout the 1100-8000A wavelength range.

- Direct imaging: four mirror surfaces. This mode will be used for acquisition of very faint objects. The maximum field size is 8 x 0.5 arc-min over the wavelength range 1100-8000A.

Incorporation of two charged particle monitors is proposed to enable automatic reduction of instrument detector high voltages upon recognition of event rates above a predetermined threshold. This situation could occur during passages through the SAA. In general mechanisms including assemblies for filter wheel rotation are being designed for simultaneous operation, when desirable. Movement times of less than ninety seconds are planned.

Present engineering studies indicate that due to thermal dissipation, it will not be possible for both DIs to be fully powered up simultaneously. Furthermore, the warmup time may be as long as 12 hours before normal observations can commence. During this warm-up period neither DI will be available for astronomical observations or serendipity observations, and therefore the spectrographs must be scheduled at these times. The actual instrument warm-up characteristics and constraints will be defined during Phase B.

There is a requirement that both spectrographs can be operational at any one time, at least in low resolution mode, and preferably in all modes. This is essential to allow successive ultraviolet and visible spectroscopy of time-variable objects. It is also assumed that switching between spectrographs does not require a warm-up period. Serendipity observations are possible with either DI while either spectrograph is gathering data.

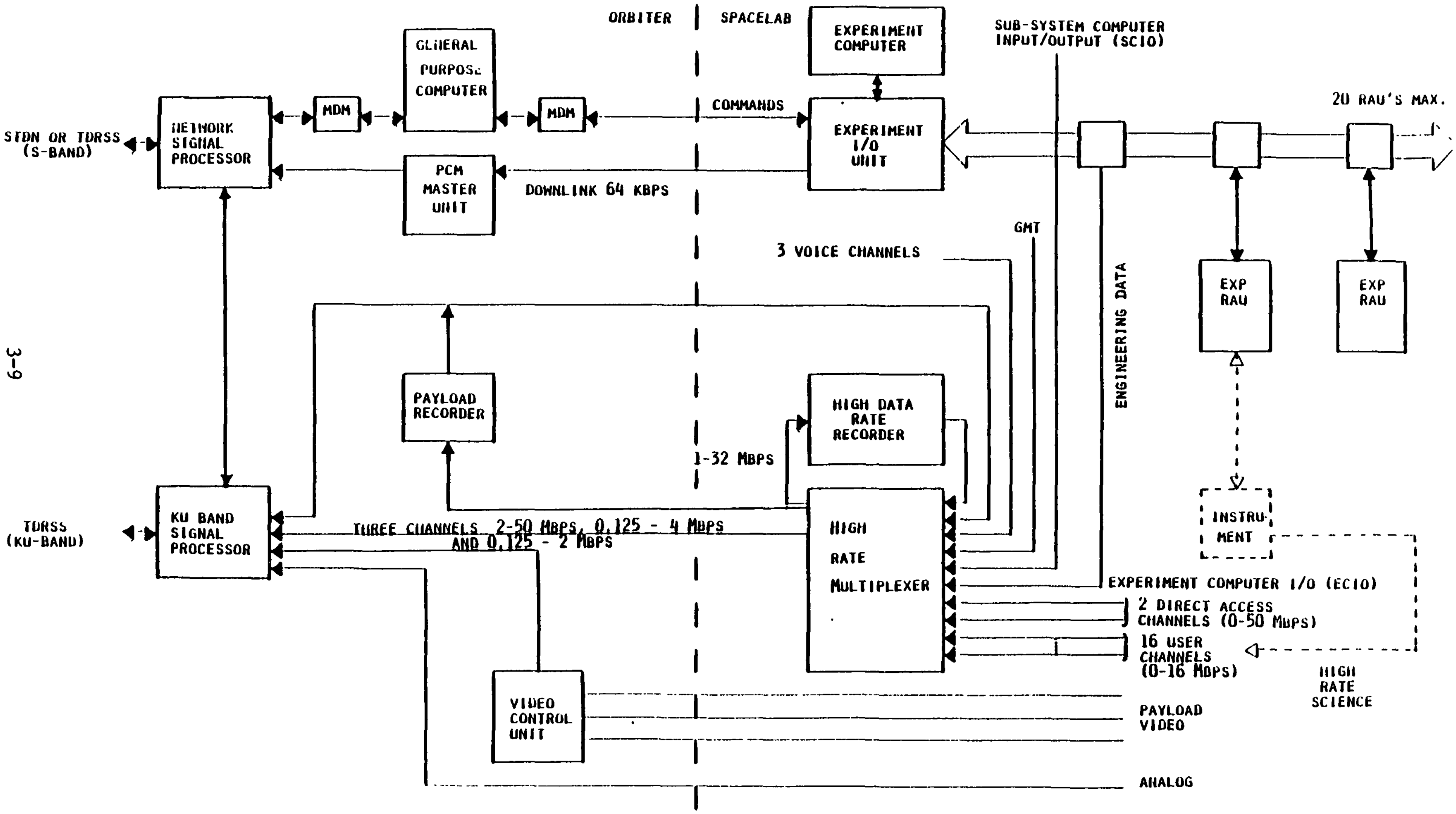
At present, the immunity of the DI detector to bright sources with the possibility of permanent damage is TBD.

3.3 SPACE SEGMENT CONFIGURATION

3.3.1 Shuttle Sortie

A three-pallet train to mount the Starlab facility carried on the IPS is planned. An overview of the Spacelab data system for supporting an attached payload in the Shuttle sortie configuration is shown in Figure 3-1. The Starlab will be interfaced with this system via Experiment Remote Acquisition Unit(s) (RAU) and a direct link(s) into the High Rate Multiplexor (HRM) for downlink of high rate science data. (An alternate approach using a Direct Access Channel (DAC) is available for the latter, but its use is considered unlikely). The RAUs are connected to the Experiment Computer (EC) via the Experiment I/O Unit. The RAUs provide for transfer of commands between the ground and/or the Aft Flight Deck (AFD) under control of the EC. Engineering data from the Starlab would normally be included in the Experiment Computer Input/Output (ECIO) data stream for downlink via the HRM and for transfer to the AFD for onboard monitoring by the crew. Alternately the engineering data could be multiplexed with the high rate science data and input into the HRM experiment channel. However

FIGURE 3-1: SPACELAB DATA SYSTEM (OVERVIEW)



without inclusion in the ECIO stream the data would be unavailable at the AFD. The ECIO stream containing multiplexed data from all instruments using this capability has a data rate of 51.2 kbps and is transferred via the Ku-band signal processor on channel 2.

High rate science data with a data rate of 16 Mbps will be transferred from Starlab to the HRM. This data may be downlinked directly via channel 3 or stored on the HDRR for later playback. The HDRR is played back through the HRM at 32 Mbps again for downlink via channel 3. The process of storing data on the HDRR following HRM processing with subsequent playback via the HRM produces data, which is multiplexed twice. Demultiplexing twice on the ground using a High Rate Demultiplexor (HRDM) is therefore required. Full details of the capabilities provided by these various Spacelab elements may be found in reference 5.

The data streams required for support of the Starlab during operations (realtime and near realtime analysis), offline analysis and scientific analysis are shown in Table 3-3. This table has been prepared using the assumption that engineering data will be included in the ECIO. The need for each data type is included. It is evident that a considerable number of data streams must be correlated in order to perform certain types of analysis. This requirement may be reduced by multiplexing specific data streams onboard as required.

An overview of the Starlab facility showing the interface with the RAU and the HRM as presented in Figure 3-1 is shown in Figure 3-2. Again, this shows the inclusion of engineering data into the ECIO. In the case where the engineering data is multiplexed into the high rate science stream, it

Table 3-3. Data Availability Requirements for Shuttle Sortie Configuration

Data Type / Function Supported	Operations	Off-line Analysis	Scientific Analysis	Reason data type required
STS				
Operational Downlink (OD)	S^*	S	S	STS Ancillary information
Payload Data Interleaver (PDI)				
Video	P			View from the AFD, unlikely inclusion of video signal on Starlab
Voice	Y			Operations Coordination
Spacelab - High Rate Multiplexor (HRM)				
Direct Access Channel (DAC)	P^+	P^+	P^+	
Experiment Channel	S	Y	Y	High Rate Science data downlink
Experiment Computer Input/ output (ECIO)	S	S	S	Engineering data from Starlab
Subsystem Computer Input/ Output (SCIO)	S	S	S	IPS Status
GMT	Y	Y	Y	Time correlation of all data types
High Data Rate Recorder (HDRR)	Y	Y	Y	Downlink of stored HRM data
Payload Recorder (PR)				

KEY

S - Subset Required

P - Potential Requirement

Y - Yes

* - Available via Shuttle/POCC Interface Facility (SPIF)

\+ - Only required if experiment channel not utilized. This is considered unlikely.

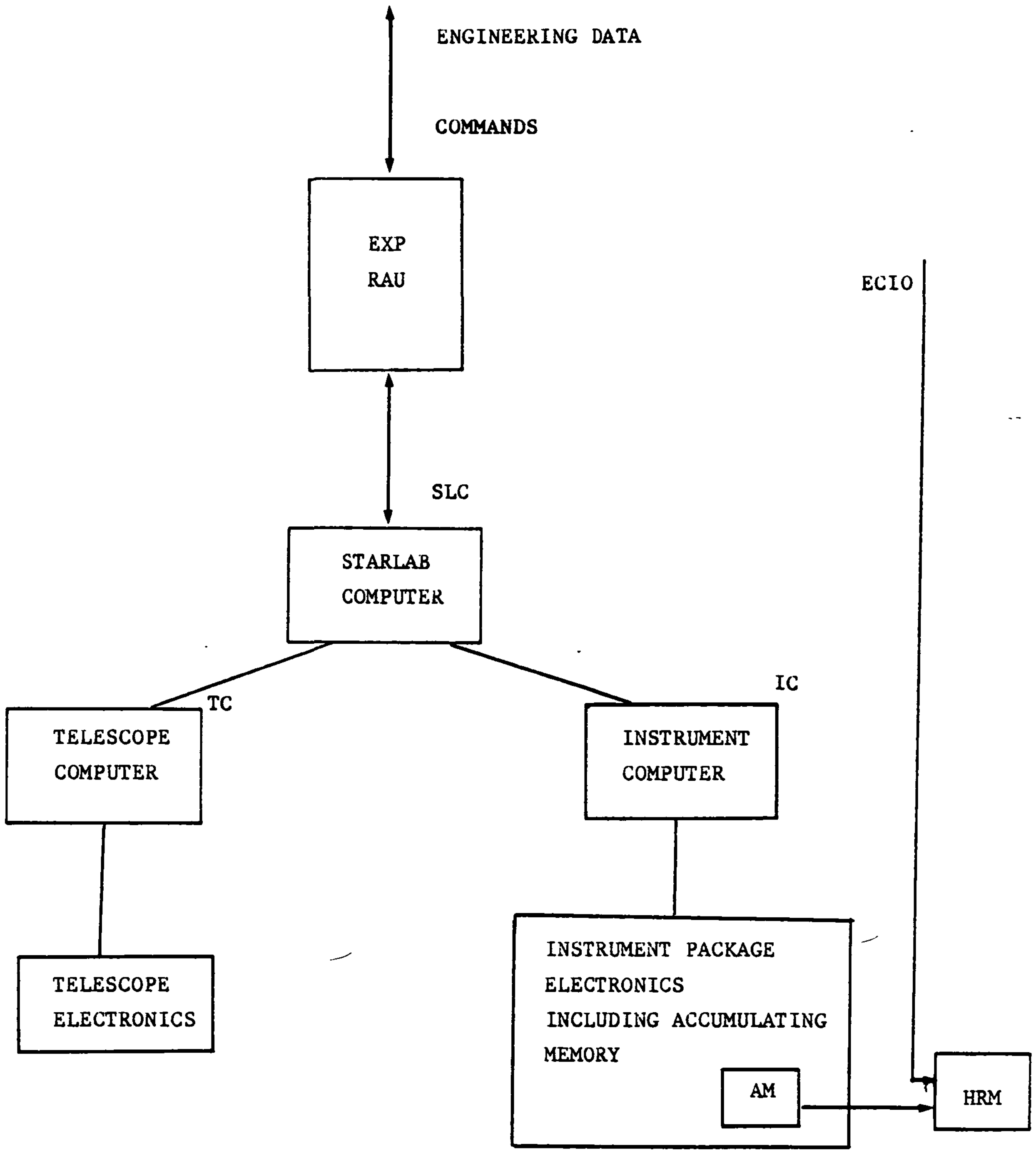


Figure 3-2. Overview of Starlab Facility Showing RAU and HRM Interfaces.

would still be necessary to provide duplicate status into the ECIO to support AFD operations.

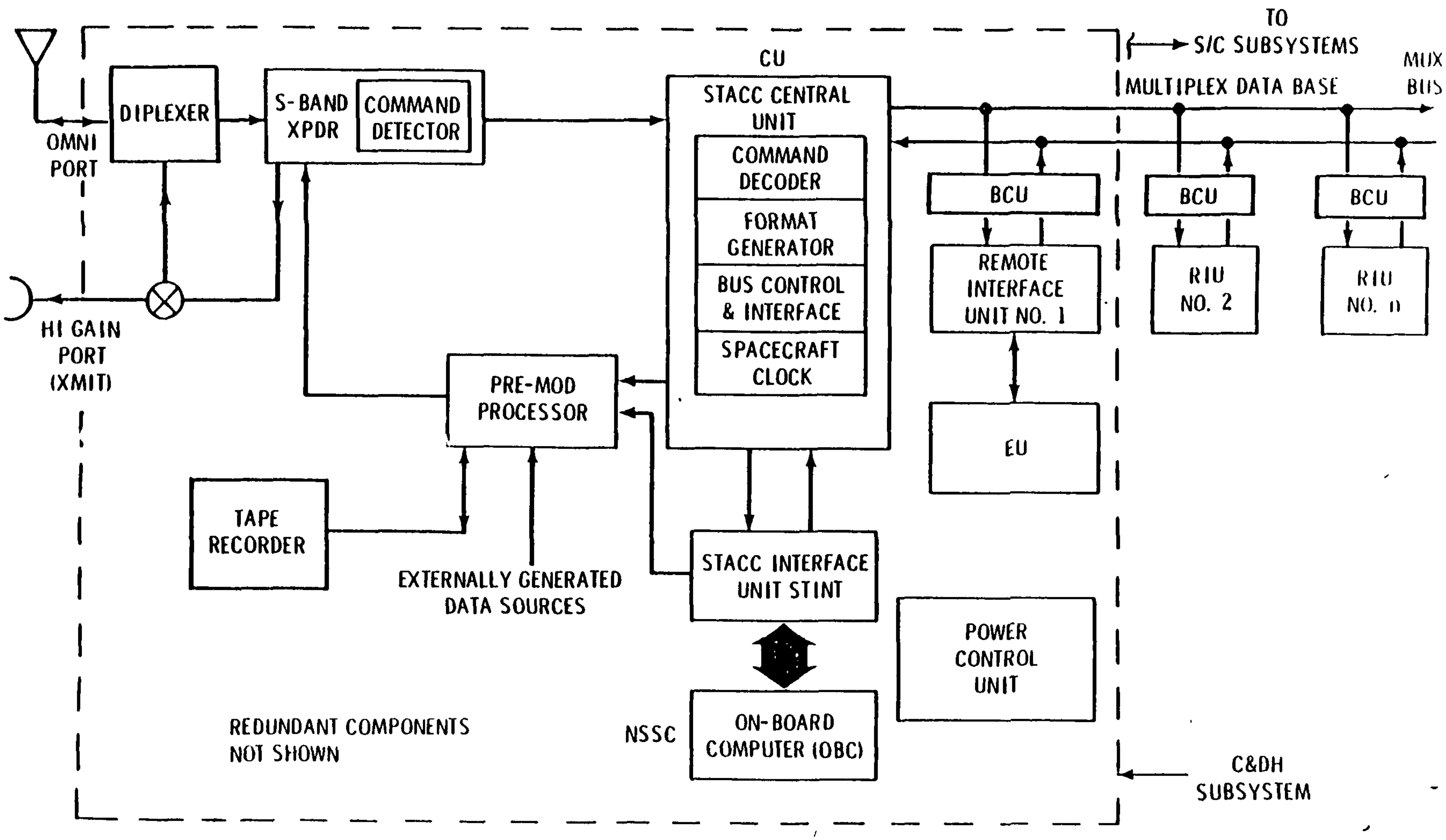
3.3.2 Space Platform/Station

A potential Leasecraft Command and Data Handling (C&DH) subsystem overview is shown in Figure 3-3. This C&DH subsystem is based on the Multi-mission Modular Spacecraft (MMS) subsystem which has been configured to support the Solar Maximum Mission (SMM) and Landsat. The Pre-Modulation Processor (PMP) provides the necessary signal conditioning and processing. Up to two separate data channels can be transmitted simultaneously, where data channel selection is by command control with candidate channels derived from the Central Unit (CU) (return link telemetry), Tape Recorder (Tape playback), Standard Interface for Computer (STINT) (computer memory contents), plus possibly a number of externally supplied relatively high data rate channels.

The forward link command and data signals are detected in the transponder receiver/detecter and delivered to the NASA Standard Telemetry and Command Components (STACC) CU as digital signals for distribution both within and external to the C&DH module. The forward link signals provide realtime commands, delayed commands (for storage in the Onboard Computer (OBC) memories), and OBC programs (also for memory storage).

The STACC system (CU, Remote Interface Unit (RIU), Electronic Unit (EU), Bus Coupler Unit (BCU), and STINT) utilizes the Multiplex Data Bus (MDB) supervisory and supply lines for the distribution and control of telemetry and command functions both within the C&DH subsystem and to all other Leasecraft functions.

Figure 3-3. Potential Leasecraft C&DH Subsystem Overview



The CU serves as the central distribution for both telemetry and command. A BCU is interposed between the RIUs and MDB for fault protection. Telemetry channel capacity increase is available by addition of an EU, which functions in conjunction with the associated RIU. The OBC provides auxiliary control of telemetry and command functions. Communication with the various subsystems is accomplished via the CU and MDB. All signals to and from the OBC are routed through the STINT. The OBC can provide control of the downlink telemetry format (otherwise derived from the CU), issue stored commands, and request telemetry data for internal use. The Leasecraft downlink telemetry data rate characteristics and onboard tape recorder storage capacity are TBD at present.

No details exist on the Space Station system at this stage.

3.4 SPACE SEGMENT OPERATIONS

3.4.1 Shuttle Sortie

Command of the Starlab may be performed from the ground or the AFD. In each case the EC provides command handling functions. The Mass Memory Unit (MMU) may be used to store command sequences and sets of commands for execution under timeline control. The IPS is controlled by the Subsystems Computer (SC).

Generation and initiation of the following command categories is provided from the ground.

a. Commands to initiate EC Operating System (ECOS)/EC Applications Software (ECAS) functions (e.g. Dedicated Experiment Processor (DEP) load, timeline maintenance)

b. Commands to make data inputs to ECOS/ECAS (e.g. constants, timeline inputs)

c. Experiment RAU Discrete Outputs (on/off)

d. Experiment RAU Serial Outputs

e. IPS pointing commands through the SC.

Commands to Spacelab and for payload functions when utilizing Spacelab are transmitted in blocks of 32 words, where each word is 16-bits. The maximum rate for transmitting these commands through the MCC/Orbiter system is approximately 1 block per second or 512 bps. In general, commands may be:

a. Single stage - Approximate 1 second execution rate per block with command rate of 512 bps.

b. Two stage - Rate of approximately 1 block every 10 to 30 seconds or 18-52 bps.

In addition, a modification to send commands single stage, but with a check on the block zero word count has been incorporated within the MCC. This utilizes the fact that BCH encoding provides a confidence of approximately 1 in 10^{15} that commands with no error detected have been received correctly. This technique allows the use of single stage commanding with high confidence. A maximum throughput of nearly 1 block per second or 512 bps is possible. Current requirements indicate that a command rate of 512 bps is needed for Starlab.

Note, that an MMU data set is 512 words and takes approximately 6-10 seconds to transmit from the ground. Also, a master timeline data set is 512 words and subordinate timeline data set 100 words.

Control of the IPS is currently planned under normal circumstances to be an Orbiter crew function. Both digital input (i.e., input Right Ascension (RA) and Declination (DEC)) and analog inputs (i.e., joystick) are provided onboard. Ground capability through the MCC currently only has the digital input capability. In addition, at the present time utilization of the ground for IPS commanding is not recommended. Software to verify that planned IPS pointing movements do not create a safety hazard (i.e., impact the payload doors, other payloads) are run pre-mission. No software capability exists at present to perform this verification in realtime. During crew control of the IPS, the system is in constant view from the AFD. If ground control is allowed the following two constraints are likely with the current capability.

a) Crew members will have to be awake and on duty to monitor IPS movement for safety compliance.

b) Only small movements (i.e., fine pointing) will be allowed and no changes to the target observed are likely.

Starlab has a requirement to provide continuity of the ground systems capability and operations concept between the Shuttle sortie and space platform configurations whenever possible. The capability to operate the IPS from the ground is therefore required, although utilization of crew involvement to support this function is not precluded. The latter constraint above is therefore not consistent with this requirement.

Further, inclusion of analog capability at the ground would be a requirement. Expansion of the ground capability is likely to require inclusion of necessary safety compliance software within the MCC.

Starlab telemetry will include engineering data output through the RAU into the ECIO data stream and transmitted via channel 2 and high rate science data. The ECIO data stream has a data rate of 64 kbps and is available both in realtime and from HDRR playback. Ground processing is required to extract the Starlab engineering data subset from the ECIO stream and to perform processing of the resultant data. The telemetry rate for the high rate science data downlinked in realtime on channel 3 will be 16 Mbps. When this data is stored onboard on the HDRR, playback will be at 32 Mbps. The maximum Starlab science data output rate in the Shuttle sortie configuration can therefore be 48 Mbps (16 + 32), when both realtime and playback data are downlinked.

3.4.2 Space Platform/Station

Operation of the Leasecraft from the MSOCC facility is currently proposed for the first two Leasecraft missions. This facility provides a range of general-purpose hardware/software systems to support a multi-satellite environment. The facilities are fully operational and undergo planned enhancement/development in order to provide up-to-date support for approved missions. Following the first two missions, consideration is being given to the development of a MSOCC type facility at the Fairchild Space Company facilities in Germantown, Maryland. If a facility of this type is developed, it is highly likely that it would be utilized to support Starlab, since the projected initial Starlab launch date in 1990 would use a Leasecraft mission in the mature operational phase. In this eventuality, consideration would have to be given to the distribution of functions and the interfaces between the Germantown MSOCC type facility, any GSFC institutional facilities utilized, and the DAF.

No details exist for the Space station configuration.

3.5 GROUND SYSTEM CONSIDERATIONS

The following preliminary ground system considerations have been identified. Table 3-4 provides a summary of these requirements.

a. In the Shuttle sortie mode the MCC has ultimate command of the Orbiter flight and control of all resources and safety aspects including the Spacelab elements. Control of the space segment to support required experimentation must therefore be performed through and coordinated with the MCC. In particular, the scheduling and utilization of all crew support must be coordinated with the JSC Crew Activity Planning System (CAPS). In addition, the JSC POCC can provide a range of standard capabilities and services to Starlab as an attached payload. If the JSC POCC is not utilized similar capability needs to be provided by a remote POCC. For the space platform, the situation is either different or presently undefined. A Leasecraft type platform could be supported from a POCC such as the GSFC Multi-Satellite Operations Control Center (MSOCC). This capability supports the space segment for a free-flyer of this type and in addition provides various capability for supporting payload health and safety. For the Space Station, the ground elements are presently undefined.

Table 3-4. Ground System Considerations Derived from the Space Segment Requirements

[Item numbers refer to sub-section numbering in the text]

Consideration	Configuration	
	Shuttle Sortie	Space Platform
a. Control of the Space Segment	● MCC has ultimate command of the flight and control of all resources and safety aspects including Spacelab elements.	● Leasecraft - supported by MSOCC type facility. ● Space Station - undefined at present.
b. Pointing System Control	● Ground control of the IPS currently fairly limited ● Upgrade is likely to need modification of MCC software and procedures. ● Crew operations involvement	● Pointing control is a standard ground operations function for Leasecraft and probably the unmanned element of the Space Station.
d. SA link availability	● Good based on Shuttle mission priority.	● Leasecraft - substantially lower priority than Shuttle, and requirement for sharing resources with other payloads ● Space station - Probability of a high priority for SA link access. Likelihood of a large number of payloads to share resources.
e. Timeline generation responsibility	NASA team with Starlab project personnel support	NASA team with Starlab project personnel support
f. Coarse pointing control characteristics	● Orbiter and IPS provided ● 0.25^{o} per second slew rate for Orbiter ● Average slew time for Orbiter and IPS including settling of 15 minutes	● Space platform provided

Table 3-4 Ground System Considerations Derived from the Space Segment Requirements (concluded)

[Item numbers refer to sub-section numbering in the text]

Consideration	Configuration	
	Shuttle Sortie	Space Platform
	o Average Slew time for IPS only including settling of 8 minutes.	
h. Coarse pointing control characteristics	o Potential for large overhead due to RCS firings introducing disturbances outside present IPS specifications o Lost observing time potentially in the range 8-75 minutes per orbit. o Introduction of additional operational constraints such as utilization of the "free drift mode". Potential for increased timelining complexity and downlink requirements	o Capability consistent with FGS operational requirements
i. Operational Support	o Centralized at Starlab Ground System.	o Starlab Ground system plus remote locations o Quicklook data transmitted to remote locations, but actual operations confined to the Starlab Ground System o Link bandwidth of $\geqslant$ 50 kbps to support remote locations o Preferable that remote locations have capability to interactively select required data.

b. As already described ground control of the IPS in the attached mode is currently fairly limited. In the space platform configuration ground control of the pointing system will be a requirement. For a Leasecraft type system this control could be supported from an MSOCC type facility directly. In the case of the Space Station the situation is not defined at present. An upgrade to available capability in the attached mode will therefore be required in order to provide continuity between Starlab configurations.

c. Limited command uplink rate is available with the attached Shuttle configuration (refer to Section 3.4.1). This is currently a concern to Starlab. It is possible that much higher capability will be made available with the space platform allowing support for more extensive operations from the ground system. Insufficient details are available at the present on potential Leasecraft and/or Space Station capabilities.

d. Telemetry rates for the DI in the attached configuration are 16 Mbps for realtime transmission of imagery and 32 Mbps for HDRR playback. In addition, a lower output mode with a rate of less than 50 Kbps will be available. The higher rates require the Single Access (SA) mode on the Tracking and Data Relay Satellite System (TDRSS), whereas the lower rate may be transmitted Multiple Access (MA). Use of the MA link enables virtually continuous coverage (with the exception of the Zone of Exclusion (ZOE), etc.) for monitoring purposes, but with substantially increased downlink times for normal image data.

In the attached mode, the required access to the SA link is likely to be available, based on the priority of the Shuttle as a manned mission.

A requirement for approximately 4 minutes SA link availability per orbit was determined for the space platform configuration based on a mission profile analysis (reference 8). However, it was stated that this value should be increased by a factor of 10 based on a number of considerations (reference item 2.2 i)). Assuming utilization of the HDRR this would correspond to a requirement for approximately 20 minutes SA link availability.

In general, scheduling of this SA link time may be made either using generic or specific scheduling. Generic scheduling is likely to provide increased link availability and reduced conflicts, especially under conditions of heavy TDRSS usage. However, use of this mode can require careful consideration in the development of planning and scheduling concepts and/or systems. The DOS currently considers that it would be exceedingly difficult (or impossible) to construct an observational schedule that took advantage of generic scheduling unless constant use is made of the HDRR or another suitable tape recorder. This conclusion was reached since exposure timing must be determined by astronomical/orbital requirements and cannot be subject to change at short notice because of sudden changes in TDRSS availability for direct data transmission. Further, even if generic scheduling could be used via utilization of short-timescale flexibility (minutes) in the timing of tape recorder playback, there would always be a need for specific scheduling to support for instance ground-assisted target acquisition.

In the case of the attached Shuttle configuration the mission priority is likely to provide sufficient link availability. The availability of SA link time for the space platform configuration is somewhat more in question, based on current program status and the possibility of support requirements for large numbers of payloads. For a Leasecraft type platform, it is likely that the platform will have substantially lower priority than for the Shuttle sortie case. The time available will also possibly need to be shared amongst a number of users. The Space Station is likely to have a far higher priority, but may carry substantially more payloads on the unmanned element than for Leasecraft.

e. For the Shuttle sortie configuration timeline generation will be performed by a NASA team with Starlab project personnel support. A corresponding operation is proposed for the space platform.

f. Coarse pointing will be performed by the Orbiter and IPS for the Shuttle sortie missions. On the space platform the platform itself will provide pointing capability.

g. Additional time is required for acquisition to provide precise alignment of the spectrograph slit. A time of 5 minutes is currently assumed for this procedure.

h. There is concern with regard to the operational characteristics of the Orbiter Reaction Control System (RCS). There is a possibility that as many as 450 RCS firings per orbit could be required. The resulting disturbances are outside the present specifications of the IPS which would require approximately 10 seconds to return to a quiescent state (not to mention any additional time required by the Starlab FGS to recover fine acquisition). This would require an overhead of approximately 75 minutes per orbit which is clearly intolerable. The RCS firing rate may be reduced to approximately 50 per orbit by optimizing the Orbiter attitude to minimize atmospheric torques. This introduces a further constraint, which will conflict at times with Starlab pointing requirements. In any event at least 8.5 minutes per orbit would still be unusable. This area obviously needs investigating since this latter number could easily be exceeded based on inclusion of all constraints.

Utilization of a "free drift mode" whereby the Orbiter is allowed to drift for approximately 10 minutes while the IPS tracks the guide star is a possible solution. At the end of this interval, the RCS system would return the Orbiter to the nominal attitude. This mode would replace unpredictable thruster firings by single bursts at presumably predictable times. This mode would permit Starlab pointing requirements to be met but would incur two penalties. First, observing time would be lost during the Orbiter/IPS/FGS attitude recovery. Second, long exposures (i.e. > 10 minutes) would not be possible. This would make the timeline scheduling more complex, and result in an increase in downlink data rates.

i. Operational support requirements differ for the two configurations. Refer to Table 3-4.

4.0 OVERVIEW OF THE MISSION OPERATIONS CONCEPT

The Starlab mission operations concept is required to provide coordination of all mission operations functions including crew operations. In the attached Shuttle sortie configuration, the crew are an integral part of the operations having involvement in many realtime operations functions including control of the IPS. In the space platform configuration, the operations are completely supported from the ground.

4.1 MISSION PLANNING PHASE

For all configurations, mission analysis and planning functions are required for the definition of appropriate requirements, capability and resources necessary for successful operations. The definition of the requirements for supporting data preprocessing and processing, and data analysis functions must be defined in these analyses. As stated in Section 2.2 a) the majority of Starlab observations will be preprogrammed.

The mission planning phase provides performance of the following functions:

- o Definition of orbit requirements (An inclination of 28.5° as a standard STS orbit has been selected for the performance of mission profile analyses, although a lower inclination is preferred)
- o Selection of candidate targets
- o Definition of Starlab instrument observation constraints
- o Definition of target observation requirements

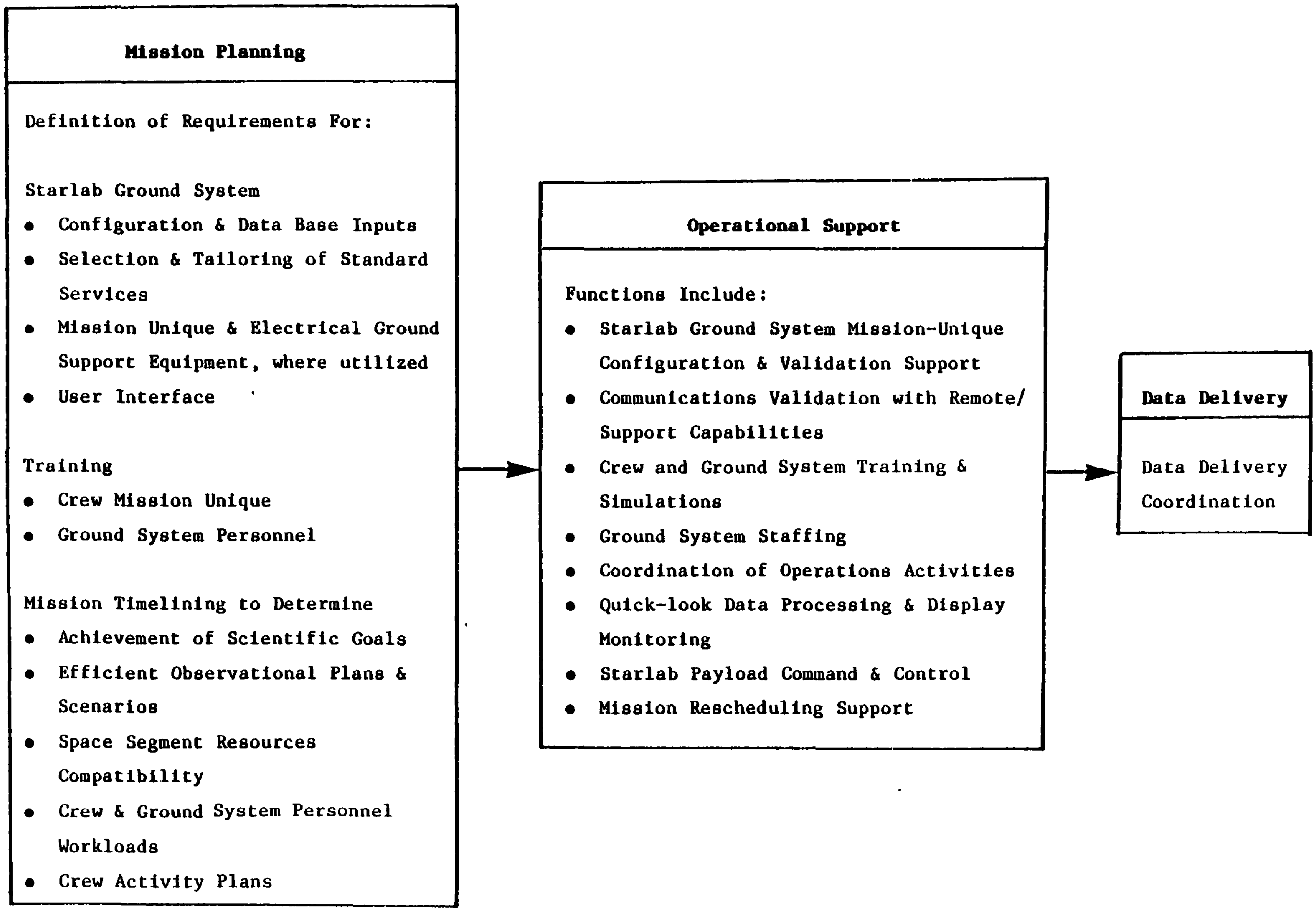
- o Starlab - space segment compatibility assessment. For the attached Shuttle sortie configuration this includes compatibility with the Space Transportation System (STS) and the Spacelab including IPS.
- o Identification of special hardware, software, and support services requirements
- o Identification of potential problems from a resource and/or operational standpoint
- o Evaluation of satisfaction of overall program objectives.

An overview of the functions required for mission operations support is shown in Figure 4-1. This figure refers specifically to the attached Shuttle sortie configuration, but is generic enough to represent many aspects of the space platform case (note: no crew are available in this mode).

4.2 INTEGRATION AND TEST CONCEPT

Integration and test of the Starlab facility with the space segment will be a function of the configuration based on the significant differences between the ground flows and interfaces for the STS/Spacelab and the space platform. Full details of this activity are outside the scope of this document. However, the elements effecting the mission operations concept need to be considered.

The availability of EGSE will be required to support various phases of the ground flow and/or operations. These include:



Mission Planning

Definition of Requirements For:

Starlab Ground System
- Configuration & Data Base Inputs
- Selection & Tailoring of Standard Services
- Mission Unique & Electrical Ground Support Equipment, where utilized
- User Interface

Training
- Crew Mission Unique
- Ground System Personnel

Mission Timelining to Determine
- Achievement of Scientific Goals
- Efficient Observational Plans & Scenarios
- Space Segment Resources Compatibility
- Crew & Ground System Personnel Workloads
- Crew Activity Plans

Operational Support

Functions Include:
- Starlab Ground System Mission-Unique Configuration & Validation Support
- Communications Validation with Remote/ Support Capabilities
- Crew and Ground System Training & Simulations
- Ground System Staffing
- Coordination of Operations Activities
- Quick-look Data Processing & Display Monitoring
- Starlab Payload Command & Control
- Mission Rescheduling Support

Data Delivery

Data Delivery Coordination

FIGURE 4-1
Mission Operations Support Phases

a) Instrument development and calibration in Australia and facility development and calibration at the developer site in Canada. Utilization of EGSE for this function is a developer decision, but availability of the same EGSE or EGSE of similar type to that needed to support operations will facilitate both crew and/or ground systems operations personnel training. In the STS arena, the conduct of operations personnel training at the development site has been shown to be cost effective based on reduced requirements for simulations capability.

b) Payload integration and test ground flow support. For the STS, ground flow processing with the Spacelab and Orbiter will be conducted at the Kennedy Space Center (KSC). Again, utilization of available time during this flow for operations personnel training has been shown to be advantageous, and utilization of the same or same type of EGSE as utilized for operations support will facilitate this activity.

c) Operations support at the POCC. The JSC POCC provides a range of standard capabilities and services to an attached payload. These include various standard data processing services for payload engineering and/or science data, where these services include functions such as demultiplexing, data stream or data subset extraction, performance of arithmetic and simple processing functions, and data monitoring and display. In the case of payload engineering and science data, the JSC POCC processing capability is limited to data streams of 2 Mbps or less. For streams of higher rate, the data may be made available to EGSE. The availability of EGSE to perform required processing functions is therefore required for Starlab based on identified data rates. Coordination of the functions performed by this EGSE by the three participating countries is required.

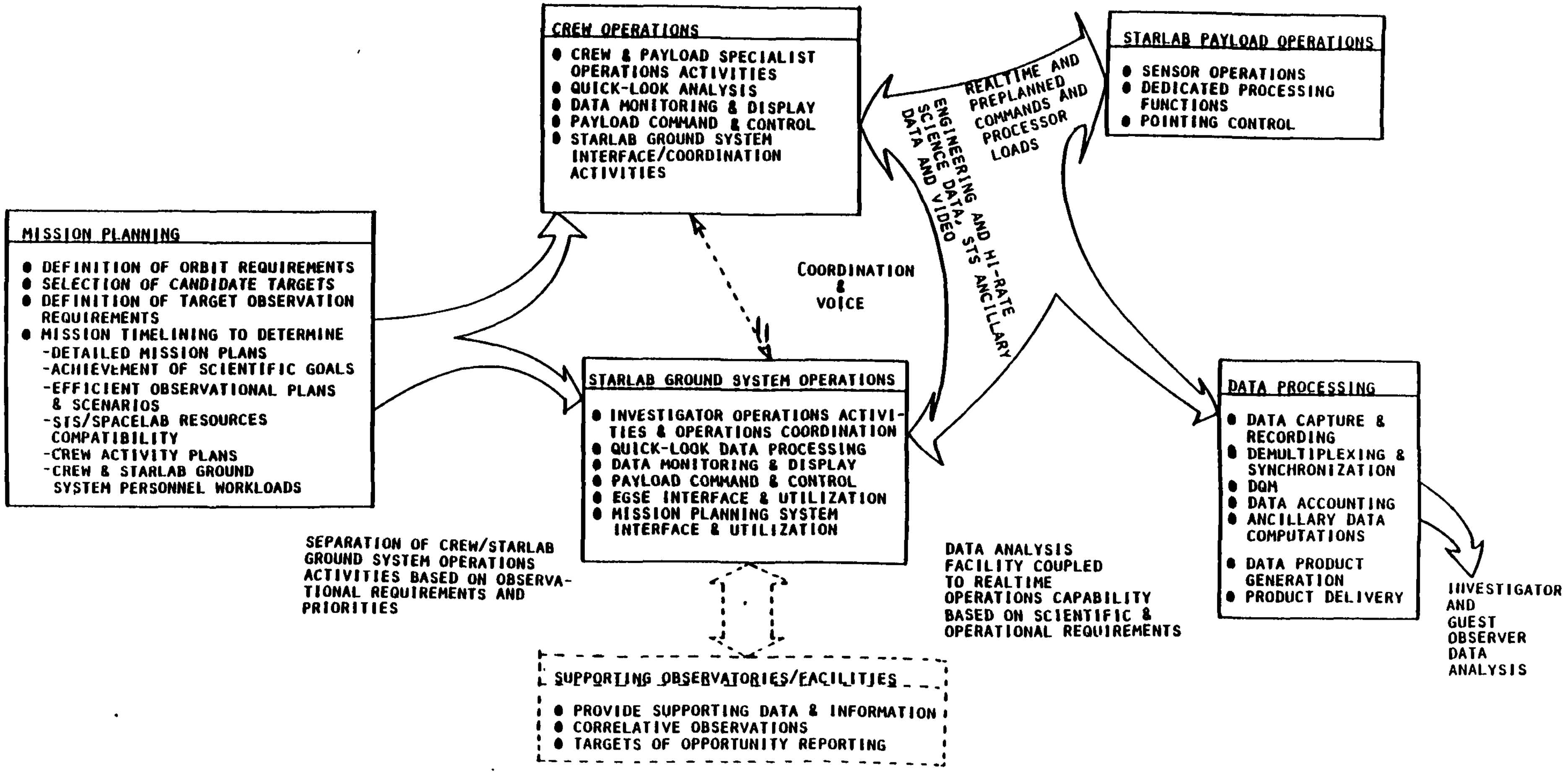
Utilization of a remote POCC capability may be considered for Starlab. In this event, EGSE is still likely to be a requirement. For the space platform case, the same applies. The MSOCC facility or a facility of similar type which could be utilized to support a Leasecraft type platform can provide similar data processing services to the JSC POCC for data streams with maximum rates of approximately 256 kbps. The MSOCC is continually being upgraded to meet future mission requirements and current plans are to install substantially increased processing capability in the form of 3 Mips machines. However, this capability would still be insufficient to meet Starlab requirements and therefore special purpose EGSE would still be needed. For the Space Station, the situation is undefined.

4.3 NORMAL OPERATIONS CONCEPT

4.3.1 Shuttle Sortie

The requirements for supporting Starlab science operations for the Shuttle sortie configuration are shown diagrammatically in Figure 4-2. The functions to be performed by the Starlab Ground System are presently planned for support out of the JSC POCC, where the EGSE will be resident within one of the seven user rooms. The possibility of developing alternate remote POCC capability is currently under review. If a remote POCC capability is developed, this facility would provide similar capability and be interfaced with the MCC in accordance with the requirements detailed in reference 7. The mission planning function supports both

FIGURE 4.2: STARLAB REQUIREMENTS - SCIENCE OPERATIONS



operations from the crew and the Starlab Ground System. Close coordination of these operations activities must be provided. Voice, downlink video, and Text and Graphics System (TAGS) uplink capabilities are available to support this coordination, in addition to the command and telemetry functions. The TAGS system provides an uplink facsimile service.

Data product generation for the Shuttle sortie case will be provided by the SLDPF as a standard service for Spacelab payloads. Any required coupling between this data processing function and the Starlab Ground System must be identified.

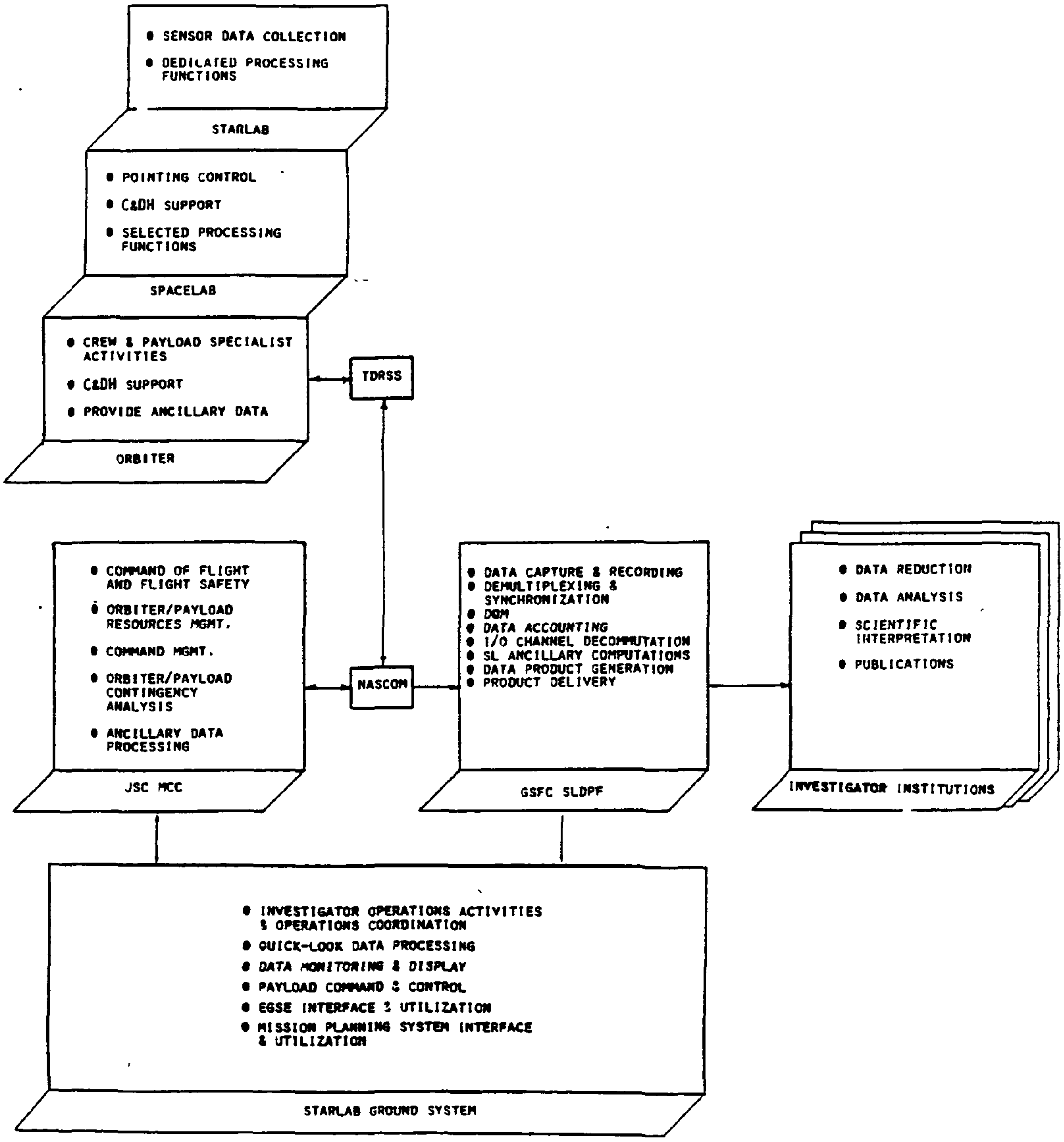
Support from other observatories and facilities for providing target of opportunity reporting, supporting data and information, and correlative observations is shown. The need for and form of this support requires definition.

Figure 4-3 provides a mission operations overview for the attached Shuttle sortie configuration. The MCC has responsibility for the command of the flight and all flight safety aspects. The JSC POCC is interfaced with the MCC and provides required functional capability for the Starlab Ground System. The MCC provides verification of safety compliance for all JSC POCC payload commands. In addition, the MCC provides STS and payload planning information, STS ancillary and orbit information, payload command verification and Orbiter Air/Ground voice. Channel 2 and 3 data are received directly both at JSC and GSFC. At JSC the Channel 2 and 3 data containing the ECIO and high rate science data, and Spacelab voice are demultiplexed, and selectively distributed and processed by the JSC POCC.

FIGURE 4-3

Overview of Mission Operations

(ATTACHED SHUTTLE SORTIE CONFIGURATION)



The GSFC SLDPF provides data preprocessing functions for Channel 2 and 3 data as a standard service for Spacelab payloads. During mission support the SLDPF provides information on Channel 2 and 3 data quality to the JSC POCC. Post mission data products are distributed to the investigator institutions for data reduction and analysis and publication preparation.

For Starlab, additional and higher capability data processing functions will be required however in order to provide calibrated data with appropriate signature removal. The investigators may be located within the U.S., Australia and/or Canada and conceivably from other nations, when participating as guest observers on the Starlab program. Distribution of data products is currently normally via Computer Compatible Tape (CCT). However, utilization of a state-of-the-art media such as optical disk should be planned for Starlab.

In the event that a remote facility is utilized to provide the Starlab Ground System capability instead of the JSC POCC, the facility would be interfaced directly to the MCC. In the case of a facility at GSFC, it is likely that high rate science and ECIO data would be extracted by the SLDPF and provided to the ground system.

4.3.2 Space Platform/Station

Current indications are that Starlab will be carried on a Leasecraft type platform which will be controlled from a MSOCC type facility located at Germantown, Maryland. The capabilities of this facility, if built, and the utilization and interface of institutional capability and a DAF at the GSFC are not defined at present. The development of a normal operations concept is therefore premature at the present time.

5.0 OVERVIEW OF THE GROUND SYSTEM

5.1 GROUND SYSTEM OBJECTIVES

The objectives of the Starlab Ground System are:

a) To provide mission planning, mission operations and data processing support services to the Starlab community, where this community will include investigators from the participating countries: namely; Australia, Canada and the United States, and potentially guest observers selected from the science community at large. For the support of the initial up to two attached Shuttle sortie missions, the Starlab Ground System will host investigators from all three countries. For subsequent long duration missions on the space platform, Australia and Canada may provide remote facilities interfaced with the Starlab Ground System to provide selected support services for utilization by their respective communities and other guest observers, as required.

b) To provide management of observing requests as input to the planning and scheduling function.

c) To provide planning and scheduling capability necessary for the generation of detailed timelines and command schedules for Starlab operations. Based on identified science requirements approximately fifty (50) percent of observations will be preprogrammed in the attached Shuttle sortie mode and eighty-five (85) percent preplanned in the space platform configuration. The higher requirement for the Shuttle mode is based on the facility commissioning needs. For realtime observations, planning will still be required in order to allocate observing periods and resources, identify and/or schedule targets on regions of particular efficiency or suitability, and to develop plans for interactive commanding.

d) To provide management of all realtime and preprogrammed command processing functions, and to provide appropriate command performance and history processing capability.

e) To provide necessary data processing support to maintain payload health and safety and for operations support. This can include data receipt and recording, data demultiplexing and/or synchronization, data decommutation and preprocessing and arithmetic and simple processing functions. It is anticipated that EGSE interfaced with the Starlab Ground System will support Starlab engineering and quick-look analysis functions. EGSE is required for the processing of streams of data rate greater than 2 Mbps.

f) To provide appropriate data product generation for dissemination to host investigators and/or for delivery or transmission to remote investigators and facilities.

g) To provide appropriate on-line storage of engineering and science data, overview data and/or command history information as required to support operations activities.

h) To provide for the transfer of appropriate data to an archive such as the National Space Science Data Center (NSSDC) and/or alternatively to provide suitable archive capability as an integral function of the Starlab Ground System.

i) To provide necessary STS or space platform and other ancillary data and information in a form suitable for mission operations support.

j) To provide all required operations, EGSE, user, and support areas and rooms necessary for the conduct of operations. These facilities will be equipped with consoles, terminals, monitors and displays as required. EGSE will be supplied by the investigators.

5.2 SYSTEM OVERVIEW

The Starlab Ground System needs to provide an overall capability for the support of mission planning, mission operations and data processing support services. In addition, a DAF will provide off-line data analysis capability for the support of U.S. investigators and possibly guest observers. In developing a system concept to support these activities there are three major considerations.

a) The ground system must be capable of supporting or be developed to allow for efficient modification or phaseover to support both the initial attached payload and the space platform configurations.

b) Utilization of existing facilities such as the JSC POCC and the SLDPF should be considered for providing cost effective support, and be incorporated into the concept in a manner consistent with item a) above.

c) The ground system needs to be able to support remote facilities in Australia and Canada if and when these facilities are developed to support missions carried on the space platform.

An overview of the current system concept for supporting the initial attached payload missions is shown in Figure 5-1. In this concept the JSC POCC augmented by EGSE provides required payload operations support activities. Figure 5-2 provides an overview of the JSC POCC. This facility will provide Starlab support functions including:

a) A user support room for accommodation of EGSE equipped with three intelligent terminals and overhead TV for display of relevant MCC and POCC information.

b) Additional user accommodations including access to a POCC planning room, conference room and office space.

c) Availability of standard arithmetic and simple processing functions on the POCC applications processor, if required. However, it should be noted that the maximum input data rate for utilization of this service is 2 Mbps, and further the maximum subset of this data which can be accepted for processing is 2000 16-bit parameters per sec. In addition, this is the maximum processing capability which must be shared with all other attached payloads utilizing this capability. The incorporation of EGSE to support Starlab is therefore considered essential.

FIGURE 5-1: STARLAB GROUND SYSTEM OVERVIEW
(ATTACHED SHUTTLE SORTIE CONFIGURATION)

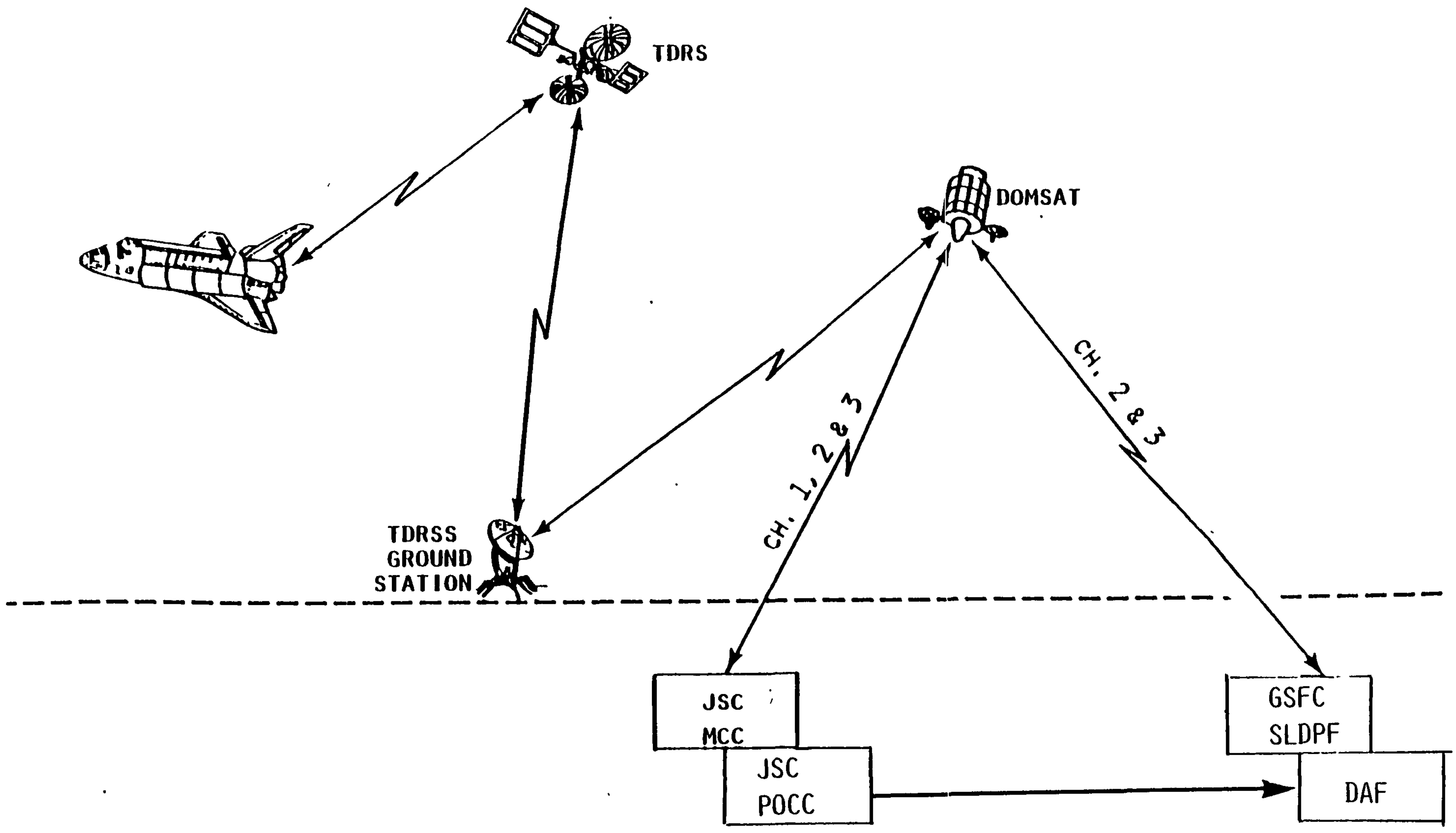
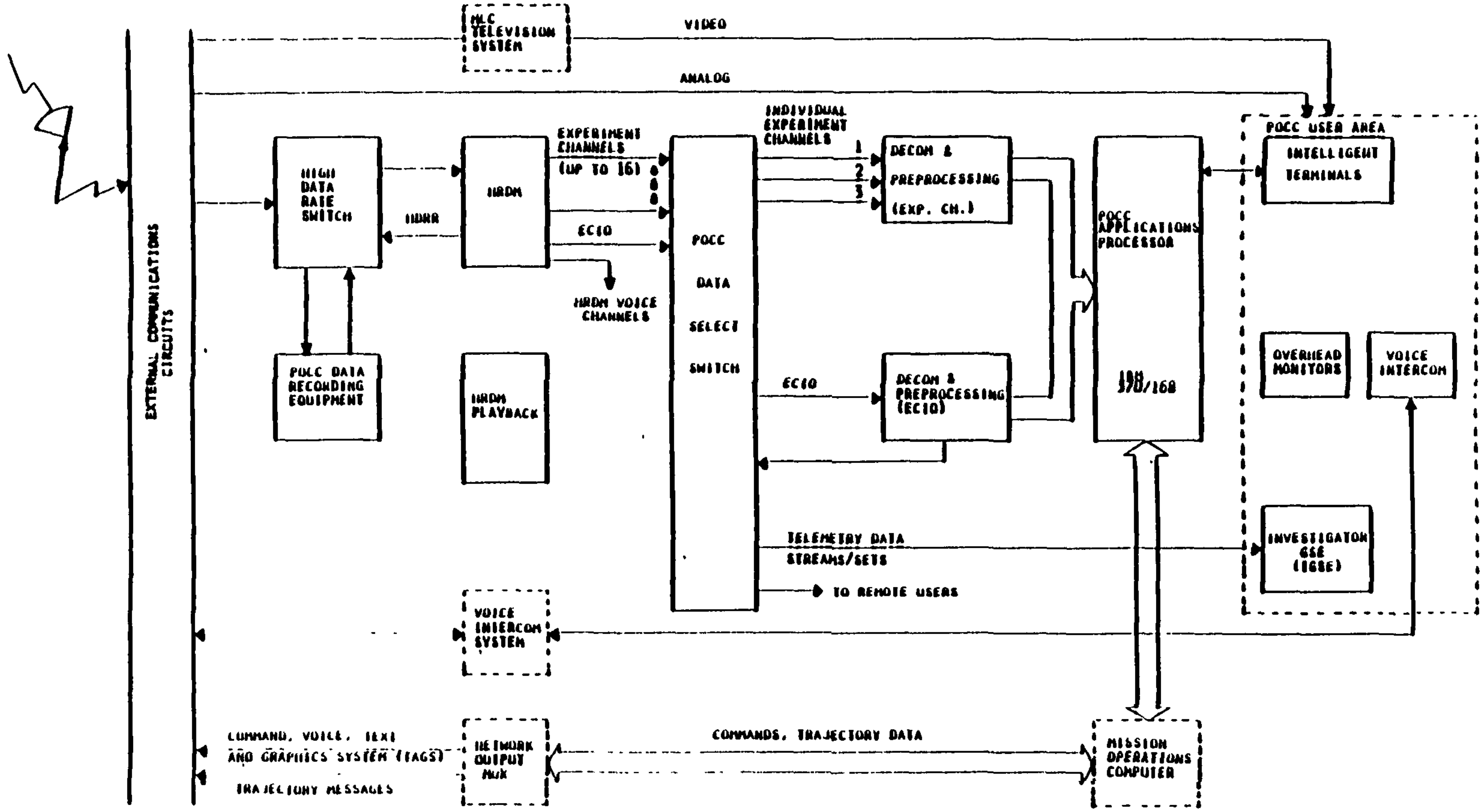


Figure 5-2 JSC POCC - STANDARD SERVICES (OVERVIEW)



d) Data monitoring display functions on the intelligent terminals and overhead monitors. Displays include the output of the functions described in item c) above.

e) Payload command and control via intelligent terminal standard functions or by external system interface to the intelligent terminals on a RS232 interface if required.

f) Accommodation of EGSE within the user room with access provided to the Starlab high rate science data (i.e., the experiment channel input to the HRM), Starlab ECIO subset, video downlink and HRM time reference. In addition, these data may be relayed to remote locations, if required, via user provided data lines.

g) Acceptance of EGSE defined command data via the intelligent terminal interface described above, as required.

Two areas need further consideration in the definition of this concept.

a) The system used to provide mission planning and scheduling functions and the interface of this system into the JSC POCC.

b) The extent of the functions provided by the DAF and the interface for inputting required data into this system. Essentially three sources are available for the input of data.

   o Data delivery from the SLDPF. The current SLDPF commitment is to provide these data 60 days following data acquisition. The receipt of level 0 data at the DAF within 24 hours is required for Starlab.

- o Data transfer from the EGSE to the DAF. This requires the capability to record data on a suitable media on the EGSE.

- o Direct data relay from the JSC POCC to the DAF. This requires utilization of Domsat, since the data rate is 16, 32 or 48 Mbps depending on mode.

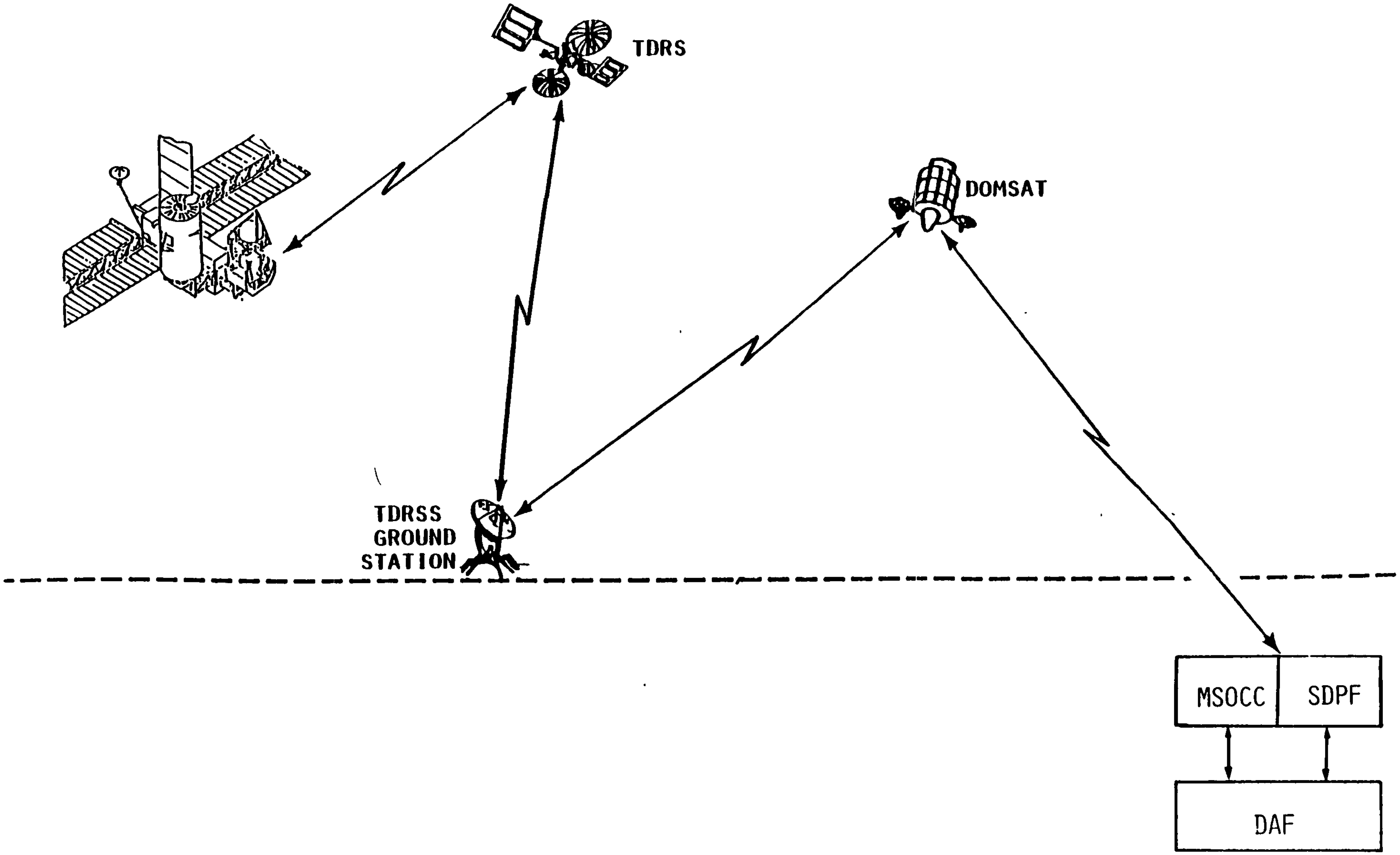
For the space platform configuration, the JSC POCC would be replaced by either a MSOCC type capability for the Leasecraft or a Space Station support facility. In either case, EGSE is likely to be required and it is therefore important to provide for similar interfaces for this equipment as provided by the JSC POCC. Similarly, alternate capability to the SLDPF would be utilized. Figure 5-3 provides an overview of a system concept for supporting a Leasecraft type platform.

5.3 POTENTIAL REMOTE FACILITY FUNCTIONS

There are several functions which can be supported by remote facilities in Australia and/or Canada, if developed. Consideration needs to be given to the functional requirements for these facilities in order to identify requirements and interfaces for the Starlab Ground System. The following are potential functions for these facilities:

a) Management of observing requests submitted by their respective national users and processing of these requests to conform with planning and scheduling input requirements for the Starlab Ground System. In addition, an interface with planning and scheduling activities especially long term planning could be maintained, if required. This subject is considered in more detail in sub-section

FIGURE 5-3. STARLAB GROUND SYSTEM OVERVIEW
(LEASECRAFT CONFIGURATION)



6.1, however, it should be noted that the procedures for the selection and prioritization of observing requests are outside the scope of this document. It is only important that the Starlab Ground System capability is configured to support the policies and procedures adopted by the Starlab participating agencies.

b) Operations support activities including evaluation of quick-look analysis data and off-line analysis including trend analysis. Several options exist for the support of these functions including transmission of selected engineering and science data for local processing, transmission of data subsets extracted by the Starlab Ground System for final local processing or the transmission of parameters suitable for direct display using similar display capability as provided at the Starlab Ground System itself.

c) Data reduction and analysis of engineering and science data transmitted from the Starlab Ground System for the support of scientific analysis by national and/or guest observers. Again several options exist for the data types to be transmitted from the Starlab Ground System. These options are considered in more detail in subsection 6.7.

d) Archival of appropriate data types to support local users. The techniques to be utilized for archival of Starlab and appropriate ancillary and correlative data need resolution. Subsection 6.7.3 contains more detail on this subject.

6.0 SYSTEM FUNCTIONAL GUIDELINES

Guidelines for the Starlab Ground System have been subdivided into eight subsections. These are Observing Proposal Management, Planning and Scheduling, Guide Star Selection System, Space Segment Control Operations, Science Control Operations, Support Requirements, Ground System Data Management and Science Data Analysis. The ground system data management includes post-flight data preprocessing, processing and archival. It should be noted that there will be a strong interdependence between several of these functions requiring good communications between the responsible individuals. For example, astronomers performing science data analysis will be continuously evaluating and updating calibration and batch processing software for support of the data processing function. It is therefore advisable to have at least the science data analysis, data processing and planning and scheduling functions located in close proximity.

For the purposes of determining ground system requirements in this section we consider two missions as characterized in Table 6-1. References 13 and 8 provide details on the typical characteristics for each of these missions respectively. The Starlab Ground System requires sufficient archival capacity to store data collected over a two year period. This requirement would enable the archival of data from four flights of type II.

6.1 OBSERVING PROPOSAL MANAGEMENT

Observing time on the Starlab will be allocated between the three participating countries responsible for the project, and could include time allocated for guest observers from the science community at large. It is likely that observing time will be allocated based on a review of observing

Table 6-1. Sample Starlab Missions

Mission	Mode	Duration	# of Images
I	Shuttle sortie	10 days	~ 500
II	Space platform (Leasecraft)	180 days	~ 9000

proposals submitted in a manner agreed upon by the three participating countries. The procedures adopted for the review of these proposals is outside the scope of this document. From the standpoint of this document it is assumed that the observing proposals go through some form of review process during which a priority or category is assigned which qualifies the acceptance of the proposal in the determination of the overall observing plan. This is assumed regardless of whether one or more bodies are responsible for the review process, since it is assumed that the prioritization or category assigned defines the coordinated outcome of this review.

The number of observing proposals is likely to increase substantially between the initial attached Shuttle sortie missions of short duration and the long duration flights on the space platform. It is therefore necessary that the proposal management function be capable of expansion or augmentation to handle the long term requirements. The number of observing proposals this system needs to handle requires resolution and until detailed requirements are available the form of this system cannot be specifically defined. The information required includes:

a) Average number of proposals per day or other specified time period for both the attached payload and space platform configurations. Any required contingency in these values is also required.

b) The time span covered by the proposals for each configuration, where this time is compatible with the planning and scheduling function.

c) Access requirements to the proposal information to meet user and planning and scheduling requirements. This will include processing requirements with corresponding timeframes.

d) The content of each proposal and if necessary the sub-division of each proposal into individual observational requirements for specific targets.

Table 6-2 lists potential requirements for the content of each proposal. This list needs to be reviewed for adequacy. It should be noted that certain information is likely to be required multiple times for many proposals, i.e., many proposals will include several or numerous targets with accompanying requirements. An assessment of the requirements in this area is needed.

The type of observing proposal information described will be needed to be stored in an observing proposal file. The technique to be used to store this information, whether manual or automated, will be a function of the volume of proposals requiring storage and retrieval. The following type of interfaces to the observing proposal management system will be required:

a) Input of observing proposals. Definition of standardized input format(s) will be required to facilitate this activity. This can take the form of a questionnaire(s) and/or a user friendly computer interface.

b) Observing proposal prioritization or category.

c) Observing proposal status output from the system.

d) Request to the user for clarification and/or additional information.

e) Input of request clarification and/or additional information.

Table 6-2. Potential Data Contained Within Each Proposal

No.	Item
1)	Proposal number/Identification (ID)
2)	Receipt date
3)	Proposal title
4)	Proposer(s) ID/address/phone/affiliation
5)	Instrument(s) required
6)	Target(s) ID, description, position
7)	Observation time(s) requested, granted and planned
8)	Special orbital conditions/requirements
9)	Special data or sequence requirements
10)	Detailed observing sequence requirements
11)	Realtime interaction requirements
12)	Special calibrations
13)	Proposal status
14)	Number of observations/sets
15)	Target attributes (spectral type, magnitude, luminosity class, etc)
16)	Acquisition mode(s)/pointing mode(s)
17)	Instrument mode(s) (Filters, spectrograph wavebands, slit parameters [length], serendipity configuration)
18)	DI image field(s)
19)	Position Angle (PA)
20)	Guide star information, coordinates, magnitudes, etc.
21)	Realtime requirements, uplink, downlink (48 Mbps, 16 Mbps, or low rate (MA link))

Table 6-2. Potential Data Contained Within Each Proposal (concluded)

No.	Item
22)	Observing time requirements, total time, number of observations, time criticality (absolute, sequential, order, uninterrupted duration)
23)	Time resolution
24)	Branching Requirements (overall requirements should not increase Starlab Ground System operational load by more than 10 percent)
25)	Proposal priority or category
26)	Date/time scheduled
27)	Background requirements, zodiacal light, South Atlantic Anomaly (SAA)
28)	Constraints and requirements, shadow, bright object avoidance (Sun, moon, planets, etc.)
29)	Data rate & volume requirements
30)	Comments

f) System summary outputs showing number of observing proposals contained within the system, proposal status, and number and type of processing performed within the last accounting or processing period.

Again, specification of requirements in this area is required.

6.2 PLANNING AND SCHEDULING

A planning and scheduling function is required to support:

a) Long term planning during which the overall mission plan can be analyzed to determine potential launch windows and orbit characteristics, suitable candidate targets, and satisfaction of science and program objectives based on candidate timelines.

b) Short term planning during which detailed timelines are generated in order to:

  - Show that the scientific objectives for selected observations may be achieved, or in cases where they are not achieved, the extent to which they are achieved.
  - Obtain a high utilization of available time on orbit to increase the scientific return, whenever possible.
  - Demonstrate that the proposed observations may be conducted within the available STS, Spacelab and supporting facilities resources, or similar resources for the space platform case as appropriate.

- o Identify potential problems and conflicts from a resource and operational standpoint.

c) Generation of command sequences, loads and allocation of realtime operations sequences based on the prepared detailed timeline requirements.

d) Changes to planned activities and timelines needed to respond to targets of opportunity, contingency operations, etc.

The planning and scheduling system required for the performance of these functions is likely to need or should have several attributes including:

a) A number of user aids may be required to facilitate the selection of candidate targets and operational sequences in order to obtain efficient timeline sequences without the need for excessive iteration. Table 6-3 provides a preliminary list.

b) Interactive and/or automated modes for the generation of timelines may be required. Full utilization of various functions such as user prompting and menu generation will facilitate the timelining process.

c) The schedule for the performance of the timelining function should be matched to the schedule required by the Network Control Center (NCC) for utilization of the TDRSS. This will aid efficient interfacing with this system.

d) Careful consideration needs to be given in the selection of scheduling technique for the TDRSS (Reference section 3.5.d)).

Table 6-3. Preliminary List of User Aids

a) Target Availability charts based on solar avoidance zone, power constraint zones, etc.

b) Skymaps showing:

-- boundary of the forbidden region around the sun

-- sun's position

-- moon's position

-- position of the anti-sun

-- continuous viewing zones

-- position of ram avoidance

c) Solar System ephemerides listing the position of the planets over a given timeframe.

Table 6-4 lists several factors which are likely to require consideration in the analysis and determination of suitable timelines, where the factors listed in Table 6-5 are relevant to target availability determination. Table 6-6 presents typical constraints for a subset of these factors for the DI, spectrograph and the FGS. In addition, other factors including environmental conditions such as incidence of thruster firings and waste dumps could be significant. It should be noted that the factors listed are specific to the attached Shuttle sortie configuration. However, many of the factors are directly applicable to the space platform case. A review of these various factors is required.

The implementation of the planning and scheduling function is likely to utilize existing NASA capability, including possibly:

a) The Mission Planning Computer System (MIPS).

b) GSFC Institutional capability.

c) ST Science Planning and Scheduling System (SPSS).

Final implementation approaches will be based on identified requirements.

6.3 GUIDE STAR SELECTION SYSTEM

Reference 16 specifies a requirement that Starlab must be capable of acquiring, and tracking, guide stars in at least 95 percent of randomly selected fields at the galactic poles. The Guide Star Selection System (GSSS) must have suitable capability to support this requirement. The implications of this requirement on the GSSS are TBD.

Table 6-4. Timeline Factors Requiring Consideration

No.	Factor
1)	Orbit Parameters
2)	Orbiter attitude profile
3)	Launch window
4)	Available support systems
5)	Resource utilization including
	a) Target availability
	b) Guide Star Availability
	c) Power
	d) Energy
	e) TDRSS availability
	f) Timesharing of support system including
	i) HDRR
	ii) Orbiter payload recorder
	iii) Video
	iv) Analog
	Iv) Experiment Computer (EC)
	g) Orbiter Reaction Control System (RCS)
	h) Crew
	i) Uplink capability
	j) Thermal
6)	Instrument operational constraints and characteristics

Table 6-5. Factors Affecting Target Availability

No.	Factor
1)	Earth occultation
2)	SAA passages
3)	Night/day orbital status
4)	Minimum angular approach to sun, moon, planets
5)	Minimum angular approach to bright Earth limb
6)	Minimum angular approach to dark Earth limb
7)	Minimum angular approach to bright Orbiter surface
8)	Minimum angular approach to dark Orbiter surface
9)	Bright object or star avoidance
10)	Zodiacal light background
11)	Ram effect
12)	Aberration effect on plate-scale

Table 6-6. Typical Constraints [Approximate Values for Guidance Only]

Constraint	System		
	DI	Spectrograph	FGS
Sun	50°	50°	TBD
Moon	20°	20°	TBD
Bright Earth limb*	15°	15°	TBD
Dark Earth limb*	5°	5°	TBD
Bright Orbiter Surface	TBD	TBD	TBD
Dark Orbiter Surface	TBD	TBD	TBD
Ram Effect	30°	30°	N/A

* Default Values, actual values condition dependent (see text)

6.4 SPACE SEGMENT CONTROL OPERATIONS

With the attached Shuttle sortie configuration the command of the Orbiter and Spacelab are directly under the control of the MCC. The Starlab Ground System therefore has no direct control over these systems. Utilization of these systems must be requested through established channels and coordinated with planned payload operations. Channels for requesting Orbiter and/or Spacelab system support include:

a) Payload Integration plan (PIP) and associated annexes.

b) Crew activity Plan (CAP).

c) Interface with appropriate MCC personnel either directly or via voice link.

d) Air to ground communications with onboard crew members, when authorized by the MCC and using uplink voice capability configured by MCC personnel.

The control of the space segment for the space platform is obviously dependent on whether a Leasecraft type or Space Station system is utilized. Leasecraft is likely to be operated with a MSOCC type facility. The system to be utilized for the Space Station is currently undefined.

6.5 SCIENCE CONTROL OPERATIONS

Various data receipt and recording, data demultiplexing and/or synchronization, data decommutation and preprocessing and arithmetic and simple processing functions are required to support the maintenance of payload health and safety. Table 6-7 lists potential standard functions required for engineering data analysis. These functions should be reviewed for completeness. In addition, various quicklook processing functions of the science data will be required for operations support. These functions can include the following:

a) Selection of a segment of the accumulating memory for transmission to the ground and display. This capability would be required to be performed without interrupting the recording of an exposure in progress.

b) Image processing of the complete field at full spatial resolution to enable rapid evaluation of the data.

Again, it is necessary to identify required quicklook processing functions together with requisite frequency of usage, data rate and volume input requirements, timeliness of processing, processing algorithms and/or requirements, on-line storage requirements, output products or information, and anticipated usage in operations support. Note, that it is anticipated that EGSE will support many, if not all, identified functions. Table 6-8 identifies anticipated EGSE functions both to support I&T and operations.

Command capability to respond to observed features or events contained within the engineering and/or science data will be required. The following type of commands have been identified:

- Discrete (on/off)
- Serial
- Pointing system control commands (fine pointing control)

Table 6-7: Engineering Data Analysis Functions

No.	Function
1)	Conversion to engineering units
2)	Conversion of analog data based on simple arithmetic expressions and calibration data
3)	Limit checking using possibly red and yellow limits with maintenance of a log of all violations.
4)	Monitoring of status indicator values, and maintenance of a log of mode changes and of deviations from the "normal" value.
5)	Tabulation of selected parameters for selected time periods.
6)	Graphical display of parameter values as a function of some other engineering parameter.
7)	Histograms of values of selected parameters for selected time intervals.
8)	Basic statistical analyses on values of selected parameters, such as means, variances, ranges, and correlation coefficients.

Table 6-8. Typical EGSE Functions

I&T

- Facility and Instrument validation and calibration
- Electrical interface verification
- Flight software validation (SLC/TC/IC)
- Instrument/RAU interfaces
- DEP load buffer and transfer
- Timeline verification via sample load execute
- Test procedure buffer
- Health and Safety analysis
- Safing groups availability
- Self test diagnostics

Operations

- Facility and instrument commissioning
- Flight software upgrade/maintenance
- DEP load buffer and transfer
- Starlab Ground System terminal/applications interface for realtime command functions
- Test procedure buffer
- Health and Safety Analysis
- Safing Groups Availability
- Self Test Diagnostics
- Receipt and synchronization of engineering and high rate science streams
- Quicklook analysis functions

- DEP loads
- Timeline updates.

In addition, air-to-ground full duplex voice will be required for coordination with the crew and availability of TAGS capability would be desirable for the Shuttle sortie configuration.

6.6 SUPPORT REQUIREMENTS

Various attitude determination and control system capabilities are needed to support the Starlab Ground System. For the attached payload mode, JSC provides these services to the JSC POCC and post-flight, as required. For the space platform these capabilities could be provided at the GSFC via institutional support facilities. The facilities include:

a) The Flight Dynamics Facility (FDF) which provides attitude determination and control system, and mission analysis and orbit maneuver system support.

b) The Orbit Computing Facility (OCF) which provides metric data collection, and trajectory and orbit computation capability.

Support capabilities likely to be needed are shown in Table 6-9. Again, review of these capabilities is required. In the event that a remote facility is provided to support the attached mode, the GSFC Shuttle/POCC Interface Facility (SPIF) could be utilized to provide required support. This facility provides a range of capabilities to support missions utilizing the STS as described in Table 6-10.

Table 6-9. Required Support Capabilities

No.	Capability
1)	Space Segment attitude determination
2)	Space Segment attitude maneuver computations
3)	Space Segment attitude dynamics evaluation
4)	Attitude sensor performance analysis
5)	Analysis of operations critical to the health and safety of the space segment during attitude maneuvers
6)	Orbit mission analysis
7)	Launch window analysis
8)	Orbit maneuver planning and evaluation
9)	Realtime monitoring and correction of orbit maneuvers
10)	Trajectory/orbit determination
11)	Tracking system performance assessment
12)	Mission maneuver suppport.

Table 6-10. SPIF Capabilities for Supporting Missions Utilizing the STS

No.	Capability
1)	Planning and coordination functions for assistance in mission planning and the integration of payloads into STS operations.
2)	Delivery of pre-flight planning data containing Orbiter trajectory data.
3)	CCTV display of Orbit tracking data (every 3 minutes under timeline control or by request) and 2 hour projections showing all planned Orbiter maneuvers.
4)	CCTV display of Orbiter attitude data (every 12 seconds under timeline control or by request). Realtime and projected data (next 48 hours) are available.
5)	CCT transfer of Crew Activity Planning System (CAPS) information from JSC with formatting for user display [planned capability].
6)	Formatting of Operational Downlink (OD) data subsets provided and building of displays for user CCTV
7)	Imagery uplink to the Orbiter via the TAGS [planned capability]

6.7 GROUND SYSTEM DATA MANAGEMENT

This system provides the following functions:

a) Data preprocessing

b) Data processing

c) Data archival.

Table 6-11 defines a number of distinct data levels which are helpful in describing the various processes presented in this and the following section. The calibrated images produced at level 2 are the images normally used by the astronomer for detailed analysis as opposed to quicklook analysis. It must be recognized however that calibration will be an on-going process; the instrument parameters will be better understood with time. Therefore reprocessing of level 0 data will be needed (in timescales of weeks to even years) using improved parameters from level 1. However this process must obviously be used judiciously and within the available capacity of the system. The level sequence provides a partition for software development and implementation responsibilities, and distinguishes activities performed within the data preprocessing and processing functions (through level 2) to those performed within the DAF (through level 4).

Table 6-12 presents the functions performed by data preprocessing and processing. The level 0 through 2 data prepared by these functions are archived. Table 6-13 provides an overview of the characteristics of the data preprocessing and processing functions extracted from reference 15.

A calibration data base will be required to support the data processing function. This data base will be developed based on pre-launch data and procedures provided by the instrument and facility teams. Table 6-14

Table 6-11. Distinct Data Levels

Level	Associated Data Product	Characteristics
0	Raw image on a non-erasable media (i.e. optical disk). corrected only for transmission errors.	o Includes science component and related ancillary data. The latter data is formatted into a header block accompanying the image, or as an associated file. o Science component organized into an image format suitable for rapid display and manipulation. o For spectroscopic observations, the serendipity field is separated from the spectral image. o A compressed image (i.e. 512 x 512 or 1024 x 1024 pixels) obtained either from the onboard quicklook memory or by summing the raw data accompanies the high resolution images. o Image summary statistics (i.e. total counts, countrates) are output to the Data Management System and a subset are included in the image header. o Capability to reformat special images (i.e. pseudo-images formed in high time resolution mode with timing appended) o Level 0 processing available on-line at the Starlab Ground System in as near realtime as possible. o Level 0 image hardcopy capability o Data accessible from remote locations and on-line for a TBD period.
1	Calibration results derived from calibration sequences	o Extracts calibration images from level 0 data. o Combines flat field exposures as appropriate and produces single flat fields suitable for division. o Derives dispersion parameters for arc line calibrations. o Characterizes image non-linearity versus both intensity and target topography o Characterizes image defects and distortion o Spectrograph response from standard star observations

Table 6-11. Distinct Data Levels (continued)

Level	Associated Data Product	Characteristics
1 cont.		o Time tags calibration results for subsequent use with associated astronomical data o On-line storage on erasable media o Summary output to Data Management System. o Hard-copy of flat field calibration files.
2	Calibrated and corrected image obtained by applying the calibration files (level 1) to the raw data (level 0)	o Flat field division. o Count-rate non-linearity correction (i.e., coincidence corrections). o Cosmetic defects repaired. o Geometrical distortion removed. o Field rotation removed? o Correction for filter spatial non-uniformity. o Combines sub-stepped images (if applicable). o Wavelength calibrations applied to spectrograph data. o Other calibrations as needed. o Provision for special image processing as noted for Level 0. o Output images and associated headers identical/similar in both content and format to level 0 data (including corrected, compressed image) o Images archived and made available for distribution o Archiving on erasable media with periodic (milestone) archiving in permanent form o Data on-line at the Starlab Ground System and accessible from remote locations o Hard-copy capability

Table 6-11. Distinct Data Levels (concluded)

Level	Associated Data Product	Characteristics
3	Images corresponding to observation mode. Result from science oriented processing of Level 2 images	o Smoothing/enhancement. o Arithmetic operations involving multiple images. o Extraction of specified regions of interest from a larger field. o Sky-subtracted spectral images. o Variety of hardcopy options including color/BW photographic reproduction, grey-scale representations, contour plots, etc. o Images most commonly needed for distribution and publication of scientific results. o Level 3 software available on-line at the Starlab Ground System to facilitate quicklook analysis for science operations control. o Majority of Level 3 processing performed off-line at national DAFs (and other institutions capable of supporting this level of image processing).
4	Specific science data rather than images	o List of all stars/objects with requested parameters (i.e. fluxes, colors) o Spectra for individual objects o List of all spectral lines with requested parameters (i.e. redshifts, equivalent widths) o Level 4 software on-line at the Starlab Ground System to further enhance the quicklook capability for science operations control. o Majority of level 4 processing off-line at national DAFs and individual institutions.

Table 6-12. Data Preprocessing and Processing Functions

Data Preprocessing

a. Data capture and recording

b. Demultiplexing and synchronization

c. Data Quality Monitoring (DQM)

d. Data accounting

e. Data delivery to data processing function, archives and/or data archival

Data Processing

a. Receive buffered pre-processed data and format into images

b. Assess data quality (preview display of images)

c. Archive raw images (level 0)

d. Determine calibration parameters from images and laboratory data

e. Maintain all necessary calibration data on-line

f. Batch process raw images to create level 2 calibrated images

g. Archive level 2 images and spectra

h. Distribute level 2 images to all three national data analysis facilities and requested level 0 images

i. Maintain a catalog of all Starlab images with a calibration history

Table 6-13. Data Preprocessing and Processing Characteristics

Function	Data Product	Distribution	Deliver Time	Recording
Data Preprocessing	o Preprocessed data which can be readily separated into image and associated engineering components	o Data Processing function o Archives o Buffered transmission to data processing function at about 16 Mbps	o Goal of delay of no more than 30 minutes before buffered transmission to the data processing function	o Raw telemetry routinely recorded to allow retransmission as required o Data kept only as long as needed.
Data Processing	o Calibrated Starlab images and spectra (level 2 data) o Intermediate results (raw images and the calibration data base) should be available to users who require them for specialized data analysis o Quicklook data (compressed versions of incoming Starlab images [1024x1024 format] should be available for display and transmission to remote sites o Hardcopy capability required	o Complete set of level 2 data distributed to DAF, Australia & Canada for archival o Distribution of requested raw images o Periodic update of current calibration data base and image catalog. o For space platform, quicklook transmission to remote sites on request. Data in form of 1024x1024 compressed raw images or subimage format. Link bandwidth of $\geqslant$ 50 kbps. data includes engineering and summary data selected interactively & transmitted within seconds.	o Shuttle-complete set of level 2 data prepared within 3 months o Space Station - quicklook data available after 30 minutes - total latency of 24 hours for all images after system fully operational	

Table 6-14. Data Processing Data Base Size Estimates

[Data bases required on-line]

Item	Approx. Size
Flat field correction for 48 filters	48*160 Mbytes
Linearity correction file	< 160 Mbytes
Blemish files	100 Mbytes
Geometric distortion files	< 100 Mbytes
Others	< 10 Mbytes
Total	~ 8000 Mbytes

Note:

These data will change with time but only one set need be online for a given calibration sequence. Different sets could be stored on removable disk cartridges. These data could be stored on a read only device such as an optical disk.

presents a preliminary analysis of the size of the data bases required to support data processing. It should be noted that a high percentage of data base information required by the data processing function will also be required by the DAF. In general, the evaluation of the overall data base requirements for the Starlab Ground System will need careful examination in order to minimize duplication and provide an integrated capability.

Image reduction techniques are a function of image type. The following subsections detail the type of processing required to provide calibrated Starlab images.

6.7.1 Direct Imager (DI) Image Reduction

The calibration functions for data processing of DI images include:

a. linearity correction
b. flat field correction
c. background subtraction
d. removing known cosmetic defects
e. locating and cataloging bad and questionable pixels
f. removing geometric distortion
g. spectrophotometric calibration of the grisms and photometric calibration of each filter.
h. correcting for filter spatial non-uniformity
i. Computation of input flux levels from the knowledge of instrument gain including filter transmission values

The first two steps will use an algorithm which is both pixel and wavelength dependent. It might, for example, be a function or an interpolation table assuming that the response curve is adequately determined. Tables of coefficients for each filter will be online for this calibration. The known cosmetic defects will include known bad areas of the detector and memory. These may change slowly with time and must be monitored. Step e. includes recognizing possible cosmic ray hits, telemetry errors, and other asynchronous events and cataloging these with identifying codes. The removal of geometric distortion will probably involve two steps. The first will be a correction for discontinuities caused by shears in the pixel array (either in the optical fiber bundle or the channel plate) and the second will correct for more gradual distortions. This second part will probably be a control grid mapping with a weighting scheme that preserves the total flux locally. The final result of these calibrations will be pseudo counts/pixel and a global calibration coefficient to convert these counts to physical units. The pseudo counts will represent the actual counts on the average and, providing the flat field corrections are not especially large, can be used to roughly determine statistical significance.

When specified in the observing schedule, some DI images will require further processing which may include:

a. removing field rotation (to align images)
b. combining several images to obtain longer exposures
c. combining sub-stepped images

6.7.2 Spectrograph Data Reduction

Spectrograph data calibration will be more complicated. Because the flat field and linearity response of each pixel may be wavelength dependent, the wavelength associated with each pixel must first be obtained. Using calibration data, the position of each spectral order for a given mode can be readily obtained although some provision for imprecise positioning of the slit may be necessary. The wavelength dependence of each pixel will probably be determined by linear interpolation from a table of coefficients for each pixel. The pixels in each spectral order will be processed for the appropriate response and geometric corrections. Note that in cases where spectral orders overlap, a given pixel may be processed as a member of more than one spectral array with orthogonal spatial and wavelength dimensions. The pixel size of these new arrays will be as close as possible to the original image pixels. Note that in cases with order overlap, the data volume will be larger than the original level 0 image.

The next step is the deconvolution of order overlaps which depend on a good calibration of the cross disperser's spectral dispersion function. With slits short enough to minimize overlap, this can probably be quickly accomplished interactively. For longer slits, the problem becomes more difficult and may need to be deferred to the data analysis function. A straightforward deconvolution (e.g., using Fast Fourier Transforms (FFT)) may also be possible but is likely to require high precision calculations and increase the necessary computer resources considerably.

The quantity stored in each pixel will be a pseudo count which is defined as the photons that would have been counted by a pixel with the average response at that wavelength. Coefficients to convert the wavelength index number into physical wavelength for each order will be contained in a record header for that order. These calibration steps can be summarized as follows:

a. spectral order boundaries will be determined
b. a wavelength calibration will be derived for each pixel
c. spacecraft doppler correction
d. linearity correction
e. flat field correction
f. removing known cosmetic defects
g. removing geometric distortion
h. each order will be "straightened" into a rectangular array with orthogonal spatial and wavelength dimensions
i. deconvolve order overlaps
j. derive absolute calibration

These processed spectra files will then be archived as a separate file type for each spectrograph mode with identifying information in the file headers. Each file will need to be organized into records corresponding to the spectral orders. A record header will contain order specific information such as physical wavelength information.

6.7.3 Grism Images

The "grism" observing mode will also require additional processing. A grating + prism combination ahead of the focal plane produces a small spectrum of objects in the DI's field of view. The desired data processing product is the spectra of each object and its position in the sky. Automating this process could be a challenging software task. It could be simplified if a short exposure without the grism was available for the same field of view. In this case, the program would simply process a parallelogram representing the potential spectra of each identifiable source. In crowded fields, there may be considerable overlap of such areas which will produce some confusing spectra and increase total processing time. Once the spectral zone of each object is determined, the processing is similar to the spectrograph processing procedure above. The data would be organized as a grism file with a record for each spectra. Record headers would contain information on the sky position of that object and wavelength calibration coefficients.

6.7.4 Image Catalog

A comprehensive catalog of all Starlab images needs to be automatically generated as part of the image processing. Each catalog entry will contain information reduced from the actual image, associated engineering data, the observing schedule (from the planning and scheduling system), and manually entered comments. A calibration history will also need to be updated each time the data is processed or re-processed.

This catalog will be the primary means of organizing the Starlab data base. Both the data processing and analysis software systems will use it to locate specific data sets. In addition, various search and survey programs need to be available to users to allow data selection based on information contained in the catalog. For example, it must be possible to ask a search program for all images available that cover a specific point in the sky taken in a particular observing mode. In general, the search program must be able to select any logical combination or range of catalog values.

The size and exact contents of the catalog entries for each image and spectrum file are TBD. However, we can roughly estimate that each file would require about a 2000 byte record. For the two year data requirement, this implies a total of 70 Mbytes of online storage for the catalog.

6.7.5 Current NASA Capabilities

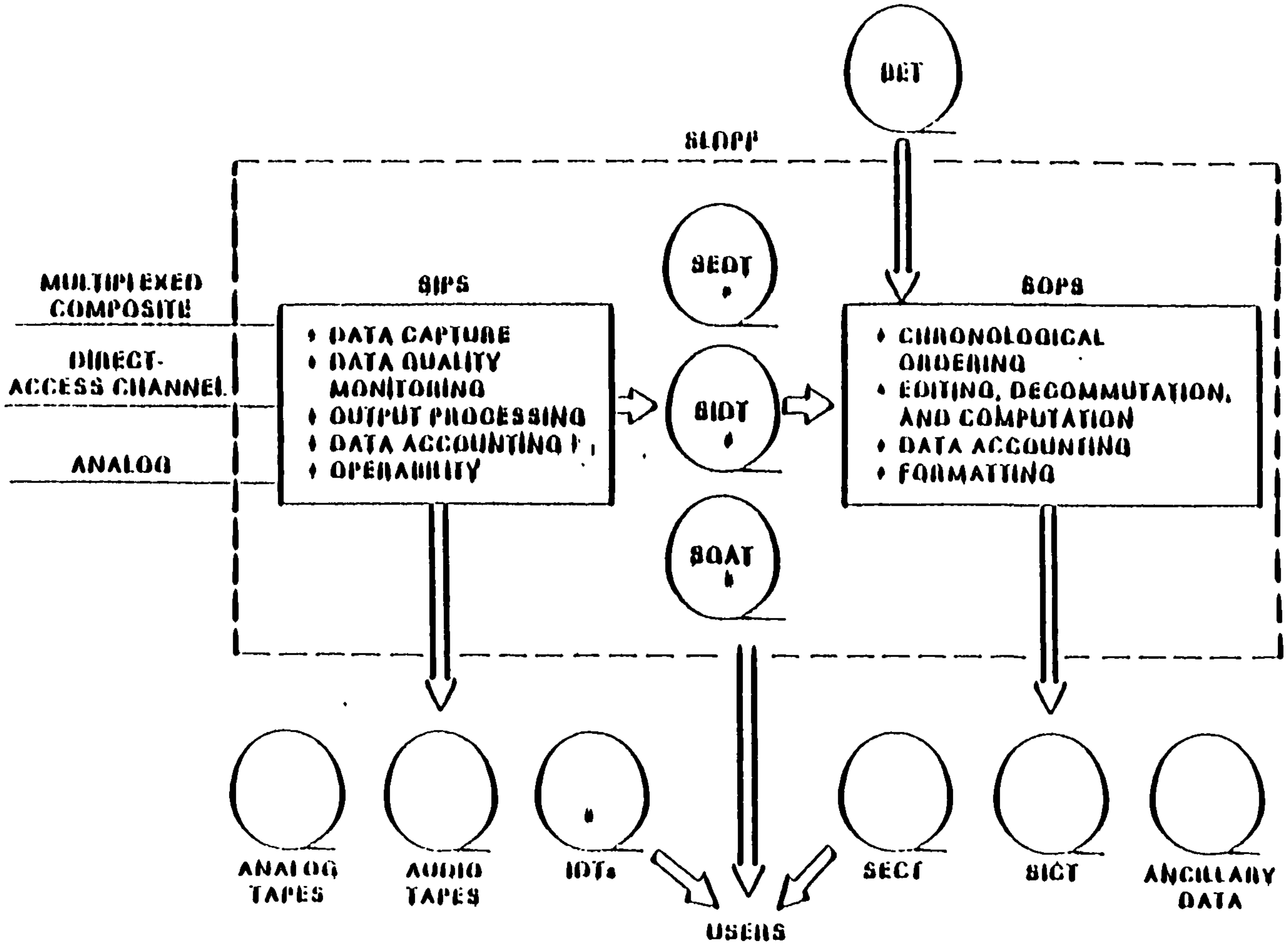
The Sensor Data Processing Facility (SDPF) provides data preprocessing functions for many NASA programs. In particular, the SLDPF provides a range of standard data processing functions and products for Spacelab payloads as shown in Figure 6-1. This facility provides these products to the users nominally 60 days after the data are acquired. Data products are normally in the form of CCT, but other media are available. Data preprocessing functions are likely to be provided by the SDPF for payloads on Leasecraft. No details on facilities to support the Space Station are available.

6.7.6 Data Archival

Following the processing of the various types of data, an archive needs to be established to support the requirements of U.S., Australian and Canadian investigators and possibly guest observers. This archive will be contained within the NSSDC and/or the Starlab Ground System. In the event that remote facilities are developed in Australia and/or Canada, the archive could be distributed, where each country retains a complete archive. Whatever distribution is determined for this archive it is important that the overall management of the function be considered in order to ensure data validity.

Table 6-15 contains a potential list of considerations which need to be reviewed in the definition of the archive requirements. In addition, it is necessary to consider the flow and the responsibilities for input of data into the archive. Table 6-16 summarizes preliminary data archive storage requirements for level 0 and level 2 data for the sample Starlab missions

FIGURE 6-1: SLDPF FUNCTIONAL DIAGRAM



* OUTPUT ONLY IF NEGOTIATED WITH THE GSFC/SPDPO

Table 6-15. Potential Archive Considerations

1) Distribution of archive

2) Data types with levels

3) Archive capacity

4) Reference information required to identify archived data

5) Data security and/or access protocols

6) Search criteria

7) Typical access scenarios with timeframe requirements

8) Archive file management requirements

9) Anticipated user access of the archive with representative requests for data type and volume, frequency, timeliness and overall loading requirements

10) Need for simultaneous access of specific data

11) Timeframe for insertion of data into the archive

Table 6-16. Preliminary Starlab Image Archive Requirements

	Mission I	Mission II
# of images per day	50	50
Image size before compression	80 Mbytes	160 Mbytes
Image size after compression	40 Mbytes	80 Mbytes
# of raw image copies to store	2	2
# of intermediate images to store	TBD	TBD
# of processed copies to store	1	1
Storage/day	6 Gbytes	12 Gbytes
# of days	10	200
Total Storage	60 Gbytes	2400 Gbytes

Note: Total storage required for a two year data requirement is 730 days x 12 Gbytes = 8760 Gbytes.

and in order to satisfy the two year data requirement. Other data storage requirements are minor in comparison. These estimates assume that the data is stored in a compressed format which reduces the storage requirements for an image by a factor of two without loss of information.

6.7.7 Computer Resource Estimate

A rough estimate of the computer power needed for the data processing can be obtained as follows. Assuming that each image is 9600 by 9600 pixels and that there are 50 images/day to process in a 16 hour shift, the system must process 80,000 pixels/second. Current estimates are that approximately 50 to 100 operations per pixel may be required and perhaps 10 I/O transfers. These figures would imply a system speed of about 8 MIPS (million instructions per second) and an I/O transfer rate capability of at least 1.6 million bytes per second. (Each pixel is 2 bytes).

6.8 SCIENCE DATA ANALYSIS

A DAF is required to provide a host facility for the support of science data analysis functions for U.S. investigators and possibly guest observers. Implementation of this concept was found to be extremely beneficial on the International Ultraviolet Explorer (IUE) program, and the development of a similar capability for Starlab is therefore proposed. The primary function of the DAF will be to extract scientific knowledge from the Starlab images and associated data. It will also provide the feedback necessary for planning subsequent observations and for developing and improving calibration procedures. In very broad terms, some of the major tasks of the DAF are:

a. Provide astronomers quick access to all archived Starlab images and related data bases

b. Interactive image processing to obtain level 3 and level 4 data

c. Provide sufficient support to allow prompt organization of results into a form suitable for publication and/or presentation

d. Continuing software development for calibration and analysis

e. Feedback of results to other Starlab system components

f. Analysis support for mission operations.

The DAF will provide the environment and the tools to permit the astronomer to carry out detailed studies of his data. Similar facilities will eventually be commissioned in Canada and Australia for the space platform missions. It is essential that the computer and data management systems be similar enough to allow the mutual exchange of analysis and data reduction software.

In contrast to the data processing function, which handles Starlab data in a systematic, uniform way, the data analysis function performs processing customized according to the specification of individual users. It is expected that two basic classes of users will utilize the data analysis capabilities. One type of user will be the observers and archival researchers who will process Starlab images and spectrograms for scientific purposes. Another type of user will be members of the observatory staff who will process Starlab images and spectrograms to help understand the

Starlab instrument, to monitor its performance, and to update its calibration functions and tables. Both types of users require some form of interactive computing and may therefore be accommodated by the functions provided.

Both classes of users will work with Starlab data in its various stages of reduction. For scientific analysis, the reduced (level 2) form of data will be used most of the time. For calibration analysis, the data will need to be examined at several stages of reduction.

6.8.1 Analysis Functions

Anticipating all of the analysis tools that will be used to process the large field survey imagery and spectrographic data from Starlab is probably impossible. Also, many techniques will be data and/or astronomer specific and only developed after experience. Table 6-17 presents some of the spectrograph and grism data analysis tools.

Two general capabilities will be required. The first is the capability for computer-assisted recognition, measurement and storage of the results of measurement for features of interest within the Starlab data. The second capability is computerized statistical analysis capability for processing of tabular data extracted from Starlab images. For either capability astronomer interaction should take a minor role (i.e. initiating the calculations and reviewing the results) with the actual processing performed in possibly a batch-mode.

The DAF software system must serve users with a wide range of computer expertise and needs. Easy to use software packages should be built for all

Table 6-17. Analysis Tools and Resources Needed for Image, and Spectrograph and Grism Data Analysis

Image Data

- Image display
- Interactive image extraction and manipulation
- Contour mapping
- Temporal change analysis
- Point source and surface photometry
- Object classification
- Geometric analysis of objects
- Multi-color classification
- High and moderate quality hardcopies

Spectrograph and Grism Data

- Spectral display
- Spectral extractions and manipulations
- Spectral comparisons
- Spectral feature identification
- Velocity analysis
- Time series analysis
- Curve of growth
- Profile fitting

commonly used tasks but generalized software should also be available for sophisticated users. Already there are many extensive software systems in use or under development that address the needs of astronomical data analysis. By the time that the Starlab project will be required to commit to a detailed hardware and software design, there will be several mature, active astronomical data analysis facilities around the world. A very important aspect of the Starlab DAF will be its ability to make use of these software systems and only embark on expensive software development projects for Starlab specific requirements. This implies a degree of computer compatibility that may determine the choice of the computer system.

6.8.2 Data Products

A large percentage of DAF activities will involve the production of level 3 and 4 data from the level 2 data processing output. The specific operations required are science oriented. As defined in Table 6-11, level 3 data are in the form of images and spectra while level 4 data are final extraction of physical parameters of specific objects. Examples of level 4 data include.

- Lists of stars/objects in a given field with extracted observables (fluxes, colors, ...)
- Cepheid periods and fluxes in M31
- A list of spectral lines with requested parameters (wavelengths, widths, redshifts, ...)
- Galactic rotation curves

Much of the level 4 data generated will be combined into a large astronomical data base that will eventually be available to the scientific community. Calibration results obtained from in-orbit calibration sequences are another product. These results converted into calibration data bases and procedures are used to convert raw images into level 2 data. This will be a continuing product as the instruments change with time and become better understood. Quality image hardcopies, graphics and other intermediate and final result representations are required.

6.8.3 Delivery Times

Analysis of some aspects of Starlab data may continue for many years, but it is essential that the major objectives are accomplished in a reasonable amount of time. It will be necessary for both the data processing and analysis functions to provide rapid quicklook analysis of the quality of the calibration data as well as the level of scientific return being achieved.

To meet these requirements, the DAF must have access to selected images (perhaps 10% of the total) within 24 hours and it must have the capability to evaluate these images within another 24 hours. Examples of such evaluations include simple quality checks such as:

- o background uniformity
- o signal to noise levels
- o focus checks
- o correctness of calibration.

Some of these tests may require only selected parts of the full images.

In addition to the requirement that the DAF be able to provide quick feedback on selected data for the effective operation of Starlab, it must also have a total throughput capability able to keep up with the observations to prevent an ever increasing backlog. The DAF together with corresponding facilities in Canada and Australia must be able to handle data at the same rate that Starlab acquires data (about 50 images/day). Because of overlaps in data analysis efforts, the GSFC DAF's share would be about 25 images/day. For a given observing program, a user should expect to be able to extract the primary scientific information within 3 months of completion.

6.8.4 Relationship With the Data Processing Function

The size of the Starlab data processing and data analysis functions is such that it would be impractical to have them operating in a single computer facility. The data processing function will need to work full time in the most efficient batch mode possible turning out the level 2 products. This involves not only the actual computation effort but also the cataloging and archiving effort. Very careful quality control will be needed to guarantee that the most recent and correct calibration is applied and that adequate records are kept. The DAF will need to provide the data processing function with sufficient response time to permit the calibration process to be properly tracked and updated. It is important that the DAF be able to run the standard data processing functions so that the testing of software and calibration modifications can be made off line to the data processing production activities.

6.8.5 Number of Users

It is required that up to 16 researchers be able to access data during any given period of time at the DAF. Eight of these will be doing Direct Imager work and eight will be doing Spectrograph work. These 16 users will be divided into two shifts, so that there will be only 8 simultaneous major users utilizing the system at any one time.

6.8.6 DAF Data Access

The DAF tasks require access to a number of large data bases and also require sufficient on-line storage to support user activities. The major data bases include:

- raw image archive
- processed data archive
- observation catalog
- calibration data
- observing plans
- stellar catalogs

The raw image and processed data archives will be too large to be entirely on line. These data could be stored on optical disks which would allow access to any given set with about 10 minutes. (The DAF access to this data will be read only. The data is generated by the data processing function). Expansion of the compressed form and higher subsequent I/O rates are likely to be required for data analysis tasks. Hence transfer of the data from an optical disk to an alternate media such as a disk is likely.

The observation catalog needs to be entirely on-line to allow its effective use for data searches. The other data bases listed need to be quickly accessible but not necessarily on-line for the DAF. However, their volume may be small enough in comparison to other on-line requirements to allow complete on-line access.

The amount of on-line read/write storage required for analysis activities will depend on the number of users that are actively using the system at a given time. The system must be designed such that a natural growth of active users can be allowed as the volume of acquired data increases. This will permit an orderly growth from a current research type of facility into a facility that can also handle archival studies of the ever growing collection of survey quality imagery.

A possible breakdown of temporary storage required for 16 simultaneous users is listed in Table 6-18. Allowing for some extra data sets the total estimate shown should be raised to about 100 Gbytes of data.

The DAF must also have access to non-Starlab data bases. One of the most important aspects of survey type of research is the ability to cross-correlate the current data to similar data obtained with other instruments and apparently unrelated research done in other fields. For example, the comparison of optical and X-ray imagery of the same region of the sky searching for and comparing H-alpha emission objects with UV excess objects. Therefore it is a requirement that the Starlab DAF have access to the existing networks of astronomical data bases, for example the GSFC NSSDC or the Catalogue of Stellar Identifications. This puts a requirement on the DAF hardware and software that it be of such a nature to permit easy access to local area networks as well as national and international packet

Table 6-18. Temporary On-line Storage

Type of user	Number original images	Number copies	Total per user	Total for system
Direct Imager	10	4	6.4E9	60.0E9
Extracted Spectra	20	4	80.0E6	1.6E9
Original Images	20	1	7.2E9	14.4E9
			Total =	76.0E9

switching networks. Table 6-19 summarizes the data access requirements for the DAF.

6.8.7 Computer System Estimate

The computer resource estimate for the Starlab DAF includes capability for the general purpose image display and analysis, image manipulation, and feature extraction. It is assumed that there will be 4 image work stations and 4 spectroscopic work stations on line at one time.

The number of instructions needed per image is difficult to quantify. It is clear that both integer and floating point operations will be needed, integer for speed and floating point for calibration accuracy. A typical image operation will require a fetching of one or more input images, 5 to 20 instructions per image operation, and storing of a modified output image. This implies 20 to 25 instructions per pixel and 2 I/O operations per line of the image in a serial type computer system. If the image size is 9000 by 9000 pixels and there are 4 active image manipulation tasks, and if a reasonable response time for an image operation is 5 minutes, then the computer system must have the equivalent computational speed of 27 million instructions per second and an I/O transfer rate of 1.6 million bytes per second.

6.8.8 Hardcopy Functions

Hardcopy output products are required to record Starlab imagery. This requirement is summarized in Table 6-20 and provides information on the hardcopy requirements as a function of user and/or workstation as appropriate.

Table 6-19. DAF Access Requirements

Item	Type of Access	On-line Requirement
Raw Data Archive	Read only	~ 5 to 10 Gbytes
Processed Data	Read only	~ 5 to 10 Gbytes
Calibration Data	Read only	~ 5 to 10 Gbytes
Observation Catalog	Read/write	70 Mbytes
Temporary User Storage	Read/write	100 Gbytes
System and User Software	Read/write	~ 100 Mbytes
Stellar Catalogs	Read	
Observing Plans	Read	~ 100 Mbytes

Table 6-20. Starlab Hardcopy Output Products Available from the DAF

Product	Standard Computer Printout	Graphical Quicklook	Graphical Journal Quality	Photographic Snapshot	Photographic Imagery
Usage	Reports and Listings	Quicklook Plots	Journal Publication	Display Snapshots	High resolution fully corrected prints and transparencies
Quantity per User	TBD pages/day	TBD graphs/day per work station	TBD journal quality products/day	TBD/day per work station	TBD per day
Hardcopy Device Location	Standard system printers	Each image and spectrographic work station	TBD number of system journal quality graphics devices	Color or B/W print or slide making device at each image work station	TBD number within DAF
Product Specification	132 lines standard computer output	TBD	TBD	Color or B/W print or slide to to match display resolution - 500 to 1000 lines per image	10,000 x 10,000 pixel resolution in an 8X8 format with color

7.0 INTERFACES

7.1 STARLAB/NASCOM/TDRSS INTERFACES

In the Shuttle sortie configuration the various STS, Spacelab and Starlab data are transmitted over channels one, two and three under normal operations. The contents and characteristics of channels one, two and three data as downlinked by the TDRSS Ku-band are shown in Table 7-1. As shown in Figure 5-1, channel 2 and 3 data are received directly at the GSFC. Channel 1, 2 and 3 data are received at JSC and selected subsets of channel 1 are extracted by the JSC MCC and forwarded to the GSFC SPIF. Table 6-10 provides a summary of the capabilities performed by the SPIF for supporting payloads utilizing the STS. With reference to Figure 5-1, the channels 1, 2 and 3 data as appropriate, are forwarded from the TDRSS Ground Station to the GSFC and JSC via the Domestic Satellite (Domsat).

In the Leasecraft space platform configuration, the Leasecraft communicates with the GSFC again via TDRSS and Domsat. The JSC is not utilized in this configuration (Reference Figure 5-3).

7.2 STARLAB/INSTITUTIONAL FACILITIES

The interfaces of the Starlab Ground System with the various GSFC institutional facilities are not provided in this document for the Shuttle sortie configuration, since current indications are that utilization of the Shuttle sortie mode will not be made for Starlab. The corresponding interfaces for the Leasecraft space platform mode are TBD at present. At the present time consideration is being made on the development of a MSOCC type facility at the Fairchild Space Company facility at Germantown,

Table 7-1. TDRSS Ku-Band Downlink for Spacelab

MODE	CHANNEL		
	1	2	3
1 (PM)	DIGITAL 192 KBPS (64 KBPS FROM SPACELAB)	DIGITAL 0.016-2 MBPS	DIGITAL 2-50 MBPS
2 (FM)	DIGITAL 192 KBPS (64 KBPS FROM SPACELAB)	DIGITAL 0.016-2 MBPS	DIGITAL 0.016-4 MBPS OR ANALOG CCTV OR 4.5 MHZ CHANNEL
PRIME PAYLOAD DATA TRANSMITTED	STS ANCILLARY AND VOICE	ECIO AND HIGH RATE SCIENCE, SPACELAB VOICE	HIGH RATE SCIENCE AND/OR VIDEO OR ANALOG

Maryland, to support Leasecraft. The location of the POCC facility is likely to have implications on the internal interfaces required within the Starlab Ground System.