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Langley Application Experiments Data Management System Study Final Report

Contract NAS 1-13657

prepared for
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia

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Aeronutronic Ford Corporation
Space Information Systems Operation
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LANGLEY APPLICATIONS EXPERIMENTS DATA MANAGEMENT SYSTEM STUDY

FINAL REPORT

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LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA

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FOREWORD

The Langley Applications Experiments Data Management System Study was conducted to provide ROM cost estimates of the ground processing to support the flights of the Advanced Technology Laboratory (ATL). The Study was conducted by the Space Information Systems Operation of Aeronutronic-Ford Corporation under Contract NAS 1-13657 for the Langley Research Center. Mr. F. O. Allamby and Ms. K. D. Brender were the technical study managers for Langley Research Center. The Study was conducted during a 12 month period from November 1974 to November 1975.

The final report consists of technical results of the Study on a task by task basis. The results of Task I, Experiments Operations Analysis, is continued in section 4 of the final report. Section 5 contains the ground processing requirements for the preprocessing of experiment data and a mini operational control center for ALT flight support. Section 6 contains the configuration and costing information. The configuration and costing is based on 1975 state-of-the art and 1975 costs. The costing was carried through fringe, burden, and profit.

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SECTION 1

INTRODUCTION

1.1 PURPOSE

The purpose of the Langley Applications Experiments Data Management System Study is to define, in functional terms, the most cost effective ground data management system to support Advanced Technology Laboratory (ATL) flights.

1.2 SCOPE

The study was divided into three major tasks.

A. Task I, Experiment Operations Analysis. This task consisted of the following three subtasks.

1. Operations Analysis Subtask. The objective of this subtask was to define the operational requirements of the Data Management System (DMS).

2. Langley Research Center (LRC) Facilities Analysis Subtask. Current pulse code modulation (PCM) and analog processing capabilities of LRC were examined for potential use in support of the ATL flights.

3. ATL Experiment Requirements Definition Subtask. The objective of this subtask was to define the data rates, data volumes, and formats generated by the experiments and to determine recording requirements.

B. Task II, Ground Support Data Management System Requirements. This task consisted of the following subtasks.

1. Functional Requirements Subtask. The objective of this subtask was to define DMS input requirements, processing requirements, and output requirements.

2. Performance Requirements Subtask. The objective of this subtask was to analyze system stressing requirements such as throughput and computational requirements. The results of this analysis would provide the basic computer characteristics for the DMS.

C. Task III, Preferred Ground Data Management System Configuration. This task consisted of the following three subtasks:

1. Configuration Concept Development Subtask. The objective of this subtask was to develop candidate configurations which could meet the requirements outlined in Task II.

2. Trade-off Analysis Subtask. This subtask involved performing engineering and cost trade analyses on the candidate systems to determine the most cost effective concept.

3. Preferred Configuration Subtask. This subtask consisted of providing a ROM cost of the preferred system configuration.

This document presents the results from each subtask and the recommended system configuration for reformatting the experiment instrumentation tapes to computer compatible tape. Included in Task III are cost factors for development of a mini control center for LRC for real-time support of the ATL flights.

SECTION 2

REFERENCES

Resources used to perform experiments analysis are as follows:

- NASA, *Study of Shuttle Compatible Advanced Technology Laboratory*. NASA, September 1973. (TM X-2813).
- NASA/LRC, ATL Experiment Data Sheets, April 1974.
- NASA/ESRO, *Spacelab Payload Accommodation Handbook*. NASA/ESRO, October 1974. (Preliminary Report, ESTEC Ref. No. SLP/2104).
- JSC, *Space Shuttle System Payload Accommodation of Level II Program Definition and Requirements*. JSC, January 1975. Vol. XIV. (JSC-07700).
- Contractor reports on individual experiments (where applicable these reports are referenced in the documentation for each experiment)
- Similar type experiments which were flown aboard the Skylab and Apollo Missions
- Technical journals and reports.

SECTION 3

ACRONYMS AND ABBREVIATIONS

A/D	analog-to-digital
A/G	air/ground
ATL	Advanced Technology Laboratory
b/s	bits per second
CCT	computer compatible tape
D/A	digital-to-analog
DMS	Data Management System
DRS	Data Reformatting System
GMT/MET	Greenwich Mean Time/Mission Elapsed Time
GSE	ground support equipment
GSFC	Goddard Space Flight Center
ID	identification
IRIG-B	Interrange Instrumentation Group Format B
I/S	inches per second
LRC	Langley Research Center
LRCDMS	Langley Research Center Data Management System
Mb/s	megabits per second
MTU	Master Timing Unit
PAM/PDM	pulse amplitude/duration modulation
PCC	Payload Control Center
PCM	pulse code modulation
PI	principal investigator
P/L	payload
PMT	Photo Multiplier Tube
POC	Payload Operations Center
POSC	Payload Operations Support Center

RF	radio frequency
RTC	real-time command
SCU	system control unit
STDN	Spacecraft Tracking and Data Network
STS	Space Transportation System
TSC	time search unit
UV	ultraviolet

SECTION 4

EXPERIMENT OPERATIONS ANALYSIS

4.1 SUBTASK 1.1, OPERATIONS ANALYSIS

The purpose of this subtask was to investigate program level operational requirements for the Advanced Technology Laboratory (ATL) in order to determine the areas of impact to the Langley Research Center (LRC) data reformatting system operations.

4.1.1 Methodology. The analysis of the operations was divided into the following four main areas of interest:

- Planning Phase
- Integration and Checkout
- Operation Phase
- Postflight Phase.

The requirements of each phase was then investigated with emphasis placed on pointing out the areas that would impact operation of the data reformatting system.

4.1.1.1 Planning Phase. This phase involves the development of plans, procedures, activities, and schedules for the ATL mission. It will require coordination, discussion, and document transfer between LRC and other NASA centers. The major interfaces will include:

- MSFC - Spacelab activities
- KSC - Shuttle/ATL integration and checkout activities
- JSC - Mission activities and postflight support
- GSFC - Spacecraft Tracking and Data Network (STDN) activities
- Principal Investigators - Experiment requirements and output products

It is assumed that experiment integration and checkout will be performed at LRC.

The major documents to be generated in this phase include:

A. Payload Mission Plan. This plan will be submitted to the NASA Headquarters approving authority. Based on this plan, the approving authority will prepare a mission requirements document. This plan will include:

- Crew requirements
- Orbital parameters
- Communication requirements
- Experiment schedules.

B. Mission Requirements Document. This document will be developed by NASA Headquarters with assistance of LRC and other NASA centers. It will be used by JSC, KSC, GSFC, and any other organizations for definition of their flight support responsibilities. This document will contain:

- Experiment descriptions
- Flight objectives
- Operations requirements from prelaunch through post-flight data processing
- Detailed requirements for flight scheduling, payload destination, data requirements, crew skills, ground facilities, and vehicle utilization.

C. Payload Crew Flight Plan. The major inputs to this plan will be experiment and principal investigator (PI) requirements, and the mission requirements document. This plan will include:

- Activities of the payload flight crew
- Activities of the payload ground crew which are related to flight crew activities.

D. Detailed Shuttle Crew Flight Plan. This plan will be developed by JSC and will require LRC support. During this period the payload crew flight plan will be finalized based on modifications required or revealed during the development of the Shuttle crew flight plan.

E. Shuttle/Payload Flight Data File Definition. This will be a joint effort between LRC and JSC. The document produced in this effort will serve as a JSC/LRC interface agreement device for the ATL mission. The definition will establish the following:

- Standard Shuttle procedures required
- New or unique Shuttle procedures required
- Shuttle/payload interface procedures required
- Standard payload procedures required
- New or unique payload procedures required
- Schedule and distribution requirements.

F. Payload Command Plan. This plan will contain the following information:

- Preplanned payload commands that may be initiated from LRC or JSC
- Critical commands which are those that could possibly constitute a hazard to the Orbiter or the ATL.

G. Experiment/ATL Integration and Checkout Plan

H. ATL/Shuttle Integration and Checkout Plan

I. Training Plan. This plan shall contain data for training of the commander and pilot and ground support personnel to support an ATL flight.

4.1.1.2 Integration and Checkout. This phase involves the LRC integration and checkout of the integrated ATL prior to shipment to the launch site (reference figure 4.1-1). The final step in this phase will be the recording of experiment data for processing by the data reformatting system. The major efforts of this phase will include:

A. Development of test procedures for checkout of the ATL subsystems and experiments

B. Development of calibration and checkout procedures for telemetry data and health and status signals for recording of transmission to the ground

C. Procedures for checkout of receiving, validating, and responding to commands from the ground system

D. Development of procedures for validating the results of the processing by the Data Reformatting System (DRS) which will include the following:

- Number of frames to be recorded by experiment
- Requirements for validation of data values contained on the recording prior to data reformatting
- Number of frames to be processed by the DRS
- Procedures for validating the reformatting process by a comparison of the output data against the recorded data tape

E. Support of the above procedures during the integration/checkout phase.

F. Complete acceptance testing and ship to launch site 3 months prior to launch date.

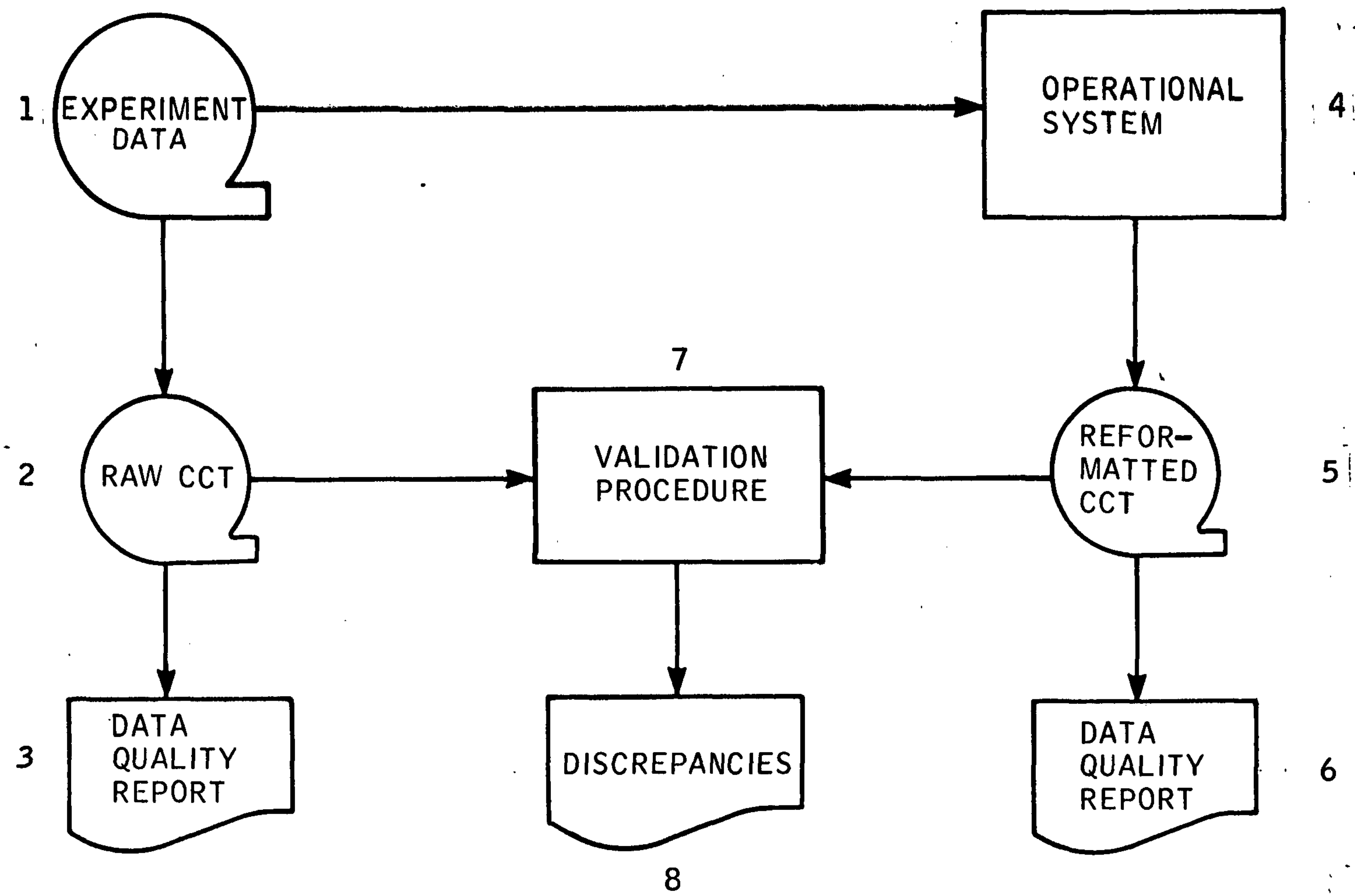


Figure 4.1-1 Integration/Checkout Function Flow

4.1.1.3 Operations Phase. The operations phase includes the integration/checkout of the ATL/Shuttle at the launch site, integrated simulations for checkout and training purposes, and the launch, orbital, entry and landing phases of the mission. The major functions to be performed during this phase include:

A. Develop an ATL checkout program or test plan for checkout of the ATL at KSC during installation and the on-pad checkout. Conduct or assist the launch site in ATL checkout and calibration. Remotely monitor the checkout from the Payload Control Center (PCC) and control the checkout sequence from the center as required.

B. Coordinate and control all ATL inflight operations. The interface from the PCC to the crew onboard the Shuttle will be through the payload officer at JSC. Maintain a voice interface with the payload crew during communication coverage periods.

C. Generate commands. Commands will be transmitted to JSC from the PCC prior to execution. These commands will be formatted to meet the JSC command requirements and will require no special handling at JSC other than storage until execution time.

D. Coordinate experiment operations with other ground systems or locations involved.

E. Receive selected experiment data during flights for the purpose of "quick-look" analysis of the experiment and its results.

F. Conduct real-time planning (replanning) of experiments as circumstances or contingencies dictate. Coordinate with the JSC payload officer in developing workaround procedures and alternatives to accomplish experiments and mission objectives.

G. Receive real-time or dumped ATL engineering data or experiment data from the Shuttle through JSC via a telecommunication link. Communication links through JSC are required for voice, telemetry, TV, and trajectory.

Current JSC plans are to support Shuttle payload operations with the following facilities and capabilities:

- Console and computer terminal facilities for two liaison representatives from the Payload Operations Center (POC)
- Office space for 6 to 10 POC representatives from about 1 month prior to flight
- Decommutation of payload data streams (up to 2 Mb/s)
- Delivery of payload data greater than 2 Mb/s in a raw data format
- Engineering unit conversion and display in real time of less than 2 Mb/s of payload data with hardcopy capability
- Command uplink capability of POC generated real-time commands (RTC's) and loads which use the Orbiter command system
- Air-to-ground voice capability for science operations
- Generation of computer-compatible tapes (CCT's) or provide electronic data transfer for all payload offline or offsite scientific processing
- Integration of payload operator detailed Payload (P/L) Crew Flight Plan with the Space Transportation System (STS) Crew Flight Plan
- Integrated crew and ground team training for integrated operations.

A standardized set of ground support tools will also be made available to the payload community for their P/L planning. These tools exist 1) to support Shuttle Operations, 2) are required by several payload operators, or 3) can only be uniquely provided. Examples of this capability include the following:

- Vehicle attitude and orbital element history
- Consumable-use predictions for maneuvers

- Vehicle lighting predictions
- Target pointing programs for celestial and orbital targets
- Occultation computations for Earth and celestial targets including vehicle occultation as viewed from Orbiter or different payload bay locations
- Orbit prediction and maneuver computations.

4.1.1.4 Postflight Phase. This phase involves the delivery of the experiment data tapes to the Data Reformatting Facility, the generation of computer compatible tapes and associated tabulations, and the delivery of the reformatted data to the PI.

4.1.1.4.1 Data Tape Routing. The procedures for routing the recorded experiment data to the Reformatting System were developed in the mission planning phase. The Reformatting System could possibly be located at LRC, JSC, or GSFC. For the purpose of this study the assumption is the location will be at LRC.

4.1.1.4.2 Data Processing.

A. Assumptions. The following assumptions have been made for data processing:

- All experiment data will be recorded. The Data Reformatting System will be required to reformat the data from all experiments defined in this study.
- Ephemeris data will be generated on CCT's at JSC and delivered in a common format to PI's.
- The Data Reformatting System will not be concerned with the ephemeris data as an input, but will be required to time tag the experiment data in a granularity that allows the ephemeris data to be merged into the applications processing.

B. Reformatting. The reformatting requirements will be generated in Task II of the study. In addition to reformatting, other functions the system will be required to perform include:

- Data and system health monitoring
- Sync loss and data quality checks
- Screening capability
- Data annotation.

C. Output Requirements. The major output will be in the form of computer compatible tape. Tabulations of data quality and time for each data reformatting process will also be required. Listed below are five of the high data rate experiments and the number of CCT's which would be generated based on mission data volume.

Experiment	Data Volume (Bits)	1600 CPI CCT's
EO-3	139,175,605,000	425
EO-7/8	2,080,685,376,000	6,351
NV-1	35,525,952,000	109
NV-3	31,850,496,000	98
EO-9	2,615,040,000	9

The numbers of CCT's were calculated on the following assumptions:

- 2400 foot reels of tape
- 3840 characters/record
- 1600 characters/inch
- 0.3 inch interrecord gap.

4.1.2 Areas of Impact. The following four areas in the ATL Integration/Operation cycle will require the support of the LRC Data System (reference 4.1-2).

- Experiment integration/checkout
- ATL/Shuttle integration/checkout
- Operations support
- Postflight data reformatting.

4.1.2.1 Experiment Integration/Checkout. The interface to the LRC Data System for this phase of operation will be magnetic tape. Prior to shipment of the ATL to the launch site, experiment data will be recorded on the ATL data recorders and processed by the Data Reformatting System. This process will accomplish two major goals:

- Ensure the data acquisition system of the ATL is functioning properly
- Ensure the hardware/software configuration of the Data Reformatting System is functioning properly.

4.1.2.2 ATL/Shuttle Integration/Checkout. The ATL checkout will occur after shipment of the ATL to the launch site and integration with the Shuttle. The process used in the experiment integration/checkout should be repeated to ensure the integrity of the data acquisition system.

4.1.2.3 Operations Support. During the ATL flight the data system will function as a mini payload control center. A data link with JSC would provide for receipt and evaluation of engineering data, experiment data, and advisories. Voice and TV links will also be supported.

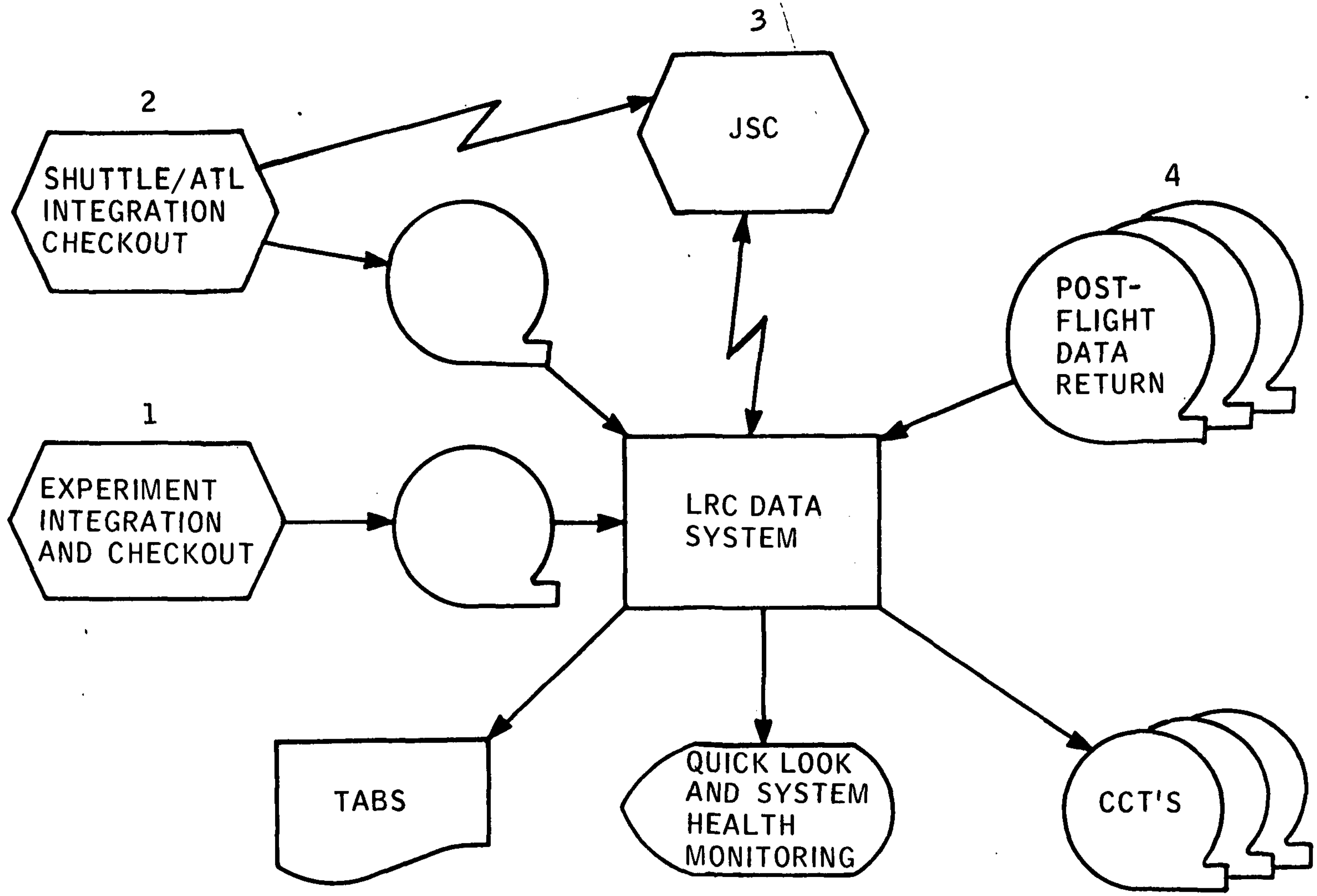


Figure 4.1-2 Data System Functional Flow

4.1.2.4 Postflight Data Reformatting. This phase represents the major effort of the LRC Data System. Reformatting the payload data will be time critical in getting the data to the PI in time for analysis and correction/modification prior to the next flight of a particular experiment. All data should be processed from one flight before integration and checkout begins for the next flight.

4.2 SUBTASK 1.2, LRC FACILITY ANALYSIS

The purpose of this subtask was to document the capabilities of LRC in the area of analog pulse code modulation (PCM) processing. This documentation became an input to Task III, Preferred Data Management System Definition.

A computer controlled system (reference figure 4.2-1) for processing, editing, and digital formatting of the following data types was installed at the LRC facility.

- Continuous analog data
- Pulse amplitude duration modulated (PAM/PDM) data
- PCM data
- Time code data.

4.2.1 Operational Capability. The system has the following operational capabilities:

- Processing - 1-32 channels of analog data
1 channel of PCM data
1 channel of PAM data

  Selected data to be formatted and output to digital tape
- "Quick Look" provisions for selected data channels to be output to an oscillograph recorder
- Simulate and calibrate capability [using digital-to-analog (D/A) and PCM simulator]
- System diagnostics
- Setup, processing, and editing completely programmable for automatic control by means of program entry.
- Existence of manual override capabilities so the operator can override any programmed function.

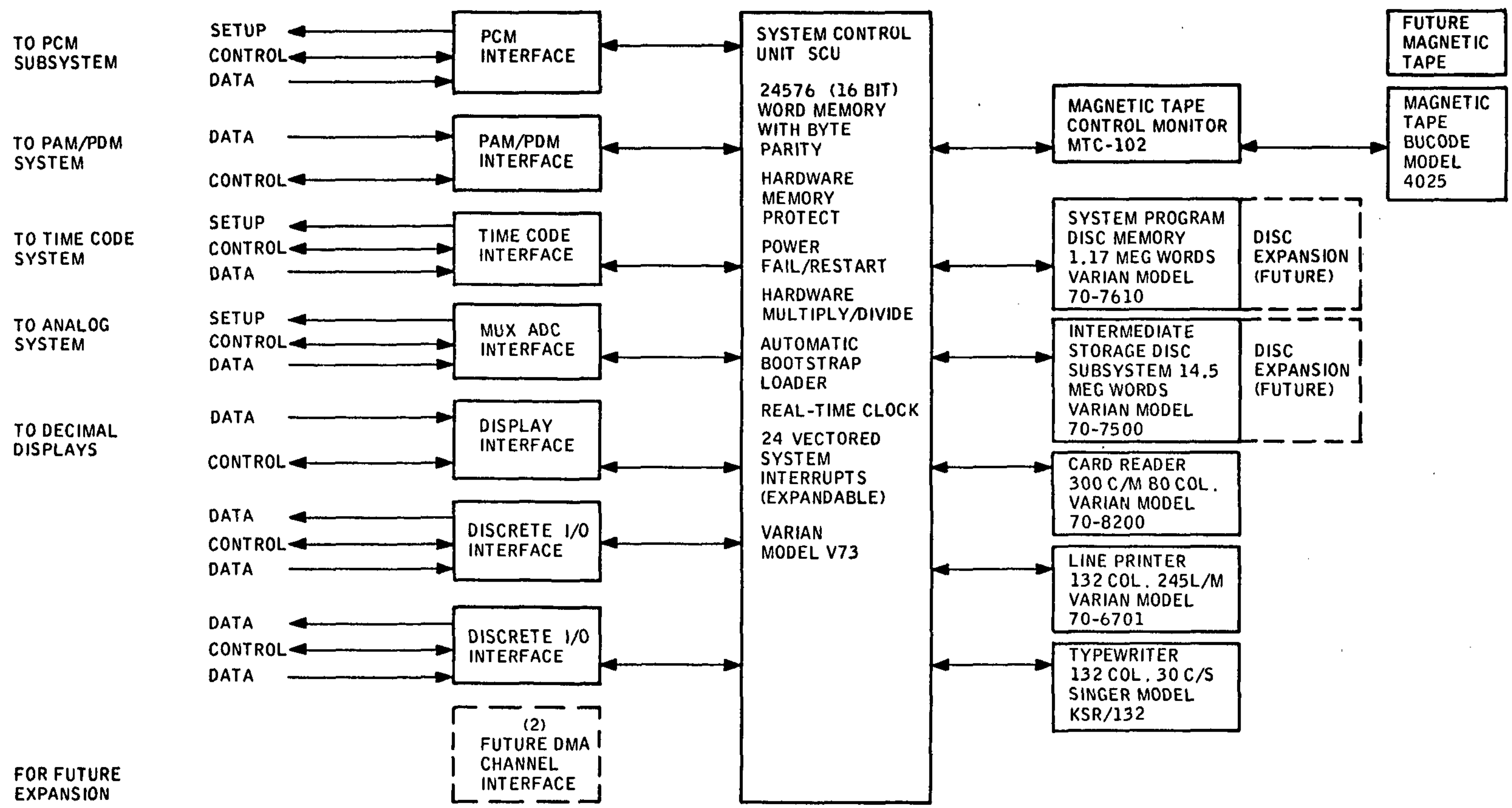


Figure 4.2-1 System Control Unit Subsystem

4.2.2 Data Throughput. There are two modes of operation:

- Normal Mode - 30K words/second without using intermediate storage

- High-Speed Mode - 120K words/second (accepting data and storing in intermediate storage)

4.2.3 System Characteristics

4.2.3.1 Hardware Characteristics

A. System Control Unit (SCU). The SCU is a Varian model V73 with 24,576 16-bit words of central memory. The SCU has the following features:

1. .66 microsecond maximum cycle time

2. Memory parity checks

3. Hardware memory protect

4. Power failure and restart

5. Fixed point multiply/divide

6. Multilevel directly vectored interrupt structure

7. Automatic bootstrap loader.

B. Standard Peripherals

1. Typewriter - 132 column, 30 character/second, Singer model KSR/132

2. Line Printer - 132 column, 245 line/minute, Varian model 70-6701

3. System Disk Unit - 1.17 megaword, Varian model 70-7610, 92K word/second transfer rate, 60 MS average access time

4. Magnetic Tape Unit - 9-track, 125 IPS, 800 CPI NRZ or 1600 CPI phase encoded, Bucode model 4025

5. Card Reader - 80 column, 300 card/minute Varian model 70-6200

6. Intermediate Storage System - 14.5 megaword, Varian model 70-7500, 156K word/second transfer rate, 35 microsecond average access time on track

7. Decimal Readouts - Up to eight selectable analog-to-digital (A/D) channels routed to digital displays for displaying present input values, system parameters, or data channels.

C. Special Interfaces

1. A/D Subsystem

a. 32 parallel input channels

b. Provision for expansion to 64 parallel input channels

c. Inputs include

(1) Subcarrier discriminators

(2) Analog tape recorders

(3) Test equipment

d. Data sampling rate includes

(1) Two or more channels at 100,000 samples per second

(2) One channel at 75,000 samples per second

e. Data word format - 12 bit quantization/sample

2. PCM Subsystem

a. One channel input

b. Input codes

(1) NRZ-L

(2) NRZ-M

(3) NRZ-S

(4) RZ

(5) Biphase-M

(6) Biphase-S

(7) Biphase-L

(8) DM-M

(9) DM-S

c. Bit Rates - Synchronization maintained over a range of 10 bits/second to 3 megabits/second for all input codes

d. Input Characteristics

(1) Frame length - 4 to 512 words

(2) Word length - 4 to 16 bits

(3) Prime frame sync - 4 to 33 bits

3. PAM/PDM Interface

a. One channel PAM/PDM input

b. Input analog signals

(1) PAM/RZ

(2) PAM/NRZ

(3) PDM

(4) DPDM

c. Throughput rate - 100,000 conversions/second

4. Time Code Interface

a. Time search unit (TSU)

(1) Maximum data rate - 100,000 CPS

(2) Time and command pulse data

(3) Time format - hours, minutes, seconds, milliseconds, microseconds

b. Command to the TSU - 10 digits of time plus 1 digit instruction code (Table 4.2-1 shows the instruction digits recognized by the TSU.)

c. Accepts command words from the SCU

5. Digital/Analog Subsystem

a. Provides for the selection of eight analog channels for "Quick Look" processing

b. Output to the oscillograph recorder

D. <u>Analog Tape Recorders</u>

1. Two Bell & Howell VR3700 - 1" or 1/2" tape

2. One Bell & Howell R3400 - 1" or 1/2" tape

3. One Ampex FR600 - 1/2" only

4. One Ampex FR1300 - 1/2" only

TABLE 4.2-1

INSTRUCTION DIGITS

INSTRUCTION DIGIT	FUNCTION
0	NOT USED
1	SINGLE SAMPLE COMMAND GENERATED
2	1.0 SECOND SAMPLE INTERVAL
3	0.1 SECOND SAMPLE INTERVAL
4	0.01 SECOND SAMPLE INTERVAL
5	0.002 SECOND SAMPLE INTERVAL
6	0.001 SECOND SAMPLE INTERVAL
7	STOP SAMPLING
8	SEARCH TO THIS TIME (NOT IMPLEMENTED)
9	STOP ANALOG TAPE TRANSPORT
A	0.1 MS SAMPLE
B	BACKSPACE COMMAND WORD (LOCAL MODE ONLY)
C	LOAD FIRST 7 DIGITS OF NEXT COMMAND WORD IN MEMORY INTO THE SAMPLE INTERVAL REGISTER
D	LOAD NEXT 7 DIGITS INTO THE SAMPLE INTERVAL REGISTER
E	ERASE COMMAND WORD PRESENTLY BEING LOADED INTO MEMORY (LOCAL MODE ONLY)
F	SAMPLE AT THE RATE DETERMINED BY THE SAMPLE INTERVAL REGISTER
•	ENTER THE REMAINING TIME DIGITS OF THE COMMAND WORD AS ZERO (LOCAL MODE ONLY)
CARRIAGE RETURN	END OF COMMAND WORD

4.2.3.2 Software Characteristics

A. Operating System

1. The Disk Operating System accepts inputs from typewriter, card reader, and system disk. Inputs are in the form of source programs, object programs, job control directives, and data.

2. The system structure is modular to allow expansion for additional processors and I/O drivers.

3. The system operates with a resident monitor for job control and interrupt answering and uses nonresident overlays for compilers, assemblers, support programs, and large application programs

B. Languages

1. FORTRAN IV

2. MACRO Assembly Language

   a. Relocatable code and link directives

   b. Compatibility with FORTRAN compiler

C. Support Software

1. Program Editor - Used for source program modification of both FORTRAN and Assembly Language

2. Debug Aids

   a. Memory Dump selectable by core location and output to disk, typewriter, and tape

   b. Core location examination and modification capability

   c. Checkpointing capability for application programs which allow suspension of execution, examining intermediate results, and return to execution

3. Library Editing and Maintenance - Used for modification of the system software, application routines, and data tables

4. File Management Software - Supports a minimum of 50 files on the system disk

D. Telemetry Software

1. Setup Procedures - The setup operation is one of the following three methods.

   a. Prepunched cards

   b. Interactive from keyboard

   c. Input from the system disk

   The operator is able to specify items which include:

   a. PCM channels to be processed

   b. Frame length

   c. Frame interval

   d. Word length

   e. Sync pattern

   f. Sync length

   g. Window

   h. Most significant bit (MSB) or least significant bit (LSB) first

   i. Zero calibration channel (PAM/PDM)

   j. Full scale calibration channel (PAM/PDM)

   k. PCM channels to be processed

2. Processing

   a. PAM/PDM Data - Scaled such that any input value greater than full scale is flagged by setting the output word to +111--1. Any input value less than zero is flagged as -000---0. Standard deviation is computed on a low priority basis and is deferred if it interferes with system throughput.

   b. PCM Data - Not scaled

   c. Time Checks - Time is checked for decreases or advances >1 second. If either occurs an error is listed.

   d. Time Tagging - Time is stored for each occurrence of frame sync.

3. Output Tape Formatting - Each data file is made up of one identification record, one name record, and a file mark.

   a. Identification Record - ASC11 format, 82 characters in length (The format is described in table 4.2-2.)

   b. Name Record - ASC11 format, length dependent on number of data words in the data record (The format is described in table 4.2-3.)

   c. Data Record - Binary format, maximum length of 3840 characters, minimum length of 3000 characters (The format is described in table 4.2-4.)

4.2.3.3 Operating Schedule. Current and planned operating schedule for the LRC facility is two shifts/day, 5 days/week with approximately three people/shift. Some work is done on weekends, depending on backlog and downtime.

TABLE 4.2-2

ID RECORD FORMAT

NAME	NO. OF CHARACTERS	DESCRIPTION
KEY	2	"ID"
NN	3	NUMBER OF REMAINING CHARACTERS IN RECORD
FILE NO.	4	A SEQUENTIAL NUMBER STARTING AT 1 AT THE BEGINNING OF THE TAPE
DATE MODE	3	DATA SOURCE = PCM, PDM, ANC
DATA TYPE	4	"DCAL", "ACAL", "DATA", "INIT"
TEST NAME	40	TEST IDENTIFICATION
TEST NO.	6	TEST IDENTIFICATION
RUN NO.	6	TEST IDENTIFICATION
DATE	6	YEAR, MONTH, DAY
"IWD"	2	NUMBER OF UNBLOCKED DATA WORDS IN DATA RECORD
KCH	3	NUMBER OF BLOCKED DATA WORDS IN DATA RECORD
NFR	3	NUMBER OF FRAMES IN A DATA RECORD (BLOCKING FACTOR)

UNBLOCKED DATA REFERS TO DATA THAT WILL OCCUR ONLY ONCE IN THE BEGINNING OF EACH DATA RECORD. BLOCKED DATA CAN BE REPEATED SEVERAL TIMES IN EACH RECORD.

TABLE 4.2-3

NAME RECORD FORMAT

NAME	NO. OF CHARACTERS	DESCRIPTION
KEY	5	NAME
NM	5	NUMBER OF REMAINING CHARACTERS IN RECORD
NAME (1)	10	"RECORD NO."
NAME (2)	10	"DAYS"
NAME (3)	10	"HRS-MIN"
NAME (4)	10	"SEC"
NAME (5)	10	"MICRO SEC"
NAME (6)	10	"STATUS" USED ONLY FOR PAM, PDM, AND PCM. THIS WORD SHALL BE DELETED FOR CONTINUOUS DATA
NAME (7) ● ●	10 ● ●	THE NAMES FOR THE REST OF RECORD WILL BE PROVIDED BY THE OPERATOR DURING SETUP TIME
(IWD+KCH)	10	

EACH NAME IN THE NAME RECORDS CORRESPONDS TO A DATA WORD IN THE DATA RECORD.

TABLE 4.2-4

DATA RECORDS FORMAT

NAME	TYPE	DESCRIPTION
KEY		"DA" (DATA)
NN		NUMBER OF REMAINING WORDS IN RECORD
RECORD NO.	UNBLOCKED	A SEQUENTIAL NUMBER STARTING AT ZERO AND INCREMENTED FOR EACH DATA RECORD IN THE FILE
TIME 1	UNBLOCKED	DAY OF YEAR FROM TIME CODE
TIME 2	UNBLOCKED	HOURS AND MINUTES FROM TIME CODE
TIME 3	BLOCKED	SECONDS FROM TIME CODE
TIME 4	BLOCKED	MICROSECONDS FROM TIME CODE
STATUS	BLOCKED	STATUS OF PCM, PAM, PDM SYSTEM, IF USED. DELETED IN CONTINUOUS DATA
EXTERNAL DIGITAL (1)	BLOCKED	DELETED IF NOT USED (ZERO, ONE, OR TWO WORDS)
EXTERNAL DIGITAL (2)	BLOCKED	DELETED IF NOT USED (ZERO, ONE, OR TWO WORDS)
DATA		FIRST ANALOG CHANNEL OF FIRST FRAME OF DATA
•		
•		
DATA (KCH,NFR)		LAST WORK OF LAST FRAME OF DATA

EACH WORD SHALL BE TWO CHARACTERS OR 16 BITS LONG.

4.2.3.4 Equipment for Support of ATL. In conclusion, the following hardware, if available, could be used to support ground processing of the ATL experiment data.

A. SCU. By expanding the central memory to 64K this system could meet the ATL requirements.

B. Standard Peripherals. The following peripherals could be used to support ATL processing.

1. Typewriter

2. Time printer

3. Card reader

4. Decimal readouts.

The costing information in section 6 lists costs for each individual component of the system including those listed above. This was done to show complete system cost if the current LRC facility was being used at a maximum with other LRC projects.

4.3 SUBTASK 1.3, EXPERIMENTS ANALYSIS

The purpose of this subtask was to analyze the ATL experiments to determine the data rate, data volume, and baseline data format associated with each experiment. The results of this subtask will become a major input to Task II, Ground Support Data Management System Requirements.

4.3.1 Methodology. Each experiment was analyzed individually to calculate data rates and establish a baseline format. The resources used to perform this analysis are listed in section 2.

Data volume for each experiment was calculated by using daily data-take times and number of days of data acquisition based on the following:

- Mission length - 7 days
- ATL experiment data sheets
- Timelines developed by LRC for a 7-day mission.

The experiments which were analyzed are listed in table 4.3-1.

4.3.1.1 Format Definitions. Items considered in the definition of formats for the ATL experiments were:

A. Spacelab Hardware. Computer and digital interfaces are byte (8 bits) or multibyte oriented[1].

B. Orbiter/Spacelab Interfaces. Interfaces are byte and multi-byte oriented[2,3].

C. Orbiter Telemetry Downlink. All formats to be downlinked from the Orbiter will be byte-structured[2].

[1] *Spacelab Payload Accommodation Handbook* (Preliminary), October 1974
[2] *Telemetry Standard* (Preliminary), January 1975, JSC
[3] *Level II Program Definition and Requirements*, Vol. XIV, "Space Shuttle System Payload Accommodations," January 1975, JSC

TABLE 4.3-1

STUDY EXPERIMENT LIST

SUBJECT	EXPERIMENT NO.	EXPERIMENT TITLE
COMMUNICATIONS AND NAVIGATION	NV-1 NV-2 NV-3	MICROWAVE INTERFEROMETER AUTONOMOUS NAVIGATION/LANDMARK TRACKER MULTIPATH MEASUREMENTS
EARTH OBSERVATIONS	EO-1 EO-2 EO-3 EO-4 EO-5 EO-6 EO-7 EO-8 EO-9	LIDAR AEROSOLS AND CLOUD MEASUREMENTS TUNABLE LASERS MULTISPECTRAL SCANNER MICROWAVE RADIOMETER PRECISION LASER RANGEFINDER MICROWAVE ALTIMETRY SEARCH AND RESCUE AIDS IMAGING RADAR RF NOISE
PHYSICS AND CHEMISTRY	PH-1 PH-2 PH-3 PH-6	SPACECRAFT WAKE DYNAMICS BARIUM PLASMA CLOUD RELEASE OPTICAL PROPERTIES OF AEROSOLS ULTRAVIOLET METEOR SPECTROSCOPY
MICROBIOLOGY	MB-1 MB-2 MB-3 MB-4 MB-5	COLONY GROWTH IN ZERO GRAVITY INTERPERSONAL TRANSFER OF MICRO-ORGANISMS IN ZERO G ELECTRICAL FIELD OPACITY IN BIOLOGICAL CELLS ELECTRICAL CHARACTERISTICS OF BIOLOGICAL CELLS SPECIAL PROPERTIES OF BIOLOGICAL CELLS
COMPONENT AND SYSTEM TESTING	CS-2	ZERO GRAVITY STEAM GENERATOR
ENVIRONMENTAL EFFECTS	EN-1 EN-3	SAMPLING OF AIRBORNE PARTICLES ENVIRONMENTAL EFFECTS ON NONMETALLIC MATERIALS

D. Ground Processing. Most computing facilities use byte-addressable hardware. This is especially true in the reformatting of wideband tapes.

4.3.1.2 Format Structure. Based on the above hardware/interface characteristics, the following assumptions were made in deriving a baseline format structure.

A. The length of each frame will be an integer multiple of 16 bits.

B. The maximum frame length will be 8192 bits. This length was selected to maintain compatibility with the current Orbiter formatting requirements.

C. Word length will be eight bits or an integer multiple of eight.

D. Nonbyte-oriented experiment data will be organized into blocks; the length of each block will be a multiple of eight bits.

E. The sequence of data in a frame will be:

- Frame sync: words 1 through 4 of all frames
- Frame counter: word 5 of all frames
- Format ID: word 6 of all frames
- Bit rate ID: word 7 of all frames
- Payload ID: word 8 of all frames
- Time: words 9 through 13
- Data measurements: words 14 through N; $N \leq 1024$.

Formats for each experiment were designed after analysis to determine parameter types and sample rates required. Data take times were supplied by LRC and were used to calculate data volume per mission.

4.3.1.3 Timing. Master timing services in the form of output data signals will be provided to attached payloads via hardline link from the Orbiter Master Timing Unit (MTU)[1]. The MTU will provide accurate frequency and time code outputs through the use of triple redundant crystal oscillators, frequency divider circuits, and Greenwich mean time/mission elapsed time (GMT/MET) accumulators.

An output sync frequency signal of 1024/kHz (square wave) will be assigned to payloads. The following spare contingency frequencies will also be available to payloads if requirements are defined.

- 4.608 MHz, sine wave
- 4.608 MHz, square wave
- 1.0 kHz, square wave
- 100 Hz, square wave
- 10 Hz, square wave
- 1.0 Hz, square wave.

All basic reference frequency signals will be mutually synchronized and can be used by the payloads to synthesize other timing frequencies if required.

The MTU will maintain separate time accumulators for GMT and MET time clock references. The accumulators are capable of being reset or updated by ground support equipment (GSE) and Orbiter crew via the keyboard interfaces. Capability will be provided to initialize or update all GMT, or all MET accumulators simultaneously. In addition, the MET accumulators will be reset to zero at liftoff. The GMT and MET clock output time codes to the payload will be provided in continuous 100 pulses per second, Inter-range Instrumentation Group B (IRIG-B) format. The serial time code digit format is coded in milliseconds, seconds, minutes, hours, and days.

In defining the data formats, the assumption was made that the on-board instrumentation unit would be able to fetch the IRIG-B time

[1]*Level II Program Definition and Requirements*, Vol. XIV, "Space Shuttle System Payload Accommodations," January 1975, JSC

from the MET or GMT input source and multiplex the time along with data in each data frame.

Figure 4.3-1 depicts the timing data flow through the payload hard-line interfaces.

4.3.2 Communications and Navigations. The following paragraphs contain detailed documentation resulting from the communications and navigation experiments analysis. Also included are the references and assumptions used to establish the data rate for each experiment and a baseline format description.

4.3.2.1 NV-1, Microwave Interferometer Navigation and Tracking Aid. The general concepts and parameter values used for this experiment were obtained from the report *Development of a Microwave Interferometer Position Location*, NASA CR-112188, dated August 1973. This report was prepared by IBM for LRC under contract NAS 1-10997. Information was also obtained from the LRC experiment data sheets and the experiment write-up in LRC ATL report NASA TMX-2813.

The following assumptions were made for this experiment:

A. The received signal spectrum will consist of four calibration (Cal) signals (Cals 1 through 4) and two beacon signals (beacons 1 and 2).

B. There will be seven RF receive channels (each RF channel will contain the four calibration and two beacon signals).

C. There will be six phase recovery channels (one for each calibration and beacon signal; the inputs to each channel will consist of the seven RF receive channels which have been down converted; the seven outputs from each channel will represent the same signal data that has been extracted from each of the seven RF receive channels; six of the outputs will be provided as inputs to individual phase meters for phase measurements and the seventh output will be used as a reference input to the six phase meters for that channel).

D. There will be 36 digital phase meters (6 for each phase recovery channel).

E. The output rate of each phase meter will be 2000 samples per second.

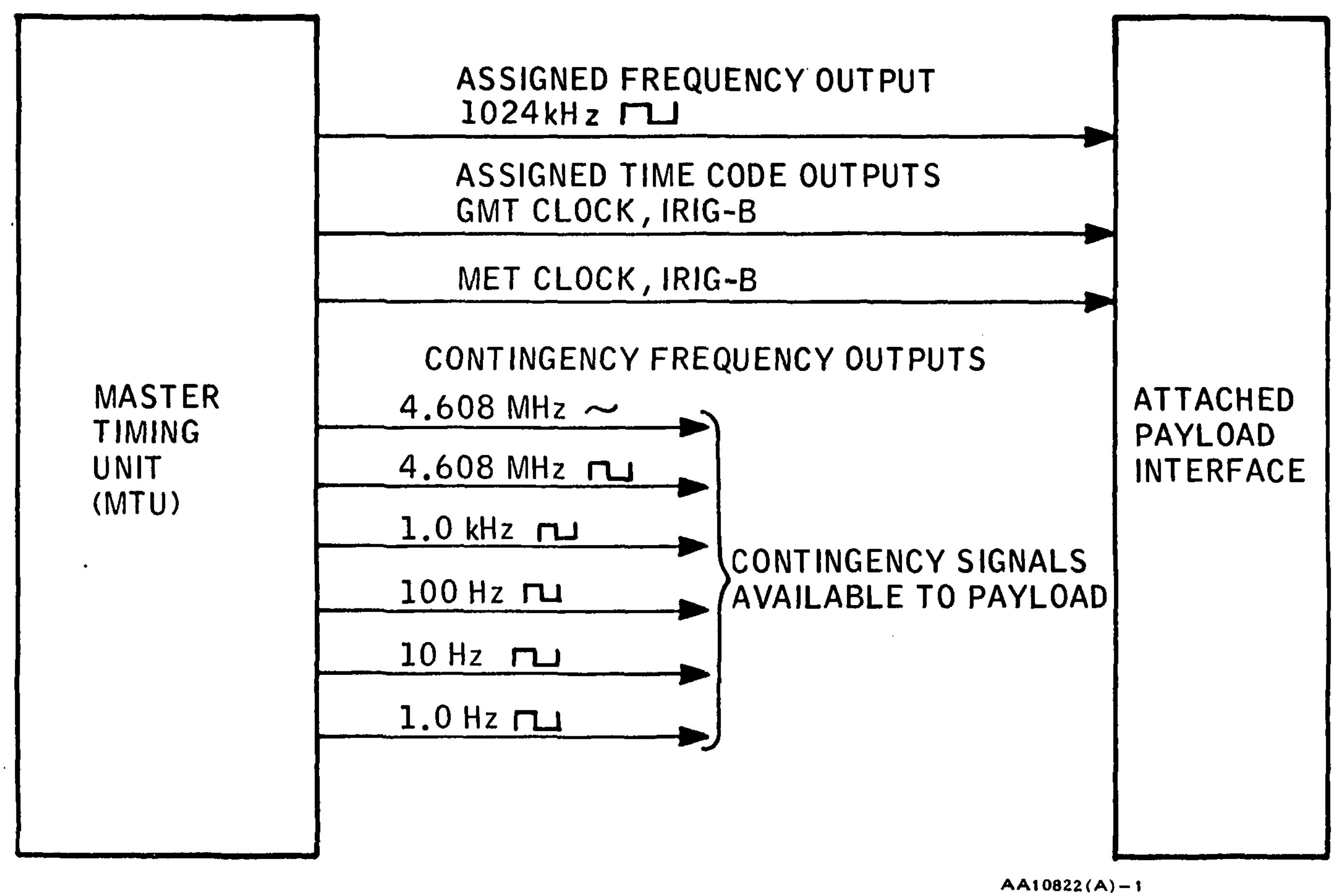


Figure 4.3-1 MTU/Payload Timing Signal Flow Diagram

F. The quantization level of experiment data will equal 10 bits.

G. All phase measurements will be performed and recorded digitally onboard the ATL.

Since the quantization level provides 10-bit words (one 10-bit word per sample) and the assumed standard format (reference paragraph 4.3.1.2) utilizes 8-bit words, word blocking is required for the experiment data. The assumed block length is 40 bits (four 10-bit words which are equivalent to five 8-bit words). If the data from each of the 36 output data lines is blocked so that each block contains four samples (four 10-bit words), then one complete data pass through all 36 output data lines would yield 144 samples. Five complete data passes through all 36 output data lines would yield 720 samples. The sample rate of the experiment data is 72,000 samples per second (36 data lines at 2000 samples per second per data line). Therefore, if five complete data passes of data (720 samples) are contained in one frame, then the frame rate would be 100 frames per second (72,000 samples per second divided by 720 samples per frame).

Each frame will contain the following number of 8-bit words of data: 900 experiment (720 10-bit words), 13 overhead, and 11 housekeeping as illustrated in table 4.3-2. By combining the overhead, experiment, and housekeeping data for 100 frames, the total data rate becomes

Overhead data rate	=	10,400 b/s
Experiment data rate	=	720,000 b/s
Housekeeping data rate	=	8,800 b/s
Total data rate	=	739,200 b/s

Types of housekeeping data include instrument calibration, boom temperature, boom motion, receiver characteristics, equipment status, etc.

4.3.2.2 NV-2, Autonomous Navigation/Landmark Tracker. The basic experiment, as described in NASA TMX-2813, was intended to investigate techniques for correlation tracking of either earth or star field targets. In order to baseline a data rate and format for this experiment, the following assumptions were made. Note: Interferometer data will be collected by another experiment and therefore, will not be included in this analysis.

TABLE 4.3-2

NV-1, MICROWAVE INTERFEROMETER NAVIGATION AND TRACKING AID

DATA RATE 739,200 BITS/SECOND
FRAME RATE 100 FRAMES/SECOND
FRAME SIZE 924 WORDS/FRAME (8-BIT WORDS)
7,392 BITS/FRAME

WORD	DESCRIPTION		BITS/WORD
1	SYNC		8
2	SYNC		
3	SYNC		
4	SYNC		
5	FRAME COUNTER		
6	FORMAT ID		
7	BIT RATE ID		
8	PAYLOAD ID		
9	TIME 1		
10	TIME 2		
11	TIME 3		
12	TIME 4		
13	TIME 5		8
14	CAL 1, RF CHANNEL 1, SAMPLE 1	BLOCK 1	10
15	CAL 1, RF CHANNEL 1, SAMPLE 2		
16	CAL 1, RF CHANNEL 1, SAMPLE 3		
17	CAL 1, RF CHANNEL 1, SAMPLE 4		
⋮	⋮	⋮	
30	CAL 1, RF CHANNEL 1, SAMPLE 17	BLOCK 5	
31	CAL 1, RF CHANNEL 1, SAMPLE 18		
32	CAL 1, RF CHANNEL 1, SAMPLE 19		
33	CAL 1, RF CHANNEL 1, SAMPLE 20		
34	CAL 1, RF CHANNEL 2, SAMPLE 1	BLOCK 6	
35	CAL 1, RF CHANNEL 2, SAMPLE 2		
36	CAL 1, RF CHANNEL 2, SAMPLE 3		
37	CAL 1, RF CHANNEL 2, SAMPLE 4		
⋮	(20 SAMPLES EACH, CHANNELS 2 THRU 6)	⋮	
130	CAL 1, RF CHANNEL 6, SAMPLE 17	BLOCK 30	
131	CAL 1, RF CHANNEL 6, SAMPLE 18		
132	CAL 1, RF CHANNEL 6, SAMPLE 19		
133	CAL 1, RF CHANNEL 6, SAMPLE 20		10

TABLE 4.3-2 (CONT'D)

WORD	DESCRIPTION		BITS/WORD
134	CAL 2, RF CHANNEL 1, SAMPLE 1	BLOCK 31	10
135	CAL 2, RF CHANNEL 1, SAMPLE 2		
136	CAL 2, RF CHANNEL 1, SAMPLE 3		
137	CAL 2, RF CHANNEL 1, SAMPLE 4		
⋮	(20 SAMPLES EACH FOR CHANNELS 1 THRU 6, 6 CHANNELS EACH FOR CALS 2 THRU 4)	⋮	
490	CAL 4, RF CHANNEL 6, SAMPLE 17	BLOCK 120	
491	CAL 4, RF CHANNEL 6, SAMPLE 18		
492	CAL 4, RF CHANNEL 6, SAMPLE 19		
493	CAL 4, RF CHANNEL 6, SAMPLE 20		
494	BEACON 1, RF CHANNEL 1, SAMPLE 1	BLOCK 121	
495	BEACON 1, RF CHANNEL 1, SAMPLE 2		
496	BEACON 1, RF CHANNEL 1, SAMPLE 3		
497	BEACON 1, RF CHANNEL 1, SAMPLE 4		
⋮	(20 SAMPLES EACH FOR CHANNELS 1 THRU 6, 6 CHANNELS EACH FOR BEACONS 1 AND 2)	⋮	
730	BEACON 2, RF CHANNEL 6, SAMPLE 17	BLOCK 180	
731	BEACON 2, RF CHANNEL 6, SAMPLE 18		
732	BEACON 2, RF CHANNEL 6, SAMPLE 19		
733	BEACON 2, RF CHANNEL 6, SAMPLE 20		10
734	HOUSEKEEPING 1		8
735	HOUSEKEEPING 2		
⋮	⋮		
743	HOUSEKEEPING 10		
744	HOUSEKEEPING 11		8

A. The video camera used to monitor the telescope pointing will not be digitized.

B. Measurements from the onboard inertial system will be made simultaneously with measurements from the holographic tracker.

C. The electro-optical readout system will consist of am image dissector placed in the image plane of the correlation system. The correlation output at the image dissector will consist of the cross-correlation function of the viewed scene and the target scene.

D. The cross-correlation function will contain a peak when properly matched to the viewed scene to allow detection by amplitude comparison on the output sensor.

E. The X-Y location of the correlation peak will be read out at a maximum rate of 200 Hz.

F. The experiment will operate in two modes, search and track.

   1. During search mode operation, the following parameters were assumed:

      - Angular position of target filter: quantized to 1024 levels
      - Position in image dissector: quantized to 1024 × 1024 discrete locations
      - Amplitude of video signal peak value: quantized to 256 levels
      - Measurements and calculations: performed 25 times per second.

   2. During track mode operation, the following parameters were assumed:

      - Number of scan cycles: 200
      - Estimated position: calculated 200 times per second
      - Major grid and location coordinates: digitized for each scan cycle.

Table 4.3-3 depicts the baseline format.

4.3.2.3 NV-3, Multipath Measurements. The general concepts and parameter values used to represent this experiment were obtained primarily from two reports in addition to the LRC experiment data sheets and experiment write-up in the LRC ATL report, NASA TMX-2813.

TABLE 4.3-3

NV-2, AUTONOMOUS NAVIGATION/LANDMARK TRACKER

DATA RATE 193,600 BITS/SECOND
FRAME RATE 25 FRAMES/SECOND
FRAME SIZE 968 WORDS/FRAME (8-BIT WORDS)
7,744 BITS/FRAME

WORD	DESCRIPTION		MODE	BITS/WORD
1	SYNC 1			8
2	SYNC 2			
3	SYNC 3			
4	SYNC 4			
5	FRAME COUNTER			
6	FORMAT ID			
7	BIT RATE ID			
8	PAYLOAD ID			
9	TIME 1			
10	TIME 2			
11	TIME 3			
12	TIME 4			
13	TIME 5			
14	MODE ID AND STATUS		TRACK	8
15-54	RING 1-40 AMPLITUDE, SAMPLE 1 (40 10-BIT WORDS ~ 50 8-BIT WORDS)	BLOCKS 1-10		10
55-94	RING 1-40 PHASE ANGLE, SAMPLE 1 (40 10-BIT WORDS ~ 50 8-BIT WORDS)	BLOCKS 11-20		
95	INTERPOLATED RADIUS, r, SAMPLE 1	BLOCK 21		
96	INTERPOLATED PHASE, ϕ_r, SAMPLE 1			
97	BROADNESS, b, SAMPLE 1			
98	MICRO STATUS, SAMPLE 1			
99	SYSTEM STATUS, SAMPLE 1	BLOCK 22		
100	ORIENTATION, SAMPLE 1			
101	X-POSITION, SAMPLE 1			
102	Y-POSITION, SAMPLE 1			10
103	PEAK AMPLITUDE, SAMPLE 1			8
104-105	INERTIAL ROLL, SAMPLE 1			
106-107	INERTIAL PITCH, SAMPLE 1			
108-109	INERTIAL YAW, SAMPLE 1			
110-774	SAMPLES 2-8 OF THE SAME PARAMETERS IN WORDS 15-109			
775	MANUAL INPUTS			
776	AUTOMATIC INPUTS		TRACK	
777	MODE ID AND STATUS		SEARCH	8
778	SYSTEM STATUS	BLOCK 177		10
779	ORIENTATION			
780	X-POSITION			
781	Y-POSITION			10
782	PEAK AMPLITUDE			8
783-784	INERTIAL ROLL			
785-786	INERTIAL PITCH			
787-788	INERTIAL YAW			
789	MANUAL INPUTS			
790	AUTOMATIC INPUTS		SEARCH	
791	SPARE			8

The two reports are 1) "Multipath Problems in Communications Between Low-Altitude Spacecraft and Stationary Satellites," *RCA Review*, Vol. 29, March 1968, and 2) *Definition of Multipath/RFI Experiments for Orbital Testing with a Small Applications Technology Satellite, Final Report for Contract NAS 9-12705* (STAR Reference No. N73-16128), prepared by the Magnavox Company for NASA/JSC, December 1972.

The assumptions for this experiment were as follows:

- Vehicle altitude (h): 185 km
- Vehicle velocity (v): 7.58 km/s
- Speed of light (c): 3×10^8 m/s
- L-band frequency (f_l): 1.6×10^9 Hz (maximum)
- S-band frequency (f_s): 2.3×10^9 Hz (maximum)
- Ku-band frequency (f_k): 15.35×10^9 Hz (maximum)
- A measure of the root mean square (rms) slope of surface undulations (σ/T): 0.05
- Quantization level (Q): 8
- Data collected simultaneously from L-, S-, and Ku-bands
- One channel of data per frequency band.

The approach that will be followed in defining the data rate and format for this experiment will be to determine the experiment sample rate for each of three frequency bands and then combine these three sample rates into a format such that the same data words in each frame will contain similar data.

The fading bandwidth (B_F) of the multipath signal can be approximated by the following equation (see reference 1 above for derivations):

$$B_F \approx Kv\sqrt{2}\,(\sigma/T)(\sin A/\tan B)$$

where:

$K = 2\Pi/\lambda$ and $\lambda = c/f$

Making these substitutions and assuming that the maximum value of (sin A/tan B) will be 1, the fading bandwidth (maximum value) approximation becomes

$$B_F \approx [2\Pi f v \sqrt{2}(\sigma/T)]/c$$

Using these parameter values, the maximum fading bandwidth for each of the three frequency bands was calculated to be 17.97 kHz for L-band, 25.8 kHz for S-band, and 172.2 kHz for Ku-band. It should be noted that to obtain the maximum fading bandwidth for each of the three frequency bands listed in the LRC ATL report, NASA TMX-2813, the maximum value of the carrier frequency in each band (as listed above) was used in the calculations.

The assumption was made that the output of the experiment has been low-pass filtered such that the highest frequency of the multipath signal will be 17.97 kHz for L-band, 25.8 kHz for S-band, and 172.2 kHz for Ku-band. The assumption was also made that the minimum sample ratio is determined by sampling the multipath signal at twice the highest frequency. Therefore, the minimum sample rate (S_R) is defined by the equation:

$$S_R = 2\ B_F$$

The minimum sample rate for each frequency band was calculated to be 35.94K samples/second for L-band, 51.6K samples/second for S-band, and 344.4K samples/second for Ku-band. Adding the sample rates from each band, the total minimum samples are 431.94K samples/second. Based on the format structure defined in paragraph 4.3.1.2, it is assumed that a frame will contain approximately 1000 samples. Therefore, the frame rate required to accommodate the experiment data would be 432 frames/second.

The number of samples of data from each frequency band which will be contained in each frame was obtained by dividing the frame rate into the sample rate for each band. Therefore, each frame will contain 84 samples of L-band data, 120 samples of S-band data, and 798 samples of Ku-band data. Since these numbers represent a rounding off of a fraction of a sample to the next highest integer sample, the actual sample rate for each frequency band will be slightly higher than previously calculated. The actual sample rate will be 36.288K samples/second for L-band, 51.84K samples/second for S-band, and 344.736K samples/second for Ku-band. Each sample will be encoded as an 8-bit word.

Each frame will contain the following numbers of 8-bit words of data: 13 overhead, 1002 experiment, and 9 housekeeping as illustrated in table 4.3-4. By combining the overhead, experiment, and housekeeping data for 432 frames, the total data rate becomes

Overhead data rate	=	44,928 b/s
Experiment data rate	=	3,462,912 b/s
Housekeeping data rate	=	31,104 b/s
Total data rate	=	3,538,944 b/s

Types of housekeeping data include carrier frequencies and position, altitude, TDRS, calibration, meterological, and receiver data, etc.

4.3.3 Earth Observations. The following paragraphs contain the detailed documentation resulting from the analysis of the earth observations experiments. Included in the documentation are the references and assumptions used in establishing the data rate for each experiment and a baseline format description.

In addition to the nine experiments assigned to this discipline, the S190A camera assembly which flew on the Skylab was analyzed. This same experiment package will fly on an early ATL flight as a forerunner to EO-3, the Multispectral Scanner.

4.3.3.1 EO-1, Lidar Measurements of Cirrus Clouds and Lower Stratospheric Aerosols. The general concepts and parameter values used to represent this experiment were obtained from LRC experiment data sheets, LRC ATL report, NASA TMX-2813, and journal articles.

The assumptions used for this experiment are as follows:

- Vehicle altitude (h): 185 km

TABLE 4.3-4

NV-3, MULTIPATH MEASUREMENTS FORMAT

DATA RATE 3,538,944 BITS/SECOND
FRAME RATE 432 FRAMES/SECOND
FRAME SIZE 1,024 WORDS/FRAME (8-BIT WORDS)
8,192 BITS/FRAME

WORD	DESCRIPTION	WORD	DESCRIPTION
1	SYNC	98	S-BAND SAMPLE 1
2	SYNC	99	S-BAND SAMPLE 2
3	SYNC	⋮	⋮
4	SYNC		
5	FRAME COUNTER	216	S-BAND SAMPLE 119
6	FORMAT ID	217	S-BAND SAMPLE 120
7	BIT RATE ID	218	Ku-BAND SAMPLE 1
8	PAYLOAD ID	219	Ku-BAND SAMPLE 2
9	TIME 1	⋮	⋮
10	TIME 2		
11	TIME 3	1014	Ku-BAND SAMPLE 797
12	TIME 4	1015	Ku-BAND SAMPLE 798
13	TIME 5	1016	HOUSEKEEPING 1
14	L-BAND SAMPLE 1	1017	HOUSEKEEPING 2
15	L-BAND SAMPLE 2	⋮	⋮
⋮	⋮	1023	HOUSEKEEPING 8
96	L-BAND SAMPLE 83	1024	HOUSEKEEPING 9
97	L-BAND SAMPLE 84		

- Vehicle velocity (v): 7.58 km/sec
- Extent of stratosphere: from 11 km to 48 km
- Lower stratospheric layer resolution: 100 meters, 0.66 μsec
- Laser firing per minute: 1
- Frame of data per laser firing: 1
- Each experiment data sample will contain data from each of the stratospheric layers (100-meter layer)
- Experiment data rate: 100 samples/minute
- Content of one sample: 8 bits.

Each frame of data will contain the following numbers of 8-bit words of data: 100 experiment, 13 overhead, and 7 housekeeping as illustrated in table 4.3-5. The total data rate is obtained from the following: 1 frame per minute, 960 bits per frame which gives a total rate of 16 bits per second.

Types of housekeeping data include pulse number, photomultiplier power supply voltage, input sensitivity, laser status, calibration data, and temperatures.

4.3.3.2 EO-2, Tunable Lasers for High-Resolution Studies of Atmospheric Constituents and Pollutants. The tunable lasers experiment package will consist of a tunable injection laser monochromator and a tunable laser heterodyne radiometer for use in measuring atmospheric constituents and pollutants.

The parameters to be measured are:

- Vertical distribution of atmospheric constituents and pollutants which contain absorption bands in the 2 or 3 μM region
- Spectroscopic parameters such as line shapes and line positions for use in computer modeling programs of the atmosphere
- Concentration of molecules in the atmosphere interior to and surrounding the Shuttle.

TABLE 4.3-5

EO-1, LIDAR MEASUREMENTS FORMAT

DATA RATE 16 BITS/SECOND
FRAME RATE 1 FRAME/MINUTE
FRAME SIZE 120 WORDS/FRAME (8-BIT WORDS)
960 BITS/FRAME

WORD	DESCRIPTION
1	SYNC
2	SYNC
3	SYNC
4	SYNC
5	FRAME COUNTER
6	FORMAT ID
7	BIT RATE ID
8	PAYLOAD ID
9	TIME 1
10	TIME 2
11	TIME 3
12	TIME 4
13	TIME 5
14	EXPERIMENT DATA 1, STRATOSPHERIC LAYER 1
15	EXPERIMENT DATA 2, STRATOSPHERIC LAYER 2
⋮	⋮
113	EXPERIMENT DATA 100, STRATOSPHERIC LAYER 100
114	HOUSEKEEPING 1
⋮	⋮
120	HOUSEKEEPING 7

The general concepts and parameter values used to represent this experiment were obtained from LRC exerpiment data sheets, LRC ATL Report (NASA TMX-2813) and from the Principal Investigator, Dr. Frank Allario. The sample rate for the active experiment, tunable injection laser monochromator, will be 2500 samples per second and the sample rate for the passive experiment, tunable laser heterodyne radiometer, will be 25 samples per second. It is anticipated that the two experiment packages will not be run simultaneously; therefore, two experiment formats are provided as illustrated in tables 4.3-6 and 4.3-7.

4.3.3.3 EO-3, Multispectral Scanner. The basis for the analysis of the Multispectral Scanner (MSS) was the work done by Aeronutronic Ford on the EOS study for JSC. This study, performed under Contract NAS 9-1261, involved analyzing data rates and formats produced by several MSS sensors with varying resolutions from 10 to 100 meters.

The basic method for calculating the data rate for an MSS sensor was as follows:

$$\text{Bits/Second} = (S)(ER)(BX) + H$$

Where: S = Number of sensors
E = Number of elements/scan
R = Resolution in bits of each element
B = Number of bands
X = Number of scans/second
H = Housekeeping and overhead in bits

The data rate for EO-3 was then calculated by using the following assumptions and information from LRC personnel.

- Number of sensors: 50
- Number of elements/scan: 1000 (this was based on a scan swath width of 20 km and a resolution of 20M/element)
- Resolution of each element: 8 bits

TABLE 4.3-6

EO-2A, TUNABLE LASER HETERODYNE RADIOMETER

DATA RATE	480 BITS/SECOND
FRAME RATE	1 FRAME/SECOND
FRAME SIZE	60 WORDS/FRAME
	480 BITS/FRAME

WORD	DESCRIPTION	WORD	DESCRIPTION
1	SYNC 1	17	LASER SWEEP RATE
2	SYNC 2	18	POSTDETECTION INTEGRATION TIME
3	SYNC 3	19	CAL DATA
4	SYNC 4	20	DETECTOR TEMPERATURE
5	FRAME COUNTER	21	DETECTOR VOLTAGE
6	FORMAT ID	22	DETECTOR CURRENT
7	BIT RATE ID	23	POWER SUPPLY VOLTAGE
8	PAYLOAD ID	24	SITE CODE
9	TIME 1	25	SITE TEMPERATURE
10	TIME 2	26	SITE PRESSURE
11	TIME 3	27	SITE REFLECTANCE
12	TIME 4	28	ALTITUDE
13	TIME 5	29	RANGE TO SITE
14	LASER ID	30	LOOK ANGLE NO. 1
15	LASER MODE ID	31	LOOK ANGLE NO. 2
16	LASER STATUS	32-56	EXPERIMENT DATA
		57-60	SPARES

TABLE 4.3-7

EO-2B, TUNABLE INJECTION LASER MONOCHROMATOR

DATA RATE 20,992 BITS/SECOND
FRAME RATE 4 FRAMES/SECOND
FRAME SIZE 656 WORDS/FRAME
5,248 BITS/FRAME

WORD	DESCRIPTION	WORD	DESCRIPTION
1	SYNC 1	17	LASER SWEEP RATE
2	SYNC 2	18	POSTDETECTION INTEGRATION TIME
3	SYNC 3	19	CAL DATA
4	SYNC 4	20	DETECTOR TEMPERATURE
5	FRAME COUNTER	21	DETECTOR VOLTAGE
6	FORMAT ID	22	DETECTOR CURRENT
7	BIT RATE ID	23	POWER SUPPLY VOLTAGE
8	PAYLOAD ID	24	SITE CODE
9	TIME 1	25	SITE TEMPERATURE
10	TIME 2	26	SITE PRESSURE
11	TIME 3	27	SITE REFLECTANCE
12	TIME 4	28	ALTITUDE
13	TIME 5	29	RANGE TO SITE
14	LASER ID	30	LOOK ANGLE NO. 1
15	LASER MODE ID	31	LOOK ANGLE NO. 2
16	LASER STATUS	32-656	EXPERIMENT DATA

- Number of bands: 8

- Number of scans: 7.12/second (this was based on a 250 nmi orbit and a ground velocity of 7.12 km/second).

By plugging these numbers into the data rate formula, the image data rate was calculated

$$(50)(1000.8)(8.7.12) = 22,784,999 \text{ b/s}$$

Data frames were calculated based on having 1 frame/element position within the scan, giving 1000 frames/scan; thus, data frames would appear as follows:

Frame 1: Element 1 for 50 sensors and 8 bands
Frame 2: Element 2 for 50 sensors and 8 bands
Frame 3: Element 3 for 50 sensors and 8 bands
. . . .
. . . .
. . . .
Frame 1000: Element 1000 for 50 sensors and 8 bands

Table 4.3-8 depicts an image data frame in detail.

The housekeeping data rate was calculated by using the following assumptions:

- 8-bit resolution/housekeeping parameter: 1

- Housekeeping frame for each scan/band: 1

- Content of each housekeeping frame:

  13 overhead words = 13
  3 high cals/sensor = 150
  3 low cals/sensor = 150
  1 temperature measurement/sensor = 50
  41 slots for additional housekeeping = 41

  404 words × 8 bits = 3232 bits/frame

TABLE 4.3-8

EO-3, MULTISPECTRAL SCANNER DATA FRAMES

WORD	DESCRIPTION	WORD	DESCRIPTION
1	SYNC 1	17	BAND 5, LINE 2, PIXEL 1
2	SYNC 2	18	BAND 6, LINE 2, PIXEL 1
3	FRAME COUNTER (MSS)	19	BAND 7, LINE 2, PIXEL 1
4	FRAME COUNTER (LSS)	20	BAND 8, LINE 2, PIXEL 1
5	BAND 1, LINE 1, PIXEL 1	21	BAND 1, LINE 3, PIXEL 1
6	BAND 2, LINE 1, PIXEL 1		
7	BAND 3, LINE 1, PIXEL 1	⋮	⋮
8	BAND 4, LINE 1, PIXEL 1		
9	BAND 5, LINE 1, PIXEL 1	397	BAND 1, LINE 50, PIXEL 1
10	BAND 6, LINE 1, PIXEL 1	398	BAND 2, LINE 50, PIXEL 1
11	BAND 7, LINE 1, PIXEL 1	399	BAND 3, LINE 50, PIXEL 1
12	BAND 8, LINE 1, PIXEL 1	400	BAND 4, LINE 50, PIXEL 1
13	BAND 1, LINE 2, PIXEL 1	401	BAND 5, LINE 50, PIXEL 1
14	BAND 2, LINE 2, PIXEL 1	402	BAND 6, LINE 50, PIXEL 1
15	BAND 3, LINE 2, PIXEL 1	403	BAND 7, LINE 50, PIXEL 1
16	BAND 4, LINE 2, PIXEL 1	404	BAND 8, LINE 50, PIXEL 1

Total overhead was then calculated by adding the number of sync bits/scan to the number of housekeeping bits/scan and then multiplying by the number of scans/second.

Housekeeping bits (3232 × 8) =	25,856
Sync bits (32 × 1000) =	32,000
Total overhead/scan bits	57,856
Scans/second	× 7.12
Total bits/second	411,935

Table 4.3-9 depicts a housekeeping frame in detail.

The total data rate in bits/second is then:

Image data rate:	22,784,000
Overhead:	411,935
Total:	23,195,935

Frame Rate: 1000 data frames/scan
8 housekeeping frames/scan
7.12 scans/second

Frame Size: 404 words/frame
3232 bits/frame

4.3.3.4 EO-4, Microwave Radiometer. The microwave radiometer experiment package will consist of a corrugated horn antenna 28 feet long and 7 feet in diameter, a radiometer RF unit and receiver, and support electronics.

The baseline format described in table 4.3-10 was defined by comparison of this radiometer with the S193 radiometer flown on Skylab.

Parameters measured along with data samples included:

- Spacelab stability
- Antenna temperatures
- Antenna look angles

TABLE 4.3-9

EO-3, MULTISPECTRAL SCANNER HOUSEKEEPING FRAME

WORD	DESCRIPTION	WORD	DESCRIPTION
1	SYNC 1	38-43	CAL SENSOR 5
2	SYNC 2	44-49	CAL SENSOR 6
3	SYNC 3	50-55	CAL SENSOR 7
4	SYNC 4	56-61	CAL SENSOR 8
5	SCAN COUNTER	62-67	CAL SENSOR 9
6	FORMAT ID	68-73	CAL SENSOR 10
7	BIT RATE ID		
8	PAYLOAD ID	⋮	⋮
9	TIME 1		
10	TIME 2	308-313	CAL SENSOR 50
11	TIME 3	314	SENSOR 1 TEMPERATURE
12	TIME 4		
13	TIME 5	⋮	⋮
14-19	CAL SENSOR 1		
20-25	CAL SENSOR 2	363	SENSOR 50 TEMPERATURE
26-31	CAL SENSOR 3	364-404	OTHER HOUSEKEEPING DATA
32-37	CAL SENSOR 4		

TABLE 4.3-10

EO-4, MICROWAVE RADIOMETER FORMAT

DATA RATE 5,120 BITS/SECOND
FRAME RATE 20 FRAMES/SECOND
FRAME SIZE 32 WORDS/FRAME (8-BIT WORDS)
256 BITS/FRAME

WORD	DESCRIPTION	WORD SIZE	WORD	DESCRIPTION	WORD SIZE
1	SYNC 1	8 BITS	16	POLARIZATION	
2	SYNC 2		17	PITCH	
3	SYNC 3		18	ROLL	
4	SYNC 4		19	ANTENNA TEMPERATURE 1	
5	FRAME COUNTER		20	ANTENNA TEMPERATURE 2	
6	FORMAT ID		21	RF UNIT TEMPERATURE 1	
7	BIT RATE ID		22	RF UNIT TEMPERATURE 2	
8	PAYLOAD ID		23	POWER SUPPLY VOLTAGE 1	
9	TIME 1 DAYS		24	POWER SUPPLY VOLTAGE 2	
10	TIME 2 HOURS		25	ANTENNA LOOK ANGLE 1	
11	TIME 3 MINUTES		26	ANTENNA LOOK ANGLE 2	
12	TIME 4 SECONDS		27	FREQUENCY 1	
13	TIME 5 MILLISECONDS		28	FREQUENCY 2	
14	RAD STATUS	9 BITS	29	DATA 1	
15	RAD CALS		30	DATA 2	

DATA WILL BE GROUPED INTO 18-WORD BLOCKS WILL WILL GIVE 16 9-BIT MEASUREMENT VALUES, OR A TOTAL OF 144 BITS/MEASUREMENT BLOCK.

- Polarization
- Frequency
- Calibrations.

The following assumptions were made to establish bit rate and format:

- Housekeeping data to sample: same as the S193 radiometer that flew on Skylab
- Data sampling: 20 samples/second
- Housekeeping and data values: 9 bits in length
- Overhead values: 8 bits in length
- Frame rate: 20 frames/second to allow a sample of each parameter to appear in every frame.

Using these assumptions as guidelines, the data rate was calculated as follows:

Overhead/frame: 13 words at 8 bits/word	=	104 bits
Radiometer status: 8 bits/frame	=	8 bits
Housekeeping: 14 words at 9 bits/word	=	126 bits
Data words/frame: 2 at 9 bits/word	=	18 bits
Total	=	256 bits

20 frames/second at 256 bits/frame = 5120 bits/second

4.3.3.5 EO-5, Precision Laser Ranging and Altimetry. To determine the utility, limitations, and accuracy of this experiment, several parameters were required to be recorded for use in analysis. These parameters included:

- Line-of-sight angle
- Transmit time

- Background radiation
- Range data including surface air temperature, surface atmospheric pressure, and site altitude.

Recording surface data simultaneously with the other data would require a ground uplink of this data to the ATL. Another option for the early evaluation flights would be recording this data on the ground and then merging it with the onboard data during ground processing.

For the purpose of this study, it was assumed, the surface data would be transmitted and it was included in the format definitions.

The following sensor characteristics were used for defining the baseline format shown in table 4.3-11 and were taken from a report done by Electronics Research Laboratory under Contract No. NAS 1-12727.[1]

Wavelength: 0.6943 μm
Total energy in train: 0.3 J
Energy in largest pulse: 0.0437 J
Peak power: 1.75×10^9 W
Rectangular pulse width: 25 psec
Maximum pulse rate: 5 pulses/min
Bandwidth: 3 Å
Transmission coefficient of transmission optics: 0.5
Transmission coefficient of rectangular optics: 0.1
Return attenuator: 0 to 30 dB
Receiver area: 180 cm^2
Retroreflector area: 1000 cm^2
Transmit beam divergence: 2×10^{-4} rad
Retroreflector beam divergence: 1×10^{-4} rad
Receiver field-of-view: 4×10^{-4} rad
Receiver field-of-view: 1.75×10^{-2} rad
Polarization loss (coarse): 0.5
Polarization loss (vernier): 1.0

[1] *Precision Laser Range Finder System Design for Advanced Technology Laboratory Applications*, *Final Report*, July 1974, LRC.

TABLE 4.3-11

EO-5, PRECISION LASER RANGING AND ALTIMETRY FORMAT

DATA RATE	1,024	BITS/SECOND
FRAME RATE	4	FRAMES/SECOND
FRAME SIZE	32	WORDS/FRAME
	256	BITS/FRAME

WORD	DESCRIPTION	WORD	DESCRIPTION
1	SYNC 1	17	RANGE DATA (LSS**), SITE 1
2	SYNC 2	18	BACKGROUND RADIATION (MSS), SITE 1
3	SYNC 3	19	BACKGROUND RADIATION (LSS), SITE 1
4	SYNC 4	20	SURFACE TEMPERATURE
5	FRAME COUNTER	21	SURFACE PRESSURE
6	FORMAT ID	22	SITE ALTITUDE (MSS), SITE 1
7	BIT RATE ID	23	SITE ALTITUDE, SITE 1
8	PAYLOAD ID	24	SITE ALTITUDE (LSS), SITE 1
9	TIME 1	25	LOS ANGLE (MSS), SITE 1
10	TIME 2	26	LOS ANGLE, SITE 1
11	TIME 3	27	LOS ANGLE, SITE 1
12	TIME 4	28	LOS ANGLE (LSS), SITE 1
13	TIME 5	29	HOUSEKEEPING DATA
14	LASER STATUS	30	HOUSEKEEPING DATA
15	RANGE DATA (MSS*), SITE 1	31	HOUSEKEEPING DATA
16	RANGE DATA, SITE 1	32	HOUSEKEEPING DATA

*MSS = MOST SIGNIFICANT SYLLABLE
**LSS = LEAST SIGNIFICANT SYLLABLE

Solar spectral irradiance: 0.137×10^{-4} W cm^{-2}/Å
Bore sight alignment: $\pm 5 \times 10^{-5}$ rad
Optical beacon tracking accuracy: $\pm 5 \times 10^{-5}$ rad
Tracking rate: 3 deg/sec

The following assumptions were made to calculate data rate and format:

- Measurements/data take: 9
- Ranging: four sites simultaneously
- Range data: 24 bits/sample
- Background radiation: 16 bits/sample
- Surface data: 8 bits/sample (except for site altitude which is 24 bits/sample)
- Line-of-sight angle: 32 bits/sample
- Housekeeping data: 4 8-bit words
- Overhead: 14 8-bit words
- Frames/second: 4 (frames 1 through 4 contain data from sites 1 through 4, respectively)
- Data acquisition time: 90 seconds
- Measurement: 1 every 10 seconds
- Data stream: continuous during data acquisition with status and housekeeping words indicating actual data take periods
- Frame size calculation:

14 overhead words	=	112 bits
Range data	=	24 bits
Background radiation	=	16 bits
Surface data	=	40 bits
LOS angle	=	32 bits
Housekeeping	=	32 bits
Total	=	256 bits

4.3.3.6 EO-6, Microwave Altimeter. The following paragraphs are the results of a comparative examination of the microwave altimeter in the Skylab Earth Resources System. They are not meant to offer firm design parameters; however, they represent typical considerations necessary for the design of the ATL microwave altimeter. Data rates, housekeeping parameters, and data formatting are based on the Skylab instrument.

The ATL microwave altimeter experiment package consists of a transmitter, receiver, peripheral electronics, an electronically steered antenna array, and various support equipment.

The transmitter will operate at a wavelength somewhere between 2 centimeters and a few millimeters; optimum wavelength has not been selected. Power will be on the order of 600 watts. The transmitter will be pulsed and swept by a linear chirp network.

The transmitter will be used in conjunction with a wide bandwidth receiver. It is proposed that the receiver and its control electronics be designed to allow usage as a passive radiometer either between altimeter returns at the same frequency or independently at a different frequency.

The antenna will be a center-fed slotted waveguide array with electronic steering. It will use synthetic aperture techniques in the along-track direction and a real aperture in the cross-track direction.

Peripheral electronics will include both automatic and manual controls and the capability to select three or four modes of operation. Possible modes include synthetic aperture mode with and without electronic steering, and a radiometer mode on an alternate frequency and/or between altimeter returns. A signal display and monitoring system and the capability to record data on magnetic tape will also be required. No data telemetry will be employed.

Support equipment will include a photographic camera and a TV camera and monitor.

The entire package will be designed with the capability to obtain height profile data of the geoid to an accuracy of 1 meter and better.

The following assumptions were made to establish bit rate and format.

- Format: patterned after the S193 altimeter which flew on Skylab
- Data and housekeeping values: 10 bits in length
- Overhead values: 8 bits in length
- Subframes per frame of data: 53 (subframe 1 will contain the overhead data and 17 words of housekeeping data; subframes 2-53 will contain 5 words of housekeeping, 20 words of sample/hold data for wave shape sampling, and 5 words of fill to obtain an integral multiple of 16 bits).

Using these assumptions as guidelines the data rate will be as follows:

- 30 word/subframe = 240 bits
- 50 subframes/second = 12,000 bits/second.

The detailed format structure is depicted in table 4.3-12; table 4.3-13 is the housekeeping measurement list; and table 4.3-14 is the data measurement list.

4.3.3.7 EO-7, Search and Rescue Aids. This experiment will use the same antenna and electronic equipment as EO-8. During the ATL mission they will operate simultaneously. For bit rate and format definition, reference paragraph 4.3.3.8, EO-7/8 Imaging Radar.

4.3.3.8 EO-7/8, Imaging Radar. The information presented in the following paragraphs does not represent a point design; however, the system description, parameter values, and format are typical

TABLE 4.3-12

EO-6, MICROWAVE ALTIMETER DATA FRAME FORMAT

SUBFRAME 1 (8-BIT WORDS)		SUBFRAMES 2 THROUGH 53*	
WORD	CONTENT	WORD	CONTENT
1	FRAME SYNC	1-4	HOUSEKEEPING, DATA AND STATUS WORDS
2	FRAME SYNC		
3	FRAME SYNC	5	FRAME COUNTER
4	FRAME SYNC	6	SAMPLE/HOLD NO. 1
5	FRAME COUNTER	7	SAMPLE/HOLD NO. 2
6	FORMAT ID	8	SAMPLE/HOLD NO. 3
7	BIT RATE ID	9	SAMPLE/HOLD NO. 4
8	PAYLOAD ID	10	
9	TIME 1	11	SAMPLE/HOLD NO. 5
10	TIME 2	12	SAMPLE/HOLD NO. 6
11	TIME 3	13	SAMPLE/HOLD NO. 7
12	TIME 4	14	SAMPLE/HOLD NO. 8
13	TIME 5	15	
14	FILL	16	SAMPLE/HOLD NO. 1
15	FILL	17	SAMPLE/HOLD NO. 2
16-30	FILL OR SPARE DATA AND HOUSEKEEPING BLOCKS	18	SAMPLE/HOLD NO. 3
		19	SAMPLE/HOLD NO. 4
		20	
		21	SAMPLE/HOLD NO. 5
		22	SAMPLE/HOLD NO. 6
		23	SAMPLE/HOLD NO. 7
		24	SAMPLE/HOLD NO. 8
		25	
		26-30	FILL

*SUBFRAMES 2 THROUGH 53 HAVE 10-BIT WORDS BLOCKED TO FIT AN 8-BIT FORMAT. EACH BLOCK CONTAINS FIVE 8-BIT WORDS WHICH IS EQUIVALENT TO FOUR 10-BIT WORDS.

TABLE 4.3-13

EO-6, MICROWAVE ALTIMETER HOUSEKEEPING MEASUREMENT LIST

DESCRIPTION	MEASUREMENT
PITCH ANTENNA POSITION	10-BIT WORD, 1 SAMPLE/FRAME
ROLL ANTENNA POSITION	
ON ORBIT ALIGN PITCH BIAS	
ON ORBIT ALIGN ROLL BIAS	
ANTENNA REFLECTOR TEMPERATURE	
RECEIVER TEMPERATURE	
RF OVEN BASE TEMPERATURE	
ANTENNA FEED TEMPERATURE	
INPUT WAVEGUIDE TEMPERATURE	
RAD PROCESSOR INTERNAL TEMPERATURE	
DRIVER TWTA TEMPERATURE	
DRIVER TWTA HELIX CURRENT	
DRIVER TWTA CATHODE CURRENT	
AGC AVERAGE DETECTOR POWER LEVEL	
TIME DISK TEMPERATURE	
NOISE GATE INTEGRATED VOLTAGE	
RAMP GATE INTEGRATED VOLTAGE	
PLATEAU GATE INTEGRATED VOLTAGE	
TDA DI VOLTAGE	10-BIT WORD, 1 SAMPLE/FRAME
VP TO AGC CONTROL VOLTAGE	4 SAMPLES/FRAME
REG SERVO BUS VOLTAGE	10-BIT WORD, 1 SAMPLE/FRAME
CLOCK PRESENT	1-BIT BILEVEL
DATA VALID FLAG	
WAVEGUIDE CALIBRATION SWITCH POSITION	
ALTIMETER READY	
ALTIMETER UNLOCK	
TRANSMITTER OVERHEAT	
TRANSMITTER MALFUNCTION	
RECEIVER MALFUNCTION	
PITCH + COMMAND	
PITCH - COMMAND	
ROLL + COMMAND	
ROLL - COMMAND	1-BIT BILEVEL

NOTE: LIST ALSO INCLUDES VARIOUS STATUS WORDS SHOWING MODE, SUBMODE, SUB-SUBMODE, ETC.

TABLE 4.3-14

EO-6, MICROWAVE ALTIMETER DATA MEASUREMENT LIST

DESCRIPTION	MEASUREMENT
SAMPLE/HOLD NO. 1	104 SAMPLES/FRAME
SAMPLE/HOLD NO. 2	
SAMPLE/HOLD NO. 3	
SAMPLE/HOLD NO. 4	
SAMPLE/HOLD NO. 5	
SAMPLE/HOLD NO. 6	
SAMPLE/HOLD NO. 7	
SAMPLE/HOLD NO. 8	104 SAMPLES/FRAME
AGC CONTROL VOLTAGE	4 SAMPLES/FRAME
ALTITUDE 1	20-BIT WORD, 1 SAMPLE/FRAME
ALTITUDE 2	
ALTITUDE 3	
ALTITUDE 4	
ALTITUDE 5	
ALTITUDE 6	
ALTITUDE 7	
ALTITUDE 8	20-BIT WORD, 1 SAMPLE/FRAME

of what can be expected for an imaging radar that is used to study earth resources. The parameter values used in deriving the data rates were obtained from an imaging radar study being performed by JPL.

Assumptions used in calculating data rates included:

- System: 2-frequency, L- and X-band
- Polarization: dual
- Orbit: 185 km
- Swath width: 76-100 km
- Spatial resolution: 25 M
- Quantization: 6-bit
- Range compression ratio: 153-347
- Pulse repetition frequency: 2182 Hz
- Presum number: 1.

Using these assumptions, the per channel data rates were calculated to be as follows in bits per second:

Image:	113,821,848
Overhead:	1,771,784
Total:	115,593,632

Since the assumed system is composed of four channels, the system data rate would be approximately four times the single channel data rate or 462,374,528 bits per second.

The following discussions will be representative of one channel. The image data rate is obtained using the equation:

$$D_R = [(SW/R)+C_R] \cdot 2 \cdot Q \cdot (PRF/PS)$$

Where:

D_R = data rate

SW = swath width

R = spatial resolution

C_R = range compression ratio

Q = quantization level

PRF = pulse repetition frequency

PS = presum number

The assumption is made that a major frame will contain all of the image data bits that are generated as the result of one transmitted pulse. The image data bits required per transmitted pulse are: 52,164 image data bits/pulse, derived from the following equation:

$$[(100,000/25)+347] \cdot 2 \cdot 6$$

Since the quantization level provides 6-bit words and the assumed standard format utilizes 8-bit words, word blocking is required. The assumed block length is 24 bits (four 6-bit words which are equivalent to three 8-bit words). Based on 52,164 bits/pulse, 2,174 blocks are required with 12 fill bits in the last block. The 2,174 blocks can be divided into 7 subframes without violating the maximum frame length of 8,192 bits. Therefore, each subframe will contain 311 blocks with the last subframe containing 3 fill blocks.

The first 13 words of each subframe will contain overhead data such as sync, time, counter, ID's, and hosekeeping data. Subframe 1 will contain the overhead data as identified in paragraph 4.3.1.2. Subframes 2 through 7 will each contain 2 words of sync, 1 count word, and 10 words of housekeeping. Examples of housekeeping data include AGC, radar mode, clutter tracker, calibration, orbit parameters, beam pointing, IMU, etc.

Each subframe will contain 13 8-bit words plus 311 24-bit blocks of data. This converts to 7,568 bits/frame or for 7 subframes (1 major frame) 52,976 bits/transmitted pulse. Since the pulse repetition frequence is 2,182 Hz, the total data rate is 155,593,632 bits per seconds.

The detailed structure of the major frame is depicted in table 4.3-15.

4.3.3.9 EO-9, RF Noise. The system concept and parameter values used to represent this experiment were obtained from a final technical report entitled *AAFE Man-Made Noise Experiment Project*, NASA CR-132509, 10, and 11 (June 1974). The following paragraphs present the results of the design project performed by the National Scientific Laboratories, Inc. for the Langley Research Center.

The assumed receiver characteristics were:

- Frequency range: 0.4 to 12.4 GHz
- Dispersion: 12 GHz maximum; 10 MHz minimum
- Dispersion rate: 200 MHz/second
- Frequency resolution: 20 kHz
- Timing (tuning) increment: 100 kHz
- Receiver dynamic range: ≥ 65 dB
- Output amplitude resolution: 1 dB
- Amplitude descriptor/sample interval: 1 (generated by demodulator function).

The assumed data characteristics were:

- Frequency resolution: 20 kHz representing 1 sample interval
- Tuning increment: 100 kHz containing 5 contiguous 20 kHz channels which operate in parallel thereby providing 5 data samples
- Encoding: 7 bits used for each data sample.

TABLE 4.3-15

EO-7/8, IMAGING RADAR FORMAT

WORD	DESCRIPTION		BITS/WORD
SUBFRAME 1			
1	SYNC 1		8
2	SYNC 2		
3	SYNC 3		
4	SYNC 4		
5	MAJOR FRAME COUNTER		
6	FORMAT ID		
7	BIT RATE ID		
8	PAYLOAD ID		
9	TIME 1		
10	TIME 2		
11	TIME 3		
12	TIME 4		
13	TIME 5		8
14	ELEMENT 1 INPHASE COMPONENT	BLOCK 1	6
15	ELEMENT 1 QUADRATURE COMPONENT		
16	ELEMENT 2 INPHASE COMPONENT		
17	ELEMENT 2 QUADRATURE COMPONENT		
⋮	⋮		
1254	ELEMENT 621 INPHASE COMPONENT	BLOCK 311	
1255	ELEMENT 621 QUADRATURE COMPONENT		
1256	ELEMENT 622 INPHASE COMPONENT		
1257	ELEMENT 622 QUADRATURE COMPONENT		6
SUBFRAMES 2-6			
1	SYNC 1		8
2	SYNC 2		
3	SUBFRAME COUNTER		
4	HOUSEKEEPING 10 n + 1		
⋮	⋮		
13	HOUSEKEEPING 10 n + 10		8
14	ELEMENT 622 n + 623 INPHASE	BLOCK 311 n + 312	6
15	ELEMENT 622 n + 623 QUADRATURE		
16	ELEMENT 622 n + 624 INPHASE		
17	ELEMENT 622 n + 624 QUADRATURE		
⋮	⋮		
1254	ELEMENT 622 n + 1243 INPHASE	BLOCK 311 n + 622	
1255	ELEMENT 622 n + 1243 QUADRATURE		
1256	ELEMENT 622 n + 1244 INPHASE		
1257	ELEMENT 622 n + 1244 QUADRATURE		6

n = 0 FOR SUBFRAME 2
n = 1 FOR SUBFRAME 3
n = 2 FOR SUBFRAME 4
n = 3 FOR SUBFRAME 5
n = 4 FOR SUBFRAME 6

TABLE 4.3-15 (CONT'D)

WORD	DESCRIPTION		BITS/WORD
SUBFRAME 7			
1	SYNC 1		8
2	SYNC 2		
3	SUBFRAME COUNTER		
4	HOUSEKEEPING 51		
⋮	⋮		
13	HOUSEKEEPING 60		8
14	ELEMENT 3733 INPHASE	BLOCK 1867	6
15	ELEMENT 3733 QUADRATURE		
16	ELEMENT 3734 INPHASE		
17	ELEMENT 3734 QUADRATURE		
⋮	⋮		
1242	ELEMENT 4347 INPHASE	BLOCK 2174	
1243	ELEMENT 4347 QUADRATURE		
1244	FILL		
1245	FILL		
1246	FILL	BLOCK 2175	
1247	FILL		
1248	FILL		
1249	FILL		
⋮	⋮		
1254	FILL	BLOCK 2177	
1255	FILL		
1256	FILL		
1257	FILL		6

Since the quantization level provides 7-bit words and the assumed standard format utilizes 8-bit words, word blocking will be required. The assumed block length is 56 bits (8 7-bit words which are equivalent to 7 8-bit words).

It is assumed that the structure of the data contained in a frame will be based on the minimum dispersion interval of 10 MHz. This interval provides a convenient grouping of the data since it is the minimum frequency range that is swept by the receiver and the grouping can conveniently be adapted to the assumed baseline format structure presented in paragraph 4.3.1.2. The number of bits in this interval is calculated as follows:

$$\begin{pmatrix}\text{NO. OF TUNING INCREMENTS IN}\\ \text{THE MINIMUM DISPERSION INTERVAL}\end{pmatrix}\begin{pmatrix}\text{NO. OF DATA SAMPLES}\\ \text{IN TUNING INCREMENT}\end{pmatrix}\begin{pmatrix}\text{NO. OF BITS FOR}\\ \text{EACH DATA SAMPLE}\end{pmatrix} =$$

$$\left(\frac{\text{10 MHz/MIN. DISP. INTERVAL}}{\text{100 kHz PER TUNING INCREMENT}}\right)\begin{pmatrix}\text{5 DATA SAMPLES PER}\\ \text{TUNING INCREMENT}\end{pmatrix}\begin{pmatrix}\text{7 BITS PER}\\ \text{DATA SAMPLE}\end{pmatrix} =$$

3500 BITS PER MINIMUM DISPERSION INTERVAL

A 3500 bit interval cannot be divided into 56-bit blocks unless fill data is added for one of the blocks. However, two intervals (7000 bits) will provide 125 56-bit blocks without the use of fill data and the length of these two intervals will not exceed the maximum frame length as defined in the baseline format structure. Therefore, it will be assumed that a frame will contain the data from two 10 MHz minimum dispersion intervals. Since the maximum dispersion interval is 12 GHz, 600 frames will then be required to format the data for the total dispersion range of the experiment.

It is also assumed that 10 housekeeping words will be provided for each 10 MHz dispersion interval. Therefore, each frame will contain 20 housekeeping words. Examples of housekeeping data include operation mode (fixed or scanning), frequency or dispersion range of operation, gain setting, calibration, antenna selection, detector function (peak hold and sample function or average value generator function), check frequencies, operational status information, etc.

The experiment data rate is determined as follows:

$$\left(\begin{array}{l}\text{NO. OF TUNING INCREMENTS}\\ \text{SAMPLED DURING 1 SECOND}\end{array}\right)\left(\begin{array}{l}\text{NO. OF DATA SAMPLES IN}\\ \text{THE TUNING INCREMENT}\end{array}\right)\left(\begin{array}{l}\text{NO. OF BITS FOR}\\ \text{EACH DATA SAMPLE}\end{array}\right) =$$

$$\left(\frac{\text{200 MHz PER SECOND}}{\text{100 kHz PER TUNING INCREMENT}}\right)\left(\begin{array}{l}\text{5 DATA SAMPLES PER}\\ \text{TUNING INCREMENT}\end{array}\right)\left(\begin{array}{l}\text{7 BITS PER DATA}\\ \text{SAMPLE}\end{array}\right) =$$

$$\text{70,000 BITS PER SECOND}$$

Since each frame contains 7000 experiment data bits, the frame rate is 10 frames/second. By combining the experiment data, the overhead data, and the housekeeping data for 10 frames, the total data rate in bits/second becomes

Experiment:	70,000
Overhead:	1,040
Housekeeping:	1,600
Total:	72,640

The detailed structure of the frame is shown in table 4.3-16.

4.3.3.10 S190A. The S190A is an assembly of six 70 mm cameras that cover the spectral regions from 4000A to 9000A in black and white and in color.

All six cameras are shuttered simultaneously. This operation was flagged and registered in status words in the S190 housekeeping data along with time. The housekeeping data was digitally recorded for use in ground processing for determination of exposure initiation times and duration. The housekeeping format is described in table 4.3-17.

The sensor characteristics are defined as follows:

A. Cameras. Six 70 mm cameras mounted together as a single unit

TABLE 4.3-16

EO-9, RF NOISE FORMAT

DATA RATE 72,640 BITS/SECOND
FRAME RATE 10 FRAMES/SECOND
FRAME SIZE 908 WORDS/FRAME (8-BIT WORDS)
7,264 BITS/FRAME

WORD	DESCRIPTION		BITS/ WORD
1	SYNC 1		8
2	SYNC 2		
3	SYNC 3		
4	SYNC 4		
5	FRAME COUNTER		
6	FORMAT ID		
7	BIT RATE ID		
8	PAYLOAD ID		
9	TIME 1		
10	TIME 2		
11	TIME 3		
12	TIME 4		
13	TIME 5		8
14	FREQUENCY RESOLUTION ELEMENT 1	BLOCK 1	7
• • •	• • •		
21	FREQUENCY RESOLUTION ELEMENT 8		
• • •	• • •	• • •	
1006	FREQUENCY RESOLUTION ELEMENT 993	BLOCK 125	
• • •	• • •		
1013	FREQUENCY RESOLUTION ELEMENT 1000		7
1014	HOUSEKEEPING 1		8
• • •	• • •		
1033	HOUSEKEEPING 20		8

TABLE 4.3-17

S190A FORMAT

DATA RATE 8,192 BITS/SECOND
FRAME RATE 64 FRAMES/SECOND
FRAME SIZE 128 BITS/FRAME

WORD	DESCRIPTION	WORD	DESCRIPTION
1	SYNC 1	9	TIME 1
2	SYNC 2	10	TIME 2
3	SYNC 3	11	TIME 3
4	SYNC 4	12	TIME 4
5	FRAME COUNTER 13	13	TIME 5
6	FORMAT ID	14	STATUS A
7	BIT RATE ID	15	STATUS B
8	PAYLOAD ID	16	FILL

ASSUMPTIONS: DATA RATE SAME AS SKYLAB PACKAGE
FORMAT THE SAME WITH BASIC ATL FORMAT ASSUMPTIONS INCLUDED

B. Lenses

- Aperture f/2.8
- Focal length 15.2 cm (6 in.)

C. Aperture Stops. f/2.8 to f/16 in 1/2 stop increments

D. Shutter Speeds

- 2.5, 5, and 10 ms (repeatability of 2.5 percent)
- Synchronization of 4 ms

E. Registration Accuracy. 12 m

F. Field of View. 21.2 deg

G. Ground Coverage. 163 × 163 km (88 × 88 nmi)

H. Film. 70 mm, 400 frames/cassette, 2.5 or 4 mm base

I. Format. 2-1/4 × 2-1/4 inches

J. Sequence Rate. 1 frame/2 sec to 1 frame/20 sec in 2-sec increments by selection of appropriate intervalometer setting.

K. Forward Motion Compensation. 10 to 30 mrad/sec (accuracy 5 percent); camera array rotated during each photographic sequence

L. Distortion Match (Dynamic)

- Channels 1 to 4: 7.5 × 28 tan θ μm
- Channels 1 to 6: 12 × 28 tan θ μm

M. Boresighting. 60 arc sec

N. Spatial Resolution. 30 m

O. Spectral Resolution. 0.1 μm

P. Design Wavelengths and Film Types

WAVELENGTHS (μm)	FILM
0.5-0.6	Panatomic X aerial B/W, type SO-022
0.6-0.7	Panatomic X aerial B/W, type SO-022
0.7-0.8	IR aerographic B/W, type SO-289
0.8-0.9	IR aerographic B/W, type SO-289
0.5-0.88	Aerochrome IR colork, type SO-127
0.4-0.7	Aerial color (high resolution), type SO-356

Q. Picture Taking Sequence

- Number of frames per sequence variable from 1 to 99.
- Duration of a photographic sequence variable from one exposure to 30 minutes of exposures.

4.3.4 Physics and Chemistry. The following paragraphs contain the detailed documentation resulting from the analysis of the physics and chemistry experiments. Included in the documentation are the references and assumptions used in establishing the data rate for each experiment and a baseline format description.

4.3.4.1 PH-1, Spacecraft Wake Dynamics. The general concepts and parameter values used to represent this experiment were obtained from LRC experiment data sheets, LRC ATL report (NASA TMX-2813), *Apollo Scientific Experiments Data Handbook* (NASA TMX-58131), and *Apollo 15 and 16 Mission Requirements Document*.

The assumptions for this experiment were as follows:

- Retarding potential analyzers: 10 with sample rate of 10 samples per second

- Electrostatic probes: 10 with sample rate of 10 samples per second

- Mass spectrometer: 1 with 400 voltage steps at a rate of 1 per second

- Flux-gate magnetometer: 1 with sample rate of 10 samples per second

- Frames per second: 1

- Sample content: 8 bits each

The detailed format structure is depicted in table 4.3-18.

4.3.4.2 PH-2, Barium Cloud Release on Sunward Side of Earth. Determination of the natural magnetospheric plasma convection patterns on the sunward side of the earth is possible by triangulation of the cloud motion through successive photographs from different locations, with a dark sky background on the sunward side of the earth.

To determine the accuracy of this experiment, several parameters are required for analysis. These parameters include:

- ATL position data

- Spacecraft position data

- Experiment sweep angle; i.e., yaw, pitch

- Spacecraft stability.

The following assumptions were made to establish bit rate and format:

- Spacecraft and ATL position data: 8-bit words

- Overhead and data values: 8 bits in length

- Frame rate: 10 frames/second

TABLE 4.3-18

PH-1, SPACECRAFT WAKE DYNAMICS

DATA RATE 4,416 BITS/SECOND
FRAME RATE 1 FRAME/SECOND
FRAME SIZE 552 WORDS/FRAME (8-BIT WORDS)
4,416 BITS/FRAME

WORD	DESCRIPTION	
1	SYNC 1	
2	SYNC 2	
3	SYNC 3	
4	SYNC 4	
5	FRAME COUNTER	
6	FORMAT ID	
7	BIT RATE ID	
8	PAYLOAD ID	
9	TIME 1	
10	TIME 2	
11	TIME 3	
12	TIME 4	
13	TIME 5	
14	EXPERIMENT ID	RETARDING POTENTIAL ANALYZERS
15	MODE ID	
16	RANGE SETTING	
17- 26	CAL DATA ANALYZER 1 FORWARD	
27- 36	CAL DATA ANALYZER 2 FORWARD	
37- 46	CAL DATA ANALYZER 3 FORWARD	
47- 56	CAL DATA ANALYZER 4 FORWARD	
57- 66	CAL DATA ANALYZER 5 FORWARD	
67- 76	CAL DATA ANALYZER 1 AFT	
77- 86	CAL DATA ANALYZER 2 AFT	
87- 96	CAL DATA ANALYZER 3 AFT	
97-106	CAL DATA ANALYZER 4 AFT	
107-116	CAL DATA ANALYZER 5 AFT	
117-126	EXPERIMENT DATA ANALYZER 1 FORWARD	
127-136	EXPERIMENT DATA ANALYZER 2 FORWARD	
137-146	EXPERIMENT DATA ANALYZER 3 FORWARD	
147-156	EXPERIMENT DATA ANALYZER 4 FORWARD	
157-166	EXPERIMENT DATA ANALYZER 5 FORWARD	
167-176	EXPERIMENT DATA ANALYZER 1 AFT	
177-186	EXPERIMENT DATA ANALYZER 2 AFT	
187-196	EXPERIMENT DATA ANALYZER 3 AFT	
197-206	EXPERIMENT DATA ANALYZER 4 AFT	
207-216	EXPERIMENT DATA ANALYZER 5 AFT	
217-226	DETECTOR TEMPERATURES	

TABLE 4.3-18 (CONT'D)

WORD	DESCRIPTION	
227	EXPERIMENT ID	ELECTROSTATIC PROBES
228	MODE ID	
229	RANGE SETTING	
230-239	CAL DATA PROBE 1 FORWARD	
240-249	CAL DATA PROBE 2 FORWARD	
250-259	CAL DATA PROBE 3 FORWARD	
260-269	CAL DATA PROBE 4 FORWARD	
270-279	CAL DATA PROBE 5 FORWARD	
280-289	CAL DATA PROBE 1 AFT	
290-299	CAL DATA PROBE 2 AFT	
300-309	CAL DATA PROBE 3 AFT	
310-319	CAL DATA PROBE 4 AFT	
320-329	CAL DATA PROBE 5 AFT	
330-339	EXPERIMENT DATA PROBE 1 FORWARD	
340-349	EXPERIMENT DATA PROBE 2 FORWARD	
350-359	EXPERIMENT DATA PROBE 3 FORWARD	
360-369	EXPERIMENT DATA PROBE 4 FORWARD	
370-379	EXPERIMENT DATA PROBE 5 FORWARD	
380-389	EXPERIMENT DATA PROBE 1 AFT	
390-399	EXPERIMENT DATA PROBE 2 AFT	
400-409	EXPERIMENT DATA PROBE 3 AFT	
410-419	EXPERIMENT DATA PROBE 4 AFT	
420-429	EXPERIMENT DATA PROBE 5 AFT	
430-439	DETECTOR TEMPERATURES	
440	EXPERIMENT ID	MASS SPECTROMETER
441	MODE ID	
442	MASS DATA (ION COUNTER) FORWARD	
443	MASS DATA (ION COUNTER) AFT	
444	CAL DATA FORWARD	
445	CAL DATA AFT	
446	DATA SWEEP START	
447	SWEEP COUNTER	
448	+ VOLTAGE MONITOR	
449	- VOLTAGE MONITOR	
450	EMISSION CURRENT	
451	FILAMENT CURRENT	
452	ELECTRON MULTIPLIER HV HIGH	
453	ELECTRON MULTIPLIER HV LOW	
454	SWEEP HV (400 STEPS, 1 STEP/SECOND)	
455	ELECTRONIC TEMPERATURE	
456	ION SOURCE TEMPERATURE	
457	HEATER CURRENT	
458	ELECTRON MULTIPLIER (HIGH/LOW)	
459	DISCRIMINATOR (HIGH/LOW)	

TABLE 4.3-18 (CONT'D)

WORD	DESCRIPTION	
460	EXPERIMENT ID	
461	MODE ID	
462-471	MAGNETOMETER B_x MAG SAMPLE 1-10	
472-481	MAGNETOMETER B_y MAG SAMPLE 1-10	
482-491	MAGNETOMETER B_z MAG SAMPLE 1-10	
492	MAGNETOMETER RANGE ID	FLUX-GATE
493	MAGNETOMETER B_x TEMPERATURE	MAGNETOMETER
494	MAGNETOMETER B_y TEMPERATURE	
495	MAGNETOMETER B_z TEMPERATURE	
496	CAL	
497	ZERO GAMMA REFERENCE VOLTAGE	
498	TETHER LENGTH	
499	TETHER AZIMUTH	
500	TETHER ELEVATION	
501	BOOM LENGTH	
502	BOOM AZIMUTH	
503	BOOM ELEVATION	
504	SHUTTLE TO TETHER ANCHOR VECTOR OFFSET 1	
505	SHUTTLE TO TETHER ANCHOR VECTOR OFFSET 2	
506	SHUTTLE TO TETHER ANCHOR VECTOR OFFSET 3	
507	SHUTTLE TO TETHER ANCHOR VECTOR OFFSET 4	
508	SHUTTLE TO BOOM BASE VECTOR OFFSET 1	
509	SHUTTLE TO BOOM BASE VECTOR OFFSET 2	
510	SHUTTLE TO BOOM BASE VECTOR OFFSET 3	
511	SHUTTLE TO BOOM BASE VECTOR OFFSET 4	
512	SUN VECTOR 1	
513	SUN VECTOR 2	
514	SUN VECTOR 3	
515	MOON VECTOR 1	
516	MOON VECTOR 2	
517	MOON VECTOR 3	
518	SUN AZIMUTH WITH RESPECT TO SHUTTLE	
519	SUN ELEVATION WITH RESPECT TO SHUTTLE	
520	MOON AZIMUTH WITH RESPECT TO SHUTTLE	
521	MOON ELEVATION WITH RESPECT TO SHUTTLE	
522	SHUTTLE VELOCITY MAGNITUDE	
523	SHUTTLE VELOCITY DIRECTION 1	
524	SHUTTLE VELOCITY DIRECTION 2	
525	SHUTTLE VELOCITY DIRECTION 3	
526	SHUTTLE POSITION VECTOR 1	
527	SHUTTLE POSITION VECTOR 2	
528	SHUTTLE POSITION VECTOR 3	
529	SHUTTLE POSITION RESULTANT	
530-549	SHUTTLE SKIN PARAMETERS	
550	VOLTAGE	
551	CURRENT	
552	SPARE	

- Camera gimbles: instrumented to provide pitch, yaw angles
- Slots/frame: provided for housekeeping information such as shutter speed, sequence rate, and temperature measurements.

Table 4.3-19 describes the data frame construction.

4.3.4.3 PH-3, Optical Properties of Aerosols. The following assumptions were used to derive data rate and format for PH-3.

A. The camera will operate at a maximum of 24 frames per second.

B. There will be four 20-minute intervals per day for data acquisition.

C. The following data will be recorded 24 times per second corresponding to the camera frame rate:

- Temperature
- Ionization
- Pressure
- Electric fields
- Dewpoint
- Composition
- Camera frame number.

The format structure is depicted in table 4.3-20.

4.3.4.4 PH-6, Ultraviolet Meteor Spectroscopy From Near-Earth Orbit. This experiment is an assembly of three ultraviolet (UV) spectrographs with associated film recorders, a photo multiplier tube (PMT) detector, control unit, onboard data recorder, and associated power supplies.

TABLE 4.3-19

PH-2, BARIUM CLOUD RELEASE FORMAT

DATA RATE 2.56 KILOBITS/SECOND
FRAME RATE 10 FRAMES/SECOND
FRAME SIZE 32 WORDS/FRAME (8-BIT WORDS)
256 BITS/FRAME

WORD	DESCRIPTION	WORD	DESCRIPTION
1	SYNC 1	12	TIME 4 SECONDS
2	SYNC 2	13	TIME 5 MILLISECONDS
3	SYNC 3	14	PHOTOMETER STATUS
4	SYNC 4	15	IMAGE INTENSIFIER STATUS
5	FRAME COUNTER	16	YAW
6	FORMAT ID	17	PITCH
7	BIT RATE ID	18	ROLL
8	PAYLOAD ID	19-22	HOUSEKEEPING DATA
9	TIME 1 DAYS	23	CAMERA PITCH
10	TIME 2 HOURS	24	CAMERA YAW
11	TIME 3 MINUTES	25-31	DATA WORDS

TABLE 4.3-20

PH-3, OPTICAL PROPERTIES OF AEROSOLS

DATA RATE 6,912 BITS/SECOND
FRAME RATE 24 FRAMES/SECOND
FRAME SIZE 36 WORDS/FRAME (8-BIT WORDS)
288 BITS/FRAME

WORD	DESCRIPTION		BITS/WORD
1	SYNC 1		8
2	SYNC 2		
3	SYNC 3		
4	SYNC 4		
5	FRAME COUNTER		
6	FORMAT ID		
7	BIT RATE ID		
8	PAYLOAD ID		
9	TIME		
10	TIME		
11	TIME		
12	TIME		
13	TIME		
14-16	PHOTO FRAME COUNTER		
17-26	GAS COMPOSITIONS 1-10		
27	SPARE		8
28	TEMPERATURE	BLOCK 1	12
29	IONIZATION		
30	PRESSURE	BLOCK 2	
31	ELECTRIC FIELD		
32	DEWPOINT	BLOCK 3	12
33	SPARE		

All three spectrographs will be actuated simultaneously by the PMT detector or by manual control (over the earth's dark side) when meteors are detected in the field-of-view of the spectrographs. Photoelectrons resulting from observed spectra will be recorded on special film; housekeeping and calibration data will be recorded by the onboard tape recorder.

Ground processing functions will require development of the film, computer digitizing of significant frames on a typically 1024 × 1024 matrix, computer processing of ATL ephemeris parameters for correlation with film images, and computer processing of spectrograph housekeeping and calibration data.

Basic sensor characteristics include:

A. Spectrograph Types and Spectral Regions: Three UV spectrographs palletized as a single unit.

- Spectrograph 1 - Carruthers Far-UV, 500A° to 1600A°
- Spectrograph 2 - Electronographic, 1300A° to 2100A°
- Spectrograph 3 - Middle-UV panchromatic, 2000A° to 7000A°.

B. Optical Systems: One per spectrograph and detector.

- Focal lengths: 75 mm to 100 mm; 100 mm typical
- Apertures: F/1 to F/2; F/1 typical
- Field-of-view: 20 degrees typical
- Sensor protection: solar shutter, electromechanical.

C. PMT Detector: Brightness range: +2 to -3 absolute meteor magnitude.

D. Film Recorders: One per spectrograph

- Film type: EK-NTB3 nuclear track emulsion on 70 mm film (special order), in 250-foot cassettes

- Format: nominal 46.5 mm × 46.5 mm
- Exposure duration: 1 second, nominal
- Cassette capacity: average 1250 frames/cassette.

Format assumptions included:

A. Three frames/second where frame 1 = spectograph 1, frame 2 = spectrograph 2, and frame 3 = spectrograph 3. Each frame includes housekeeping, calibration, and detector data.

B. Frame Size Calculation

- Overhead words: 14 = 112 bits
- Spectrograph status and calibration words: 29 = 232 bits
- Housekeeping words: 13 = 104 bits
- Data words: 8 = 64 bits
- Total 64 words = 512 bits.

An example of a frame format and candidate parameters is presented in table 4.3-21.

4.3.5 Microbiology. The following paragraphs contain the detailed documentation resulting from the analysis of the microbiology experiments. Included in the documentation are the references and assumptions used in establishing the data rate for each experiment and a baseline format description.

The major share of data collected for this discipline is common to all experiments with the exception of MB-2 which will require no electronic monitoring.

The approach taken in the analysis of this discipline was to have a microbiology unit which would support one or all of the experiments.

TABLE 4.3-21

PH-6, UV METEOR SPECTROGRAPHS CANDIDATE PARAMETERS AND FORMAT

DATA RATE 1,536 BITS/SECOND
FRAME RATE 3 FRAMES/SECOND
FRAME SIZE 64 WORDS/FRAME
512 BITS/FRAME

WORD	DESCRIPTION	WORD	DESCRIPTION
		26	EXPOSURE COMPLETE 5
1	SYNC 1	27	FRAME COUNT 1
2	SYNC 2	28	FRAME COUNT 2
3	SYNC 3	29	PMT INTENSITY MAGNITUDE
4	SYNC 4	30	PMT THRESHOLD
5	FRAME COUNTER	31	PMT HOUSING TEMPERATURE
6	FORMAT ID	32	PMT HV
7	BIT RATE ID	33	TEMPERATURE CAL 1
8	PAYLOAD ID	.	.
9	TIME 1	.	.
10	TIME 2	.	.
11	TIME 3	40	TEMPERATURE CAL 6
12	TIME 4	41	CURRENT CAL 1
13	TIME 5	42	CURRENT CAL 2
14	SENSOR ID	43	SOLAR SHUTTER STATUS
15	MODE ID	44	HOUSEKEEPING 1
16	FILTER ID	.	.
17	SHUTTER INITIATE 1	.	.
.	.	.	.
.	.	56	HOUSEKEEPING 13
.	.	57	DATA WORD
21	SHUTTER INITIATE 5	.	.
22	EXPOSURE COMPLETE 1	.	.
.	.	.	.
.	.	64	DATA WORD
.	.		

Basic assumptions for this unit included the following:

A. All parameters except photo time will be expressed in 8-bit words; time will be represented in 16 bits.

B. A complement of common equipment will include four incubators, one cold storage area, and a work area. Common sensors present will be six thermometers, six pressure sensors, and six humidity monitors (one for each incubator, one for cold storage, and one for ambient readings in the work area). Also included among the common equipment sensors will be five accelerometers (one for each incubator plus one used as a vibration monitor) and one radiation alarm.

C. Atmospheric constituents monitored will be pO_2, pCO_2, pNH_3, and pH_2O.

D. The ON/OFF condition of five thermostatic thermocouples (one for each incubator heater and one for cooler) will be combined into one 8-bit status word.

E. Alarms and status will be "latched;" i.e., if a change in monitored condition occurs, the sensor will continue to show the change until it is sampled even if the condition returns to its original status in the interim.

F. Mission duration will be 7 days. Each featured experiment will be performed three times: once at the beginning, once in the middle, and once towards the end of the mission.

G. For MB-4, the plotting of cell positions will occur at 30-second intervals in a semi-automatic mode.

H. Micro-photos could be recorded on 16 mm film although they are tabulated separately.

Common measurements to be taken will include:

- Temperature: 3 samples/hour
- Thermostatic status: 60 samples/hour

- Accelerometer: 3 samples/hour
- Pressure: 3 samples/hour
- Relative humidity: 3 samples/hour
- Atmospheric constituents: 1 sample/hour
- Radiation: 60 samples/hour
- Event verification/ID's: 1 sample/hour.

Other experiment support such as voice, film, and TV will include:

EXPERIMENT	VOICE/DAY (MIN)	16 mm FILM/ DAY (MIN)	TV/DAY (MIN)	MICRO PHOTOS/DAY	NO. DAYS
MB-1	10	36	-	-	3
MB-2	15	-	15	-	7
MB-3	-	-	-	240(1)	3
MB-4	-	-	-	-	3
MB-5	10	-	-	960(1)(2)	5

(1) Time-lapse, one photo every 15 seconds
(2) Two 2-hour sessions per day

4.3.5.1 MB-1, Colony Growth in Zero Gravity. The purpose of this experiment is to validate bacterial colony growth patterns previously observed in cultures grown on a clinostat, a device designed to neutralize the effect of gravity in a terrestrial laboratory.

The culture tubes will be transported in cold storage (278° K) and will be placed in an incubator (310° K ±1° K) for a 24-hour growth-observational period. During the growth period the back-lighted culture tubes will be cine-photographed for 3-minute runs every 2 hours. The culture tube racks will be mounted in a manner that will avoid accelerations above some designated level (e.g., 10^{-3} g) during the incubation period. After the completion of the 24-hour observational period, the culture tubes will once again be refrigerated for return to earth. The film and recorded annotation parameters will be analyzed after the mission.

In addition to the common parameters previously mentioned, camera mode and photo time will be monitored. A detailed format structure is depicted in table 4.3-22.

4.3.5.2 MB-2, Interpersonal Transfer of Micro-Organisms in Zero Gravity. The purpose of this experiment is to explore the effect of zero gravity interpersonal transfer patterns for micro-organisms.

An important factor in the design of environmental control and life support systems is a knowledge of the manner in which micro-organisms are transferred between crewmen in a closed environment. Much experimental, ground-based work has been conducted and is planned in this area. Although the absence of gravity is expected to affect the transfer pattern, this is difficult to simulate on the ground or assess analytically.

The experiment will rely upon postflight analysis of microbial samples collected by the crewmen during the mission. Prior to flight, a known trace organism and a crewman carrier will be identified. During the mission (at intervals of at least once every 24 hours) crewmen will collect microbial samples from their nose, throat, and skin, label them, and place them in an incubator to be grown for a suitable length of time (24 to 48 hours). This task will require about 15 minutes for each collection period. There will be no onboard data processing requirements.

During the mission and after suitable incubation at 310° K, the samples will be transferred to a 278° K refrigerator for preservation. Postflight analysis will determine the transfer history of the trace organism. This experiment is closely related to the Sampling of Airborne Particles and Micro-Organisms Experiment, and the postflight data analysis will include the air-sampler data from that experiment. This investigation is an extension of current ground-based experimentation at LRC.

TABLE 4.3-22

MB-1, COLONY GROWTH IN ZERO GRAVITY

DATA RATE 1,392 BITS/HOUR (0.38666 BITS/SECOND)
FRAME RATE 1 FRAME/HOUR
FRAME SIZE 174 WORDS/FRAME (8-BIT WORDS)
1,392 BITS/FRAME

WORD	DESCRIPTION
1	SYNC 1
2	SYNC 2
3	SYNC 3
4	SYNC 4
5	FRAME COUNTER
6	FORMAT ID
7	BIT RATE ID
8	PAYLOAD ID
9	TIME 1
10	TIME 2
11	TIME 3
12	TIME 4
13	TIME 5
14-16	INCUBATOR TEMPERATURE SAMPLES 1-3
17-19	INCUBATOR PRESSURE SAMPLES 1-3
20-22	INCUBATOR RELATIVE HUMIDITY SAMPLES 1-3
23-25	COLD STORAGE TEMPERATURE SAMPLES 1-3
26-28	COLD STORAGE PRESSURE SAMPLES 1-3
29-31	COLD STORAGE RELATIVE HUMIDITY SAMPLES 1-3
32-34	WORD AREA TEMPERATURE SAMPLES 1-3
35-37	WORD AREA PRESSURE SAMPLES 1-3
38-40	WORK AREA RELATIVE HUMIDITY SAMPLES 1-3
41-43	INCUBATOR ACCELEROMETER SAMPLES 1-3
44-46	VIBRATION MONITOR ACCELEROMETER SAMPLES 1-3
47-50	ATMOSPHERIC CONSTITUENTS pO_2, pCO_2, pNH_2, pH_2O
51-110	THERMOSTATIC STATUS SAMPLES 1-60
111-170	RADIATION SAMPLES 1-60
171	EVENT VERIFICATION ID'S
172	CAMERA MODE
173-174	PHOTO TIME

4.3.5.3 MB-3, Electrical Field Opacity in Biological Cells. The purpose of this experiment is to correlate independent cell volume measurements with Coulter counter readings. The Coulter counter (Coulter Electronics Inc., Florida) is an electronic device that measures the dielectric properties of a sample and outputs a cell volume count. Electronic measurements of this sort yield very quick readings; however, electric properties of cells may induce significant measurement error. Independent cell volume measurements (difficult in a one-g environment due to sedimentation, attachment and cell shape changes) can be carried out for comparison with electronic volume counts by photographing in zero-g cell samples which have also been measured on the Coulter counter.

Samples for this experiment will be transported in cold storage (278° K) and tested at incubator temperatures of 310° K ±1° K. A culture pH between 7.0 and 7.3 must be maintained until completion of tests. Acceleration levels should not exceed 10^{-3} during incubation and testing.

In addition to the common parameters previously mentioned, the following data must also be monitored.

- Cell counts: 240 samples/hour
- pH level: 60 samples/hour
- Photo times: 240 samples/hour.

A detailed format structure is depicted in table 4.3-23.

4.3.5.4 MB-4, Electrical Characteristics of Cells. The purpose of this experiment is to exploit the zero-g environment to increase the sensitivity of cell electrophoretic mobility measurements. On earth these measurements are adversely affected by convection currents and the sedimentation of the cells under gravitational forces.

The cell cultures will be transported in cold storage (278° K). For performing the experiment the cells will be incubated at 310° K with $7.0 \le pH \le 7.3$. The cultures will be chemically synchronized; i.e., all cells in a culture will be induced to divide

TABLE 4.3-23

MB-3, ELECTRICAL FIELD OPACITY IN BIOLOGICAL CELLS

DATA RATE 7,616 BITS/HOUR ($\approx$ 2.1155 BITS/SECOND)
FRAME RATE 1 FRAME/HOUR
FRAME SIZE 952 WORDS/FRAME (8-BIT WORDS)
7,616 BITS/FRAME

WORD	DESCRIPTION
1	SYNC 1
2	SYNC 2
3	SYNC 3
4	SYNC 4
5	FRAME COUNTER
6	FORMAT ID
7	BIT RATE ID
8	PAYLOAD ID
9	TIME 1
10	TIME 2
11	TIME 3
12	TIME 4
13	TIME 5
14-16	INCUBATOR TEMPERATURE SAMPLES 1-3
17-19	INCUBATOR PRESSURE SAMPLES 1-3
20-22	INCUBATOR RELATIVE HUMIDITY SAMPLES 1-3
23-25	COLD STORAGE TEMPERATURE SAMPLES 1-3
26-28	COLD STORAGE PRESSURE SAMPLES 1-5
29-31	COLD STORAGE RELATIVE HUMIDITY SAMPLES 1-3
32-34	WORK AREA TEMPERATURE SAMPLES 1-3
35-40	WORK AREA RELATIVE HUMIDITY SAMPLES 1-3
41-43	INCUBATOR ACCELEROMETER SAMPLES 1-3
44-46	VIBRATION MONITOR ACCELEROMETER SAMPLES 1-3
47-50	ATMOSPHERIC CONSTITUENTS pO_2, pCO_2, pNH_3, pH_2O
51-110	THERMOSTATIC STATUS SAMPLES 1-60
111-170	RADIATION SAMPLES 1-60
171	EVENT VERIFICATION/ID'S
172-411	CELL COUNT SAMPLES 1-240
412-471	pH LEVEL SAMPLES 1-60
952	SPARE

at the same time. This will permit cell mobility and cell size measurements (15-minute observation periods every 2 hours) to characterize different points in the cell life cycles. Acceleration levels in excess of 10^{-3} g must be avoided. Electrostatic probes and magnetometers will be used to detect strong fields which may adversely affect the experiment. Data will be recorded for postflight analysis of cell surface potential and charge as a function of time in the cell life cycle. Cell cultures will be disposed of after completion of the experiment.

In addition to the common data previously mentioned, the following data must also be monitored.

- pH level: 60 samples/hour
- Cell position: 120 samples/hour
- Position time tag: 120 samples/hour
- Magnetic field: 120 samples/hour
- Electrical field: 120 samples/hour.

A detailed format structure is depicted in table 4.3-24.

4.3.5.5 MB-5, Special Properties of Biological Cells. The object of this experiment is to conduct advanced studies of mammalian cells in a zero-g environment.

A number of important characteristics and activities of human and mammalian cells cannot be accurately or mammalian cells cannot be accurately or meaningfully studies on earth because of the significant interference of gravity or gravity-related effects, such as sedimentation and convectivity. Study of such activities under conditions of weightlessness will potentially provide a greatly increased accuracy of measurement, as well as elucidation of specific phenomena not otherwise observable.

Several very important biological phenomena, particularly those involved in the fundamental processes of morphogenesis, involve geotropism. Study of such processes under weightlessness can

TABLE 4.3-24

MB-4, ELECTRICAL CHARACTERISTICS OF CELLS

DATA RATE	3.8	BITS/SECOND
FRAME RATE	3	FRAMES/HOUR
FRAME SIZE	570	WORDS/FRAME (8-BIT WORDS)
	4560	BITS/FRAME

WORD	DESCRIPTION
1	SYNC 1
2	SYNC 2
3	SYNC 3
4	SYNC 4
5	FRAME COUNTER
6	FORMAT ID
7	BIT RATE ID
8	PAYLOAD ID
9	TIME 1
10	TIME 2
11	TIME 3
12	TIME 4
13	TIME 5
14	INCUBATOR TEMPERATURE
15	INCUBATOR PRESSURE
16	INCUBATOR RELATIVE HUMIDITY
17	COLD STORAGE TEMPERATURE
18	COLD STORAGE PRESSURE
19	COLD STORAGE RELATIVE HUMIDITY
20	WORK AREA TEMPERATURE
21	WORK AREA PRESSURE
22	WORK AREA RELATIVE HUMIDITY
23	INCUBATOR ACCELEROMETER
24	VIBRATION MONITOR ACCELEROMETER
25-28	ATMOSPHERIC CONSTITUENTS pO_2, pCO_2, pNH_3, pH_2O
29-48	THERMOSTATIC STATUS SAMPLES 1-20
49-68	RADIATION SAMPLES 1-20
69	EVENT VERIFICATION/ID'S
79-89	pH LEVEL SAMPLES 1-20
90-129	CELL POSITION 1 SAMPLES 1-40
130-169	CELL POSITION 2 SAMPLES 1-40
170-249	POSITION TIME TAG SAMPLES 1-40
250-289	MAGNETIC FIELD SENSOR 1 SAMPLES 1-40
290-329	MAGNETIC FIELD SENSOR 2 SAMPLES 1-40
330-369	MAGNETIC FIELD SENSOR 3 SAMPLES 1-40
370-409	MAGNETIC FIELD SENSOR 4 SAMPLES 1-40
410-449	ELECTRIC FIELD SENSOR 1 SAMPLES 1-40
450-489	ELECTRIC FIELD SENSOR 2 SAMPLES 1-40
490-529	ELECTRIC FIELD SENSOR 3 SAMPLES 1-40
530-569	ELECTRIC FIELD SENSOR 4 SAMPLES 1-40
570	SPARE

yield crucial and otherwise unattainable information as to the basic mechanisms of their functional and morphological involvements in response to gravity.

Ten special properties of cells will be studied in this total experimental effort. These special properties are as follows:

- Cellular shape variation
- Cellular volume changes
- Cellular spreading and attachment
- Cell locomotion
- Cell-to-cell adhesion
- Cell surface molecular properties
- Serum sedimentation
- All clones and clonal growth
- Slime-mold morphogensis
- Molecular basis of geotropism.

All studies must be performed with the cells at 310° K and at pH between 7.0 and 7.3. At the completion of the experiment, the cells will be disposed of. All of the studies will use time-lapse micrography to observe and record the cells under study. Extensive postflight analysis of the film will be required.

In addition to the common parameters previously mentioned, pH level and photo-time will be monitored. A detailed format structure is depicted in table 4.3-25.

4.3.6 Component and System Testing. CS-2, Zero Gravity Steam Generator, is the only experiment in this discipline which was analyzed. The remaining experiments in this discipline were removed from the study requirements by direction of LRC.

TABLE 4.3-25

MB-5, SPECIAL PROPERTIES OF BIOLOGICAL CELLS

DATA RATE 5,696 BITS/HOUR ($\approx$1.5822 BITS/SECOND)
FRAME RATE 1 FRAME/HOUR
FRAME SIZE 712 WORDS/FRAME (8-BIT WORDS)
5,696 BITS/FRAME

WORD	DESCRIPTION
1	SYNC 1
2	SYNC 2
3	SYNC 3
4	SYNC 4
5	FRAME COUNTER
6	FORMAT ID
7	BIT RATE ID
8	PAYLOAD ID
9	TIME 1
10	TIME 2
11	TIME 3
12	TIME 4
13	TIME 5
14-16	INCUBATOR TEMPERATURE SAMPLES 1-3
17-19	INCUBATOR PRESSURE SAMPLES 1-3
20-22	INCUBATOR RELATIVE HUMIDITY SAMPLES 1-3
23-25	COLD STORAGE TEMPERATURE SAMPLES 1-3
26-28	COLD STORAGE PRESSURE SAMPLES 1-3
29-31	COLD STORAGE RELATIVE HUMIDITY SAMPLES 1-3
32-34	WORK AREA TEMPERATURE SAMPLES 1-3
35-37	WORK AREA PRESSURE SAMPLES 1-3
38-40	WORK AREA RELATIVE HUMIDITY SAMPLES 1-3
41-43	INCUBATOR ACCELEROMETER SAMPLES 1-3
44-46	VIBRATION MONITOR ACCELEROMETER SAMPLES 1-3
47-50	ATMOSPHERIC CONSTITUENTS pO_2, pCO_2, pNH_3, pH_2O
51-110	THERMOSTATIC STATUS SAMPLES 1-60
111-170	RADIATION SAMPLES 1-60
171	EVENT VERIFICATION/ID'S
172-231	pH LEVEL SAMPLES 1-60
232-711	PHOTO TIME SAMPLES 1-240
712	SPARE

4.3.6.1 CS-2, Zero-Gravity Steam Generator. The general concept for this experiment was obtained from the LRC ATL report, NASA TMX-2813. Additional sensors were added to the experiment for the purpose of providing a better data base from which to analyze the experiment results.

The assumptions for this experiment were that the following sensors are necessary:

- High pressure water tank sensors: one temperature and one pressure for each of four tanks
- Water reservoir pressure sensor: one
- Generator inlet water sensors: one water flow, one temperature, and one pressure
- Generator outlet steam sensors: one flow meter, one temperature, one pressure, and one flow control valve
- Steam condensor sensors: one temperature, one pressure, one agitator current, and one agitator voltage
- Low pressure condensate collection tank sensors: one temperature and one pressure for each of two tanks
- Condensate collection tank sensor: one 3-position sensor for the 3-way valve at the input to the two tanks
- Heater fluid reservoir sensors: one pressure and six temperature
- Fluid reservoir resistance heater sensors: one heater current and one heater voltage
- Heating fluid circuit sensors: one flow meter, one pump ΔP, one pump current, one pump voltage, and one pump switch position.

The following assumptions were also made:

- Sensor output sample rate: 10 samples per second
- Encoding: 8 bits for each analog data sample.

The measurement list will consist of 36 analog signals which are converted to digital data and five event indicators. It will be assumed that a frame will contain one data sample from each sensor. Since the sample rate is 10 samples per second, the frame rate will be 10 frames per second which will provide for a timing sample at 0.1 second intervals.

Each frame will contain 37 8-bit words of experiment data and 13 8-bit words of overhead data as illustrated in table 4.3-26. By combining the overhead data and the experiment data for 10 frames, the total data rate will become:

Overhead:	1,040 bits per second
Experiment:	2,960 bits per second
Total:	4,000 bits per second

4.3.7 Environmental Effects. The following paragraphs contain the detailed documentation resulting from the analysis of the environmental effects experiments. Included in the documentation are the references and assumptions used to establish the data rate for each experiment and a baseline format description.

4.3.7.1 EN-1, Sampling of Airborne Particles and Micro-Organisms in Space Cabin Environment. The cabin air sampling experiment package will consist of two sampling units; each unit will have three manifolded 6-stage sieve-type samplers. Cabin air will be drawn into the units by pumps, and microflora and particulate matter will be collected on surfaces in the units for postflight analysis.

The parameters to be measured will include:

- Types of micro-organisms present in the cabin air environment

TABLE 4.3-26

CS-2, ZERO-GRAVITY STEAM GENERATOR

DATA RATE 4,000 BITS/SECOND
FRAME RATE 10 FRAMES/SECOND
FRAME SIZE 50 WORDS/FRAME (8-BIT WORDS)
400 BITS/FRAME

WORD	DESCRIPTION
1	SYNC 1
2	SYNC 2
3	SYNC 3
4	SYNC 4
5	FRAME COUNTER
6	FORMAT ID
7	BIT RATE ID
8	PAYLOAD ID
9	TIME 1
10	TIME 2
11	TIME 3
12	TIME 4
13	TIME 5
14	HIGH PRESSURE WATER TANK 1 TEMPERATURE
15	HIGH PRESSURE WATER TANK 2 TEMPERATURE
16	HIGH PRESSURE WATER TANK 3 TEMPERATURE
17	HIGH PRESSURE WATER TANK 4 TEMPERATURE
18	HIGH PRESSURE WATER TANK 1 PRESSURE
19	HIGH PRESSURE WATER TANK 2 PRESSURE
20	HIGH PRESSURE WATER TANK 3 PRESSURE
21	HIGH PRESSURE WATER TANK 4 PRESSURE
22	WATER RESERVOIR PRESSURE
23	GENERATOR INLET WATER FLOW METER
24	GENERATOR INLET WATER TEMPERATURE
25	GENERATOR INLET WATER PRESSURE
26	GENERATOR OUTLET STEAM FLOW METER
27	GENERATOR OUTLET STEAM TEMPERATURE
28	GENERATOR OUTLET STEAM PRESSURE
29	STEAM CONDENSER TEMPERATURE
30	STEAM CONDENSER PRESSURE
31	STEAM CONDENSER AGITATOR CURRENT
32	STEAM CONDENSER AGITATOR VOLTAGE
33	LOW PRESSURE CONDENSATE COLLECTION TANK 1 TEMPERATURE
34	LOW PRESSURE CONDENSATE COLLECTION TANK 2 TEMPERATURE
35	LOW PRESSURE CONDENSATE COLLECTION TANK 1 PRESSURE
36	LOW PRESSURE CONDENSATE COLLECTION TANK 2 PRESSURE
37	HEATING FLUID RESERVOIR PRESSURE
38	HEATING FLUID RESERVOIR TEMPERATURE 1
39	HEATING FLUID RESERVOIR TEMPERATURE 2
40	HEATING FLUID RESERVOIR TEMPERATURE 3
41	HEATING FLUID RESERVOIR TEMPERATURE 4

TABLE 4.3-26 (CONT'D)

WORD	DESCRIPTION
42	HEATING FLUID RESERVOIR TEMPERATURE 5
43	HEATING FLUID RESERVOIR TEMPERATURE 6
44	HEATING FLUID RESERVOIR HEATER CURRENT
45	HEATING FLUID RESERVOIR HEATER VOLTAGE
46	HEATING FLUID FLOW METER
47	HEATING FLUID PUMP ΔP
48	HEATING FLUID PUMP CURRENT
49	HEATING FLUID PUMP VOLTAGE
50	EVENT INDICATORS
	BIT 1 STEAM FLOW CONTROL VALVE
	BIT 2 CONDENSATE COLLECTION TANK INLET VALVE POSITION 1
	BIT 3 CONDENSATE COLLECTION TANK INLET VALVE POSITION 2
	BIT 4 CONDENSATE COLLECTION TANK INLET VALVE POSITION 3
	BIT 5 HEATING FLUID PUMP SWITCH
	BIT 6-8 SPARES

- Quantification of micro-organism types
- Rate of change of micro-organism types with respect to operations of, and in, the spacecraft
- The type, quantity, and rates of change of nonviable particles
- Origin of nonviable particles by size
- Size classification of both viable and nonviable particles.

Based on requirements for this type experiment, which is similar to the T003 and the Atmospheric Volatile Concentrator experiments performed on Skylab 3 and 4, no telemetry or electronic recording will be required. Crew comments on properly labeled canisters will be required, such as:

- Time measurement start/end
- Temperature at experiment location
- Humidity of environment
- Description of any event (scheduled or unscheduled) which coincides with sampler operation and has the potential for producing particles.

4.3.7.2 EN-3, Environmental Effects on Non-Metallic Materials. The environmental effects on non-metallic materials experiment will utilize one array of test material which will be deployed during the mission, exposed to solar radiation for the maximum time possible, retrieved after a minimum of 5 days exposure, and returned at mission end to the ground laboratory for analysis.

No data from the material samples will be required since ground analysis will yield the required data. However, the temperature of the array will be required to be recorded for factoring into the analysis results.

The sampling frequency must be high enough to assure that temperature changes occasioned by temporary shadowing, as from a rolling Orbiter, will be detected. For this reason, a sampling rate of once per 100 seconds was chosen. Even if the roll rate exceeded this figure, a mass-averaged temperature reading would still be available.

Based on the sampling consideration stated, a format was established as shown in table 4.3-27, consisting of 13 header words and 1 temperature reading.

TABLE 4.3-27

EN-3, ENVIRONMENTAL EFFECTS OF NONMETALIC MATERIALS

DATA RATE	1.12	BITS/SECOND
FRAME RATE	1	FRAME/100 SECONDS
FRAME SIZE	14	WORDS/FRAME
	112	BITS/FRAME

WORD	DESCRIPTION	WORD	DESCRIPTION
1	FRAME SYNC	8	PAYLOAD ID
2	FRAME SYNC	9	TIME
3	FRAME SYNC	10	TIME
4	FRAME SYNC	11	TIME
5	COUNTER ID	12	TIME
6	FORMAT ID	13	TIME
7	BIT RATE ID	14	ARRAY TEMPERATURE

4.3.8 Data Recording. During the data recording analysis, three instrumentation recorders were used to calculate tape volume. These were the high data rate recorder as listed in the *Spacelab Payload Accommodation Handbook*, a medium capacity 14-track recorder, and a high-capacity 32-track recorder.

4.3.8.1 Spacelab Recorder. The characteristics of this recorder are listed in table 4.3-28. Some of the disadvantages are single record/reproduce speed and the inability to handle more than 30 megabits of data. Table 4.3-29 depicts the number of tapes required to record the experiment data on the spacelab recorder. An important factor to the mission planning phase of the ATL is that each instrumentation tape weighs approximately 14 pounds.

4.3.8.2 Medium Capacity Recorder. Table 4.3-30 depicts the characteristics of the medium capacity recorder. Table 4.3-31 depicts the number of tapes required using a recorder of this type. As shown in table 4.3-31, EO-2A, EO-2B, and EO-4 require a significant number of tapes; this is primarily due to the long data acquisition cycles. Where possible single track recording was assumed.

4.3.8.3 High-Capacity Recorder. Table 4.3-32 depicts the characteristics of the high-capacity recorder and table 4.3-33 shows the number of tapes required to record EO-3 and EO-7/8 using a recorder of this type.

4.3.8.4 Low Data Rate Experiments. Experiment analysis points out six experiments which should not have their output recorded on the spacelab recorders. There are two main reasons for this:

- The data rates of these experiments are too low to record with an instrumentation recorder.

- The data take time for MB-1 and EN-3 would tie up a recorder for the entire mission.

In order to record the data from these experiments, the data rates would have to be increased significantly. Table 4.3-34 shows the experiments and their bit volumes/mission recorded and nonrecorded.

TABLE 4.3-28

SPACELAB RECORDER CHARACTERISTICS

TRACK GEOMETRY	28 TRACKS IRIG
DATA TRACKS	26 (TRACKS 2-27)
PACKING DENSITY PER TRACK	12.5 KB/IN.
RECORD/REPRODUCE SPEED	92 IPS
DATA RATE PER TRACK	1.15 MB/S
DATA RATE PER 26 DATA TRACKS	30 MB/S
TAPE LENGTH	9200 FEET
RECORD TIME	20 MIN
TAPE WIDTH	1 INCH

TABLE 4.3-29

SPACELAB RECORDER TAPE VOLUME

EXPERIMENT	DATA TAKE TIME/DAY	RECORDING SPEED (IPS)	FEET OF TAPE/DAY	FEET OF TAPE/5-DAY DATA TAKE MISSION	NO. TAPES/5-DAY DATA TAKE MISSION (9200 FT/TAPE)
NV-1	2.67 HRS	92	73,692	368,460	40.05
NV-2	2.16 HRS		59,616	298,080	32.4
NV-3	0.5 HRS		13,800	69,000	7.5
EO-1	4 HRS		110,400	552,000	60
EO-2A	8 HRS		220,800	1,104,000	120
EO-2B	8 HRS		220,800	1,104,000	120
EO-3	20 MIN		9,200	46,000	5
EO-4	16.8 HRS		463,680	2,318,400	40.05
EO-5	2.67 HRS		73,692	368,460	30
EO-6	2 HRS		55,200	276,000	30
EO-7[1]	15 MIN				
EO-8[1]	15 MIN				
EO-9	2 HRS		55,200	276,000	30
PH-1	1 HR		27,600	138,000	15
PH-2	80 MIN		36,800	36,800[2]	4
PH-3	80 MIN		36,800	184,000	20
PH-6	20 MIN		9,200	46,000	5
CS-2	5 MIN		2,300	4,600[3]	0.5
EN-1	N/A				
EN-3	24 HRS	92	662,400	3,312,000	360

[1]RECORDER CAPABILITY NOT SUFFICIENT TO RECORD THIS DATA
[2]1-DAY DATA TAKE PERIOD
[3]2-DAY DATA TAKE PERIOD

TABLE 4.3-30

MEDIUM CAPACITY RECORDER CHARACTERISTICS

DATA TRACKS	14 TRACKS
PACKING DENSITY PER TRACK	10 KB/IN.
RECORD/REPRODUCE SPEED	VARIABLE - 7-1/2 TO 120 IPS
DATA RATE PER TRACK	1.2 MB/S MAXIMUM
DATA RATE PER 14 TRACKS	16.8 MB/S MAXIMUM
TAPE LENGTH	7200 FT
RECORD TIME	12 MIN AT 120 IPS; 170 MIN AT 7-1/2 IPS
TAPE WIDTH	1 INCH

THE CHARACTERISTICS OF THE MEDIUM CAPACITY RECORDER ARE REPRESENTATIVE OF TODAY'S STATE-OF-THE-ART IN GROUND RECORDING AND ONBOARD AIRCRAFT RECORDING. RECORDERS OF THIS TYPE ARE CURRENTLY IN USE IN BOTH OF THESE AREAS.

TABLE 4.3-31

MEDIUM CAPACITY RECORDER TAPE VOLUME

EXPERIMENT	DATA TAKE TIME/DAY	RECORDING SPEED (IPS)	FEET OF TAPE/DAY	FEET OF TAPE/5-DAY DATA TAKE MISSION	NO. TAPES/5-DAY DATA TAKE MISSION (7200 FT/TAPE)
NV-1[1]	2.67 HRS	7.5	6,007.5	30,037.5	4.17
NV-2[2]	2.16 HRS	7.5	4,860	24,300	3.38
NV-3[3]	30 MIN	30.0	4,500	22,500	3.13
EO-1	4.0 HRS	7.5	9,000	45,000	6.25
EO-2A	8.0 HRS	7.5	18,000	90,000	12.5
EO-2B	8.0 HRS	7.5	18,000	90,000	12.5
S190A	20 MIN	7.5	750	3,750	0.52
EO-4	16.8 HRS	7.5	37,800	189,000	26.25
EO-5	2.67 HRS	7.5	6,007.5	30,037.5	4.17
EO-6	2.0 HRS	7.5	4,500	22,500	3.13
EO-9	2.0 HRS	7.5	4,500	22,500	3.13
PH-1	1.0 HR	7.5	2,250	11,250	1.56
PH-2	80 MIN	7.5	3,000	3,000[4]	0.42
PH-3	80 MIN	7.5	3,000	15,000	2.08
PH-6	20 MIN	7.5	750	3,750	0.52
CS-2	5 MIN	7.5	187.5	375[5]	0.05

[1] 10 TRACKS USED FOR RECORDING
[2] 3 TRACKS USED FOR RECORDING
[3] 12 TRACKS USED FOR RECORDING
[4] 1-DAY DATA TAKE
[5] 2-DAY DATA TAKE

TABLE 4.3-32

HIGH CAPACITY RECORDER CHARACTERISTICS

DATA TRACKS	32 TRACKS
PACKING DENSITY PER TRACK	33 KB/IN.
RECORD/REPRODUCE SPEED	VARIABLE - 7-1/2 TO 120 IPS
DATA RATE PER TRACK	3.96 MB/S MAXIMUM
DATA RATE PER 32 TRACKS	126.7 MB/S MAXIMUM
TAPE LENGTH	9200 FT
RECORD TIME	15 MIN AT 120 IPS; 245 MIN AT 7-1/2 IPS
TAPE WIDTH	1 INCH

THE CHARACTERISTICS OF THE HIGH CAPACITY RECORDER WERE TAKEN FROM A GROUND OPERATIONAL RECORDER IN EXISTENCE TODAY. THE MAIN PURPOSE IN SELECTING THESE CHARACTERISTICS WERE TO PERMIT THE SIZING OF THE GROUND DATA SYSTEM WHICH WILL BE REQUIRED TO SUPPORT EXPERIMENTS SUCH AS THOSE LISTED IN THIS STUDY.

TABLE 4.3-33

HIGH CAPACITY RECORDER TAPE VOLUME

EXPERIMENT	DATA TAKE TIME/DAY	RECORDING SPEED (IPS)	FEET OF TAPE/DAY	FEET OF TAPE/5-DAY DATA TAKE MISSION	NO. OF TAPES/5-DAY DATA TAKE MISSION (9200 FT/TAPE)
EO-3[1]	20 MIN	90	9,000	45,000	5.0
EO-7[2]	15 MIN	120	36,000	180,000	19.57
EO-8[2]	15 MIN	120	36,000	180,000	19.57

[1] 8 TRACKS USED FOR RECORDING DATA (1 BAND PER TRACK)
[2] ALL TRACKS USED FOR RECORDING DATA, FOUR RECORDERS OPERATED SIMULTANEOUSLY

TABLE 4.3-34

LOW DATA RATE SENSORS

EXPERIMENT	DATA TAKE TIME/DAY	BITS/MISSION REQUIRED	BITS/MISSION REQUIRED FOR RECORDING
EO-1	4.0 HRS	432,000	28,800,000
MB-1	24.0 HRS	100,224	360,806,400
MB-3	1.0 HR	22,848	82,252,800
MB-4	3.0 HRS	123,120	148,744,000
MB-5	4.0 HRS	113,920	410,112,000
EN-3	24.0 HRS	483,840	193,536,000

4.3.8.5 Data Volume. Table 4.3-35 shows the data volume in bits per day and mission for each experiment. All mission volumes assume 5-day data take except where otherwise indicated.

4.3.9 Major Considerations. The major consideration resulting from this analysis is data acquisition. As shown in paragraph 4.3.8, there are three areas which will require further study and development. These are 1) low data rate experiments, 2) medium data rate and high data take time experiments, and 3) EO-7/8.

4.3.9.1 Low Data Rate Experiments. An alternate method of data acquisition needs to be considered for these experiments other than using a spacelab recorder. Possible alternatives include:

- Self-contained data acquisition within the experiment
- Onboard processing of the data as it is collected
- Insertion of the data into the Orbiter downlink.

4.3.9.2 Medium Data Rate Experiments. The two experiments of concern in this area are EO-2 and EO-4. The data rate of these experiments is readily manageable but the long periods of data take will require many instrumentation tapes per ATL mission. Some possible alternatives for these experiments include:

- Insertion of the data streams into the Orbiter downlink
- Reduction of the data acquisition time where possible
- Self-contained data acquisition equipment within the experiment.

4.3.9.3 EO-7/8. The major consideration is the high data rate. Data rates of this magnitude are going to require multiple recorders which would mean this experiment, as defined in this study, would require its own recording system.

TABLE 4.3-35

DATA VOLUME BY EXPERIMENT

EXPERIMENT	DATA RATE	DATA TAKE TIME/DAY	BITS/DAY	BITS/MISSION
NV-1	739,200 B/S	2.67 HRS	7,105,190,400	35,525,952,000
NV-2	193,600 B/S	2.16 HRS	1,505,433,600	7,527,168,000
NV-3	3,538,944 B/S	0.5 HR	6,370,099,200	31,850,496,000
EO-1	16 B/S	4.0 HRS	86,400	432,000
EO-2A	480 B/S	8.0 HRS	13,824,000	69,120,000
EO-2B	20,992 B/S	8.0 HRS	604,569,600	3,022,848,000
EO-3	23,195,935 B/S	20 MIN	27,835,121,000	139,175,605,000
S190A	8,192 B/S	20 MIN	9,830,400	49,152,000
EO-4	5,120 B/S	16.8 HRS	309,657,600	1,548,288,000
EO-5	1,024 B/S	2.67 HRS	9,842,688	49,213,440
EO-6	12,000 B/S	2.0 HRS	86,400,000	432,000,000
EO-7	462,374,528 B/S	15 MIN	416,137,075,200	2,080,685,376,000
EO-8	462,374,528 B/S	15 MIN	416,137,075,200	2,080,685,376,000
EO-9	72,640 B/S	2.0 HRS	523,008,000	2,615,040,000
PH-1	4,416 B/S	1.0 HR	15,897,600	79,488,000
PH-2[1]	2,560 B/S	80 MIN	12,288,000	12,288,000
PH-3	6,912 B/S	80 MIN	33,177,600	165,888,000
PH-6	1,536 B/S	20 MIN	1,843,200	9,216,000
MB-1[3]	1,392 B/H	24.0 HRS	33,408	100,224
MB-3[3]	7,616 B/H	1.0 HR	7,616	22,848
MB-4[3]	3.8 B/S	3.0 HRS	41,040	123,120
MB-5	5,696 B/H	4.0 HRS	22,784	113,920
CS-2[2]	4,000 B/S	5 MIN	1,200,000	2,400,000
EN-3	1.12 B/S	24.0 HRS	96,768	483,840

[1] 1-DAY DATA TAKE/MISSION
[2] 2-DAY DATA TAKE/MISSION
[3] 3-DAY DATA TAKE/MISSION

SECTION 5

GROUND SUPPORT DATA MANAGEMENT SYSTEM REQUIREMENTS

5.1 SUBTASK 2.1, FUNCTIONAL REQUIREMENTS

The purpose of this subtask was to define the functional requirements of the Langley Research Center Data Management System (LRCDMS). The primary inputs were the results of the experiment analysis and the operations analysis performed in Task I of the study.

5.1.1 Support Requirements. The LRCDMS will be required to support the following four major areas of each Advanced Technology Laboratory (ATL) mission.

- Experiment integration/checkout
- ATL/Orbiter integration/checkout
- Mission operations
- Postflight processing

All of the above areas except mission operations will require the same system configuration in the support function. This configuration, referred to in this document as the Data Reformatting System (DRS), will be required to perform the following functions:

- Instrumentation tape input
- Reformatting of experiment data
- Generation of computer-compatible tapes (CCT's) and associated tabulations.

The configuration for support of the mission operations will be referred to as the Payload Operations Support Center (POSC).

5.1.2 DRS Requirements. The DRS will be required to accept and reformat the recorded data from each of the experiments analyzed in Task I.

5.1.2.1 Input Requirements. The DRS will have the capability of accepting data that has been recorded on 14- or 32-track instrumentation tape. These recorded tapes will have various formats and track configurations, dependent on the particular experiment.

5.1.2.1.1 Instrumentation Interface. The instrumentation tape interface will be required to provide independent logic for each track for detection of frame sync codes, accumulation of serial data into computer words and control of data transfer to computer memory. Each track will have the capability to transfer data asynchronously with respect to the other tracks. The interface tracks will be input and output patchable to accommodate all possible tape configurations and will have the following programmable capabilities:

- Accept pulse code modulation (PCM) or analog input
- Input storage buffers for address and word count, frame length, and frame buffer
- Pack 8-bit data bytes into one memory word to allow 2 bytes/16-bit word, 4 bytes/32-bit word, etc., to optimize memory requirements
- Synchronization code with maximum 32 bits and sync window width
- Tape speed with variable 1-7/8 IPS to 120 IPS
- Analog sample rate and resolution
- Time search in forward or reverse direction.

Each track interface will be required to automatically perform the following functions:

- Buffer switching
- Sync verification

- Reset and search when loss of sync occurs
- Initiate interrupts to the processor on buffer full and error conditions
- Right justify data words prior to transfer to the computer.

5.1.2.1.2 Buffering Requirements. The DRS will be required to double buffer all input data. Buffer sizes will vary by experiment, time tagging requirements, and processing time. Minimum input buffer requirements are shown in table 5.1-1. As can be seen by the number of bytes required for buffering, the imaging sensors (EO-3 and EO-7/8) are the main drivers.

5.1.2.2 Reformatting Requirements. The reformatting requirements are divided into either imagery or nonimagery.

5.1.2.2.1 Imagery Reformatting. The two experiments in this category are EO-3 and EO-7/8.

A. EO-3, Multispectral Scanner. The serial input bit stream must be reformatted into a scan line by sensor format. As is shown in figure 5.1-1, the data is recorded by sensor and band. A complete scan line cannot be retrieved until the last element is in the buffer.

   The CCT output will consist of a 17 record data set for each scan line and each band (reference figure 5.1-2). Each record is 3006 bytes in length. The first record will contain 1002 bytes of ancillary information which will contain the housekeeping data frame, annotation information, and data quality. The next 1002 bytes will be the scan line from sensor 1. The last 1002 bytes will be the scan line from sensor 2. The remaining 16 records of the data set will also be 3006 bytes in length with each record containing scan line data from three sensors.

B. EO-7/8, Imaging Radar. The 6-bit elements of the imaging radar data must be reformatted into 8-bit bytes with the six data bits right-justified. The seven subframes of

TABLE 5.1-1

MINIMUM INPUT BUFFER REQUIREMENTS

EXPERIMENT	BITS/FRAME	BUFFER REQTS IN BYTES (8-BIT WORDS)
NV-1	7392	1848
NV-2	7744	1936
NV-3	8192	2048
EO-1	960	240
EO-2A	480	120
EO-2B	5248	1312
EO-3*	3232	108,808
EO-3**	3232	814,464
S190A	128	32
EO-4	256	64
EO-5	25	64
EO-6	12,720	3180
EO-7/8	52,976	17,598
EO-9	7264	1816
PH-1	4416	1104
PH-2	256	64
PH-3	288	72
PH-6	512	128
MB-1	1392	358
MB-3	7616	1904
MB-4	4560	1140
MB-5	5696	1424
CS-2	400	100
EN-3	112	28

*REFORMATTING 1 BAND, 50 SENSORS

**REFORMATTING 8 BANDS, 50 SENSORS/BAND SIMULTANEOUSLY

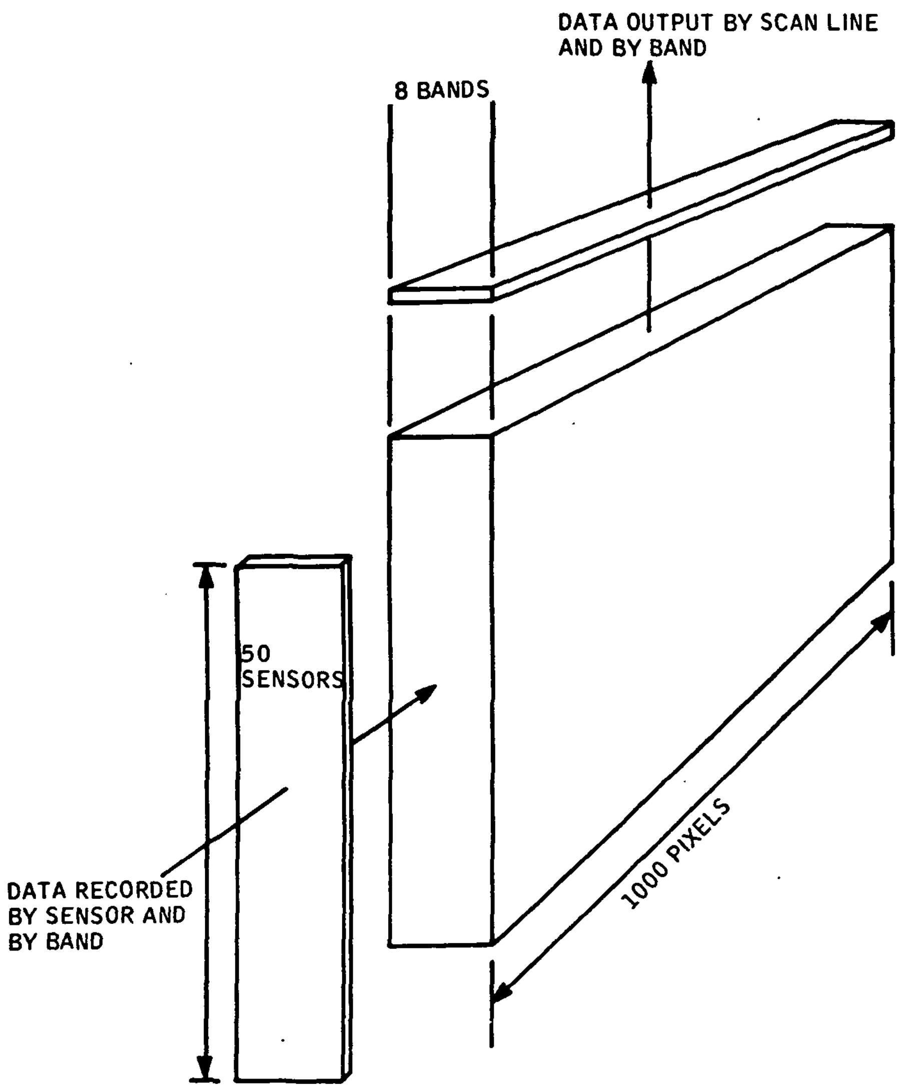


Figure 5.1-1 Reformatting Process for EO-3

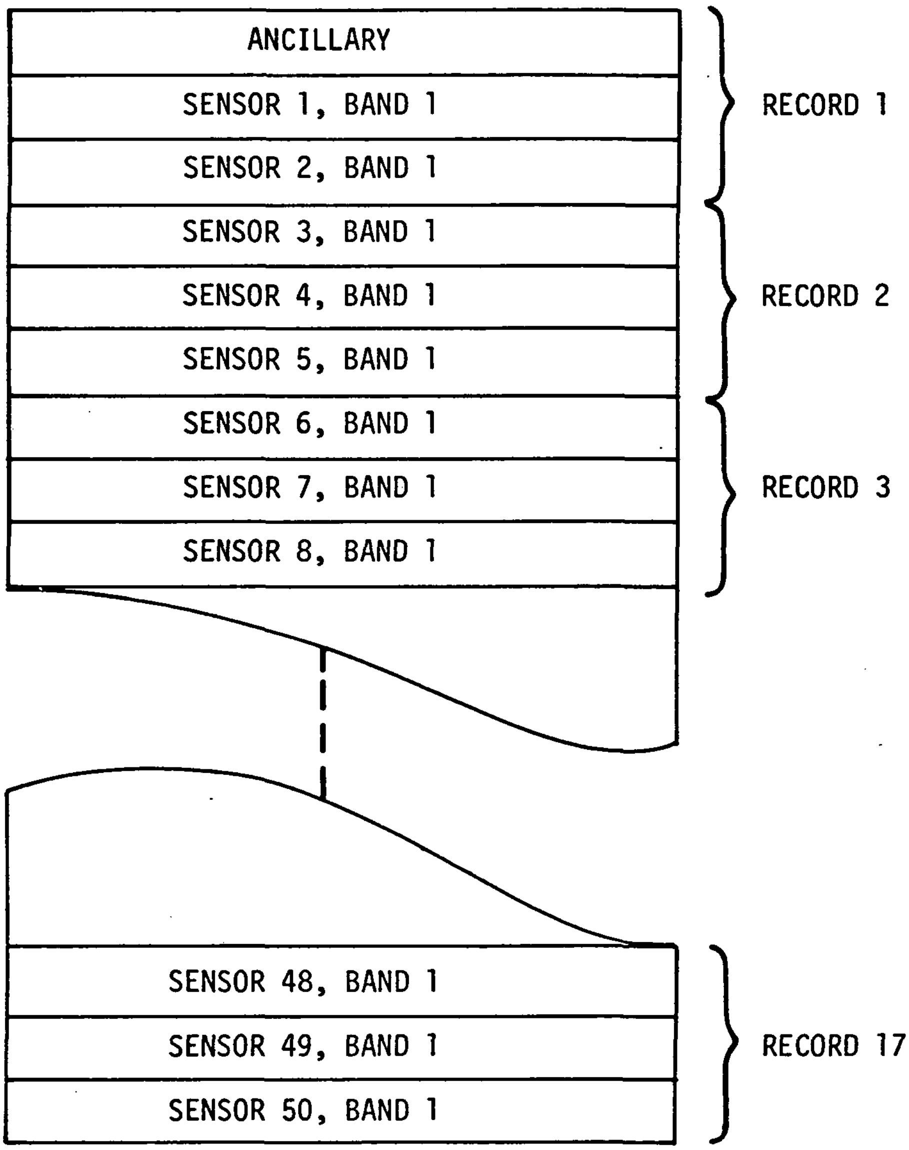


Figure 5.1-2 CCT Scan Line Data Set

serial input represent the return pulse of the radar. These subframes should remain contiguous in the data record to maintain time homogeneity and merging capability with other radar data. This would require each data set on output to be 8786 bytes in length. Figure 5.1-3 is representation of this record. Words 1 through 92 of the record contain overhead, housekeeping, and data quality information. Words 93 through 8786 contain the data elements.

5.1.2.2.2 Nonimagery Reformatting. The remaining experiments in this study fall into nonimagery requirements. For this class of experiments a standard formatting procedure will be assumed. The output tape will be formatted in a manner which will permit the application processing to identify and locate specific parameters. The output tape will contain the descriptor file and the data file.

A. Descriptor File. The descriptor file (reference figure 5.1-4) will be the first file on tape and will describe the position of each parameter within a data record. It will have the following characteristics:

- 3026 bytes record length
- Variable number of records depending on amount of data parameters recorded
- Data record description
- Mission number and date.

As shown in figure 5.1-4, each parameter recorded will have an ID block containing descriptive and retrieval information. Each ID block will be 18 bytes in length. If there are more than 166 blocks needed, a second record will be required in the descriptor file. This record will be 3026 bytes in length and will contain only parameter

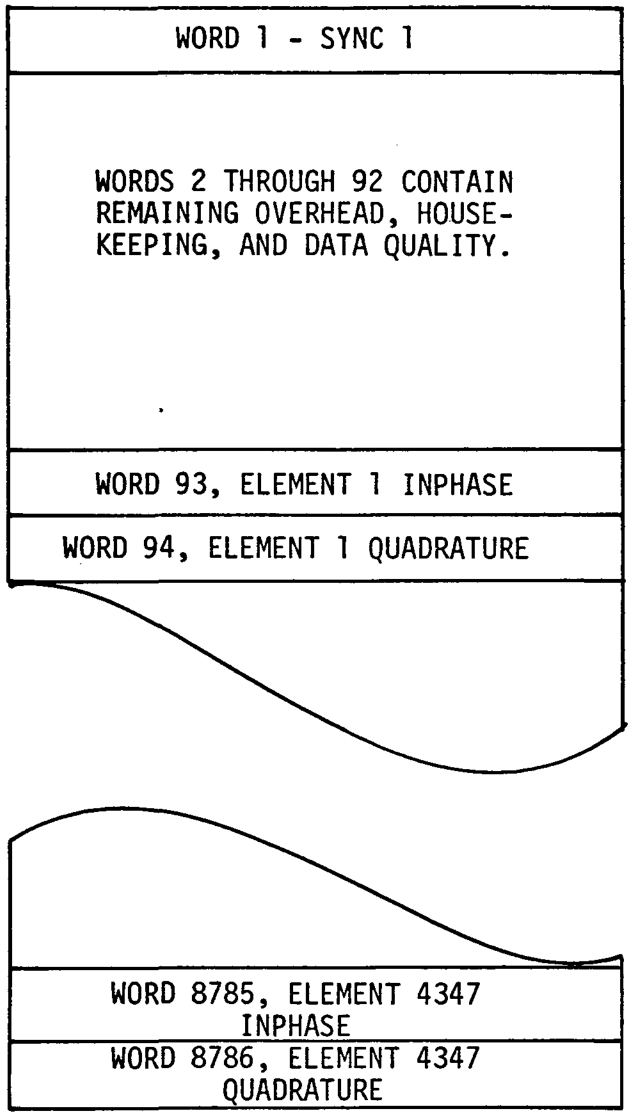


Figure 5.1-3 Imaging Radar Data Record

BYTE NO.		
1-8	FILE ID	
9-14	MISSION DATE	
15-16	MISSION NUMBER	
17-18	FORMAT NUMBER	
19-20	FRAMES/RECORD	
21-22	FRAME LENGTH	
23-24	RECORD LENGTH IN BYTES	
25-26	RECORD SPEED	
27-28	BITS/SECOND	
29-36	PARAMETER ID	ID BLOCK NO. 1
37-38	PARAMETER POSITION	
39-40	FIRST FRAME ADDRESS	
41-42	PARAMETER INCREMENT	
43	NUMBER OF BITS	
44	LSB	
45	FIELD LENGTH	
46	SAMPLES/RECORD	

2999-3006	PARAMETER ID	ID BLOCK NO. 166
3007-3008	PARAMETER POSITION	
3009-3010	FIRST FRAME ADDRESS	
3011-3012	PARAMETER INCREMENT	
3013	NUMBER OF BITS	
3014	LSB	
3015	FIELD LENGTH	
3016	SAMPLES/RECORD	
3017-3026	FILL ZERO	
	IRG OR EOF	

Figure 5.1-4 Descriptor File

ID blocks. The descriptor file will consist of the following:

- File ID - Eight character identification
- Mission Date - Launch date (month, day, year)
- Mission Number - ATL mission number
- Format Number - Format identification (experiment unique)
- Frames/Record - Number of data frames in data record
- Frame Length - Data frame length in bytes
- Record Length - Data record length in bytes
- Record Speed - Tape speed which data was recorded
- Bits/Second - Data rate in bits/second
- Parameter ID - Eight character identification
- Parameter Position - Byte position of the data field
- First Frame Address - Frame number in which this parameter first appears
- Parameter Increment - Byte count or frame count between samples
- Number of Bits - Bit length of sample
- LSB - Least significant bit within data field
- Field Length - 8, 16, 24, 32, etc. bits
- Samples/Record - Number of samples of this parameter within a data record.

B. Data File. The data file will be made up of binary records of parameter values. The minimum record length will be 3000 bytes and the maximum 3872 bytes. Table 5.1-2 depicts record lengths and number of frames per record for each experiment. For the purpose of this report, it was assumed that all data on the instrumentation tape would be converted to CCT.

Figure 5.1-5 represents an EO-4 pulse code modulation (PCM) frame on CCT. The data words are 9 bits in length while the overhead words are 8 bits in length.

5.1.2.3 Data Quality Requirements. The DRS will be required to monitor data lock on all tracks of the instrumentation input tape and report to the operator in real time when a sync loss occurs. It will provide the capability for output to oscillograph recorders for additional data quality checks and quick-look processing. Figure 5.1-6 depicts a functional diagram of the DRS.

The CCT output will be monitored for error conditions. Any error which might prohibit further processing will be reported in real time to the operator.

On completion of each reformatting process, a data quality report will be generated. This report will contain the following information:

- All operator commands
- Instrumentation tape status consisting of loss of lock and tape time by track, number of data frames processed, and number of data frames lost
- CCT status with parity errors by reel
- All system messages generated during processing.

5.1.3 POSC Requirements. The purpose of the LRC POSC is to provide a focal point or central facility through which LRC ATL payload operations support is conducted. It is assumed that the

TABLE 5.1-2

RECORD LENGTH BY EXPERIMENT

EXPERIMENT	FRAMES/RECORD	RECORD LENGTH IN BYTES
NV-1	4	3696
NV-2	4	3872
NV-3	3	3072
EO-1	30	3600
EO-2A	60	3600
EO-2B	5	3280
S190A	225	3600
EO-4	113	3616
EO-5	113	3616
EO-6	2	3180
EO-9	4	3632
PH-1	6	3312
PH-2	113	3616
PH-3	100	3600
PH-6	56	3584
MB-1	21	3654
MB-3	4	3808
MB-4	6	3420
MB-5	5	3560
CS-2	70	3500
EN-3	258	3612

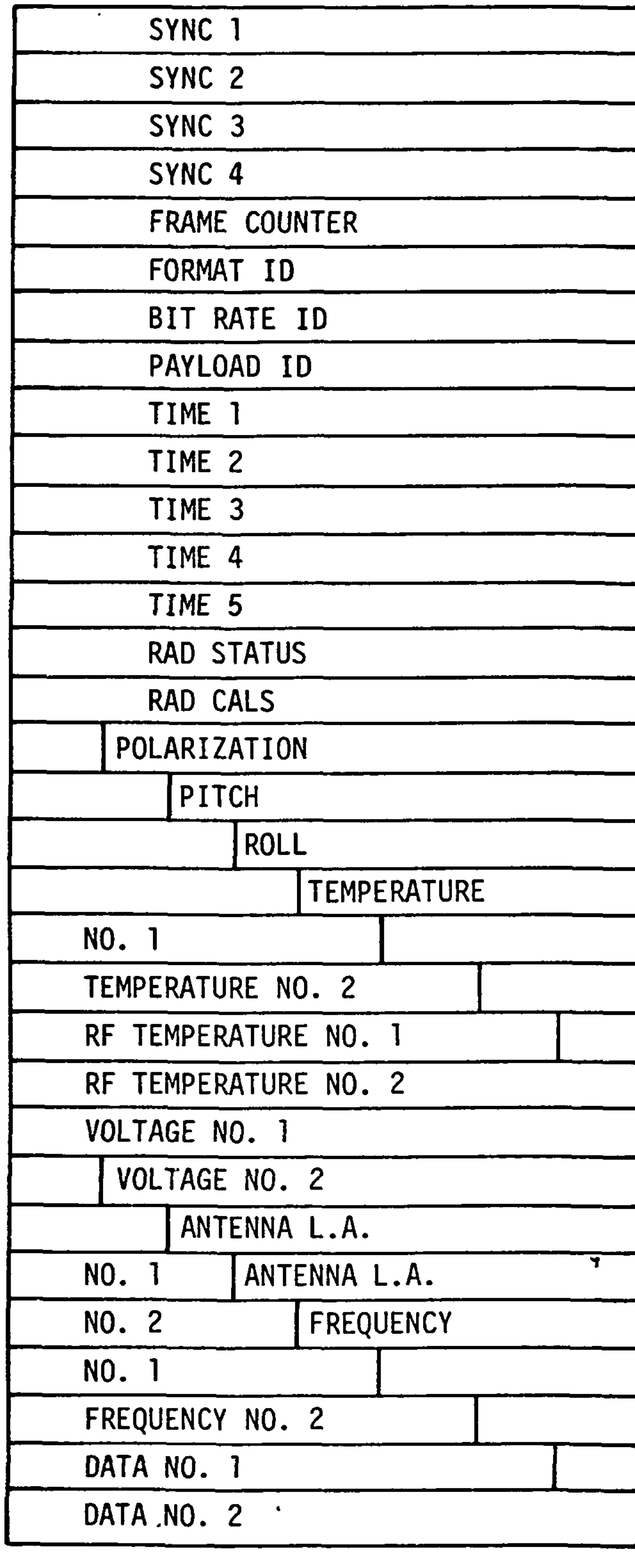


Figure 5.1-5 EO-4 PCM Frame on CCT

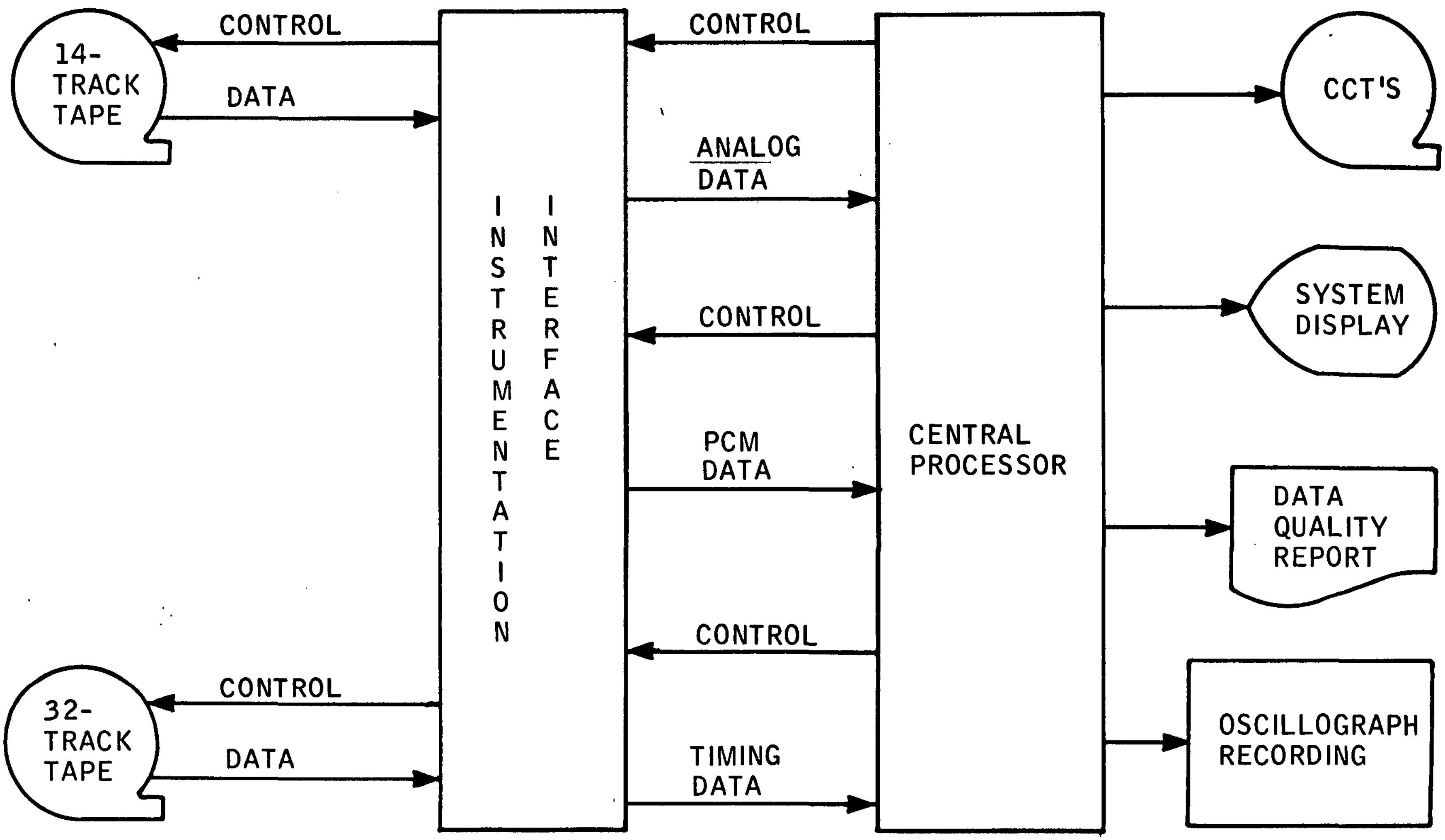


Figure 5.1-6 DRS Functional Flow

ATL mission will be controlled from the MCC-H by LRC flight controllers and that the POSC will function in support of the ATL mission through interfaces with JSC. In this capacity, the major functions of the POSC are payloads management and contingency analysis.

LRC personnel could perform all necessary flight operations support at JSC but the POSC will provide support to the principal investigators and operations personnel. Experiment and mission performance can be monitored through the POSC.

5.1.3.1 <u>Functions</u>. The POSC will provide for real-time support during ATL missions. In addition, limited support will be required to retrieve postflight data, to participate in crew and mission simulations, and to participate in active vehicle ground tests. The POSC will function primarily in a support role and will provide the following services:

- Permit ground-based user personnel to interface with onboard experiment operators and to interact with their experiments
- Provide ground-based personnel with mission data for evaluation and mission input
- Manage onboard payload functions and operations
- Perform contingency analysis
- Perform payload activities rescheduling.

5.1.3.2 <u>Data Categories</u>. To perform the POSC functions listed in paragraph 5.1.3.1, several categories of data will be required. Six categories of data that have been identified are voice, telemetry, trajectory, command, video, and a category containing miscellaneous data.

A. <u>Voice</u>. Voice communications will be required with the onboard experiment operators and with the mission operations personnel at MCC-H. The following types of voice channels must interface with the POSC:

- Air/ground (A/G) channel with onboard experiment operators*
- Channel with the payload officer in the Flight Control Room at JSC*
- Channel with the multipurpose support rooms at JSC*
- Channel with the Master Operations Planning Room at JSC*
- Channel with the Flight Director at JSC**
- Operations status channel**
- Network channel.*

B. Telemetry. Telemetry data will be required at the POSC so the ground personnel will have mission data for evaluation and mission input. The telemetry data will include spacelab systems data, experiment equipment data, and Shuttle systems data.

C. Trajectory. Trajectory data will be required for determining the position and attitude of the space vehicle. This data will consist of tracking data and guidance/navigation data. The trajectory data will provide a basis for generating orbit ephemeris, maneuver profiles, and experiment/crew timelines. In addition, site coverage times, sunrise/sunset times, and communication coverage times will be obtained from this data.

D. Command. The MCC-H will have command responsibility for all Orbiter and payload commands. It is intended for LRC personnel at JSC to do ATL command; however, limited command capability should exist at the POSC for cases of specialized experiment management and contingency situations. In any event, all commands will be routed via JSC.

---

*Dual voice channel (task and monitor)
**One-way voice channel (monitor only)

ATL commands are required for experiment equipment and data take operations. Typical functions to be performed by commands include on/off experiment control, pointing control, data acquisition control, and operating mode selection. Commands to perform these functions may be single commands or multicommands (command loads).

E. Video. Video data will provide a visual record of both experiment equipment operations and of scientific data. This data will allow the ground-based personnel to better evaluate the experiment functions being performed by the crew and will allow for more timely mission inputs. Visual scientific data will provide a quick-look capability whereby the quality and sufficiency of experiment output data can be determined. Video data will aid in performing real-time payload activities rescheduling.

F. Miscellaneous. This category will contain data which does not specifically fall in any of the previous categories and which could better be handled in a general category. The majority of this data will be supportive type data which has been generated from other data sources. It will be used for mission operations, ground-control system operations, contingency analysis, activities planning, etc. Types of data to be included in this category are as follows:

- Command histories
- Data logs
- Status/verification messages
- Environmental data consisting of meterological and space environment
- Simulation/training data
- Consumable usage.

5.1.3.3 Data Link Estimates. An estimates of the data link capabilities that will be required to support the data categories described in paragraph 5.1.3.2 is as follows.

A. Voice. It is estimated that one full duplex voice channel will be required for air/ground science communications. This channel may be either digital or analog. If the voice channel is kept in the original uplink/downlink form, it will be 32 kb/s digital.

   Four full duplex voice channels will be required for POSC/JSC mission operations and coordination functions. In addition, two monitor channels will be required. These channels may be either analog or digital.

B. Telemetry. An estimate of the required telemetry data is listed as follows:

   - Spacelab systems data up to 5 kb/s
   - Experiment equipment data up to 20 kb/s
   - Shuttle system data up to 5 kb/s.

C. Trajectory. The trajectory data loading is estimated to be up to 5 kb/s. This will include ground station generated tracking data and JSC generated data.

D. Command. Uplink command capability of up to 8 kb/s is estimated for payload commands.

E. Video. One 4 MHz bandwidth analog channel is required for video data.

F. Miscellaneous. It is estimated that a 5 kb/s rate will be sufficient to handle the miscellaneous data as outlined in paragraph 5.1.3.2,F.

5.1.3.4 Data Interfaces. An overview of the typical data interfaces for the NASA Space Transportation System flights is illustrated in figure 5.1-7. The POSC could have data links with the

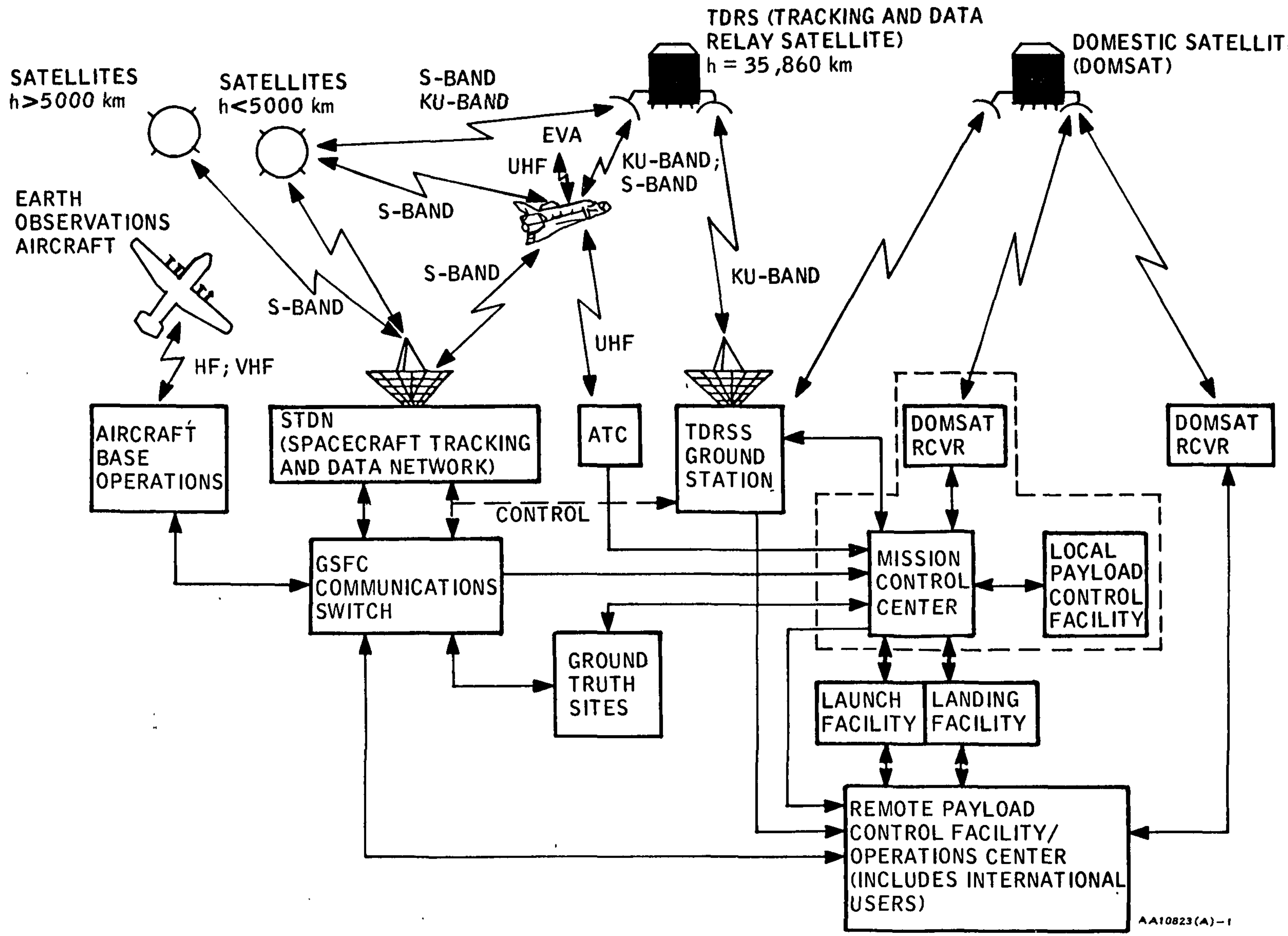


Figure 5.1-7 Data Interface Overview

Goddard Space Flight Center (GSFC), the Tracking Data Relay Satellite System (TDRSS) receiving station, the launch facility, and the landing facility. The requirements for each link will depend on the POSC operations philosophy as defined by LRC.

5.1.3.5 Support Classifications. The degree of support provided by the POSC can vary from voice only support to a complete support capability required for the coordination and control of all payload operations. This degree of support will affect both the complexity and cost of the POSC. To provide a basis for identifying support capabilities, the following support classifications (utilizing the previously discussed data categories) have been defined:

- Class I - Voice
- Class II - Voice and video
- Class III - Voice, telemetry, and miscellaneous
- Class IV - Voice, video, telemetry, and miscellaneous
- Class V - Voice, telemetry, trajectory, command, video, and miscellaneous.

5.2 SUBTASK 2.2, PERFORMANCE REQUIREMENTS

The purpose of this subtask was to establish the performance requirements of the Langley Research Center Data Management System (LRCDMS). Determination of these requirements consisted of analysis of data volumes and processing cycles.

The performance requirements are based, by direction of LRC, on one ATL flight per year. The experiment groupings for five ATL payloads were provided by LRC. These groupings, along with data volumes, are shown in tables 5.2-1 thru 5.2-5.

The major areas of support for the LRCDMS are integration and checkout, mission operations, and postflight processing. As shown in the functional requirements document, there are the following two main system configurations:

- Data Reformatting System (DRS) consisting of 1) integration and checkout and 2) postflight processing

- Payload Operations Support Center (POSC) consisting of mission operations.

5.2.1 DRS Throughput Requirements. The driving requirement for throughput of the DRS is EO-7/8. Playback of the instrumentation recording at minimum speed produces a throughput rate of nearly 2 megabits per second (Mb/s). EO-7/8 is recorded using four recorders simultaneously. Each recorder is handling 115,593,632 bits per second (b/s) at a speed of 120 inches per second (I/S). The minimum playback speed of the recorder is 1-7/8 I/S. This playback rate produces a throughput rate of 1,806,150 b/s. This is equivalent to a reduction of 64:1 in playback versus recording speed. This means that for every one second of data acquisition, 64 seconds will be required to reformat the data. Using these figures total processing time can be calculated as shown below.

Mission acquisition time for EO-7/8 = 1.25 hours
One recorder reduced 64:1 = 64 × 1.25 = 80 hours
Four recorders = 4 × 80 hours = 320 hours

TABLE 5.2-1

ATL PAYLOAD NO. 1

EXPERIMENT	DATA TAKE TIME/DAY	DATA VOLUME DAILY (BITS)	DATA VOLUME MISSION (BITS)
NV-1	2.67 HRS.	7,105,190,400	35,525,952,000
NV-2	2.16 HRS	1,505,433,600	7,527,168,000
EO-7/8	15 MINS.	416,137,075,200	2,080,685,376,000
EO-1	4.0 HRS.	86,400	432,000
PH-6	20 MINS.	1,843,200	9,216,000
MB-1*	24.0 HRS.	33,408	100,224
MB-2	-	-	-
MB-4*	3.0 HRS.	41,040	123,120
MB-5	4.0 HRS.	22,784	113,920
CS-2**	5 MINS.	1,200,000	2,400,000
EN-1	-	-	-
EN-3	24.0 HRS.	110,592	552,960

*3 DAY DATA TAKE/MISSION

**2 DAY DATA TAKE/MISSION

TABLE 5.2-2

ATL PAYLOAD NO. 2

EXPERIMENT	DATA TAKE TIME/DAY	DATA VOLUME DAILY (BITS)	DATA VOLUME MISSION (BITS)
EO-5	2.67 HRS.	368,640	1,843,200
NV-3	.5 HRS.	6,370,099,200	31,850,496,000
EO-9	2.0 HRS.	523,008,000	2,615,040,000
EO-2	16.0 HRS.	618,393,600	3,091,968,000
PH-2*	80 MINS.	12,288,000	12,288,000
PH-3	30 MINS.	33,177,600	165,888,000
MB-1**	24.0 HRS.	33,408	100,224
MB-3**	1.0 HR.	7,616	22,848
EN-1	-	-	-

*1 DAY DATA TAKE/MISSION

**3 DAY DATA TAKE/MISSION

TABLE 5.2-3

ATL PAYLOAD NO. 3

EXPERIMENT	DATA TAKE TIME/DAY	DATA VOLUME DAILY (BITS)	DATA VOLUME MISSION (BITS)
EO-6	2.0 HRS.	86,400,000	432,000,000
EO-3	20 MINS.	27,835,121,000	139,175,605,000
PH-1	1.0 HR.	15,897,600	79,488,000
PH-3	80 MINS.	33,177,600	165,888,000
PH-6	20 MINS.	1,843,200	9,216,000
MB-1*	24.0 HRS.	33,408	100,224
MB-2	-	-	-
CS-2**	5 MINS.	1,200,000	2,400,000
EN-1	-	-	-
EN-3	24.0 HRS.	110,592	552,960

*3 DAY DATA TAKE/MISSION

**2 DAY DATA TAKE/MISSION

TABLE 5.2-4

ATL PAYLOAD NO. 4

EXPERIMENT	DATA TAKE TIME/DAY	DATA VOLUME DAILY (BITS)	DATA VOLUME MISSION (BITS)
EO-4	16.8 HRS.	309,657,600	1,548,288,000
EO-9	2.0 HRS.	523,008,000	2,615,040,000
EO-1	4.0 HRS.	86,400	432,000
PH-1	1.0 HR.	15,897,600	79,488,000
MB-3*	1.0 HR.	7,616	22,848
MB-4*	3.0 HRS.	41,040	123,120
EN-3	24.0 HRS.	110,592	552,960

*3 DAY DATA TAKE/MISSION

TABLE 5.2-5

PALLET ONLY PAYLOAD

EXPERIMENT	DATA TAKE TIME/DAY	DATA VOLUME DAILY (BITS)	DATA VOLUME MISSION (BITS)
NV-1	2.67 HRS.	7,105,190,400	35,525,952,000
NV-2	2.16 HRS.	1,505,433,600	7,527,168,000
EO-7/8	15 MINS.	416,137,075,200	2,080,685,376,000
EO-1	4.0 HRS.	84,400	432,000
PH-6	20 MINS.	1,843,200	9,216,000
EN-1	-	-	-
EN-3	24.0 HRS.	110,592	552,960
EO-4	16.8 HRS.	309,657,600	1,548,288,000
PH-2*	80 MINS.	12,288,000	12,288,000

*1 DAY DATA TAKE/MISSION

This calculation shows 320 hours of processing time will be required to reformat the data from one ATL mission for EO-7/8. Achieving a 2 megabit throughput rate will allow most experiments to be processed at a minimum ratio of 1:1. Several will be capable of being processed at a higher playback rate than they were recorded.

Table 5.2-6 depicts the processing time for each experiment based on data acquisition time and playback reduction. Any experiment which did not require a reduction in playback speed was assumed to be processed at a 1:1 ratio. Using the processing times shown in this table, the total processing time for reformatting each payload grouping can be calculated. The hours shown below are for actual processing of one pass only. They do not include any set up or rerun time.

ATL No. 1	587 Hours
ATL No. 2	197 Hours
ATL No. 3	242 Hours
ATL No. 4	251 Hours
Pallet only	571 Hours

5.2.2 DRS Computational Requirements. The DRS computational requirements involve decommutation, verification, and recording of the experiment data. These items must be performed in a real-time mode since the instrumentation tapes cannot be stopped and restarted in a fashion similar to digital tapes. For calculating the computational requirements the following numbers of instructions/byte were used.

Decommutation and Verification	-	25
Recording	-	3
	TOTAL	28

Table 5.2-7 shows the number of computations required per second by experiment based on the playback rates defined in table 5.2-6.

TABLE 5.2-6

EXPERIMENT PROCESSING TIMES

EXPERIMENT	TOTAL DATA ACQUISITION TIME PER MISSION	PLAYBACK RATIO	PROCESSING TIME
NV-1	13.35 HRS.	1-1	13.35 HRS.
NV-2	10.80 HRS.	1-1	10.80 HRS.
NV-3	2.50 HRS.	1-4	10.00 HRS.
EO-1	20.00 HRS.	1-1	20.00 HRS.
EO-2A	40.00 HRS.	1-1	40.00 HRS.
EO-2B	40.00 HRS.	1-1	40.00 HRS.
EO-3	1.66 HRS.	1-16	26.56 HRS.
S190A	1.66 HRS.	1-1	1.66 HRS.
EO-4	84.00 HRS.	1-1	84.00 HRS.
EO-5	13.35 HRS.	1-1	13.35 HRS.
EO-6	10.00 HRS.	1-1	10.00 HRS.
EO-7/8	1.25 HRS.	1-64	320.00 HRS.*
EO-9	10.00 HRS.	1-1	10.00 HRS.
PH-1	5.00 HRS.	1-1	5.00 HRS.
PH-2	1.33 HRS.	1-1	1.33 HRS.
PH-3	6.66 HRS.	1-1	6.66 HRS.
PH-6	1.66 HRS.	1-1	1.66 HRS.
MB-1	72.00 HRS.	1-1	72.00 HRS.
MB-3	3.00 HRS.	1-1	3.00 HRS.
MB-4	9.00 HRS.	1-1	9.00 HRS.
MB-5	20.00 HRS.	1-1	20.00 HRS.
CS-2	.16 HRS.	1-1	.16 HRS.
EN-3	120.00 HRS.	1-1	120.00 HRS.

*FOUR RECORDERS

TABLE 5.2-7

COMPUTATIONS/SECOND FOR ATL EXPERIMENTS

EXPERIMENT	BYTES/SECOND	COMPUTATIONS/SECOND
NV-1	92,400	2,587,200
NV-2	24,200	677,600
NV-3	110,592	3,096,576
EO-1	120	3,360
EO-2A	60	1,680
EO-3B	2,624	73,472
EO-3	181,218	5,074,104
S190A	1,024	28,672
EO-4	640	17,920
EO-5	128	3,584
EO-6	1,500	42,000
EO-7/8	225,769	6,321,532
EO-9	9,080	254,240
PH-1	552	15,456
PH-2	320	8,960
PH-3	864	24,192
PH-6	192	5,376
MB-1	174	4,872
MB-2	952	26,656
MB-4	570	15,960
MB-5	712	19,936
CS-2	500	14,000
EN-3	56	1,568

5.2.3 DRS Computer Compatible Tapes (CCT). Based on generating CCT's at 1600 characters per inch, table 5.2-8 depicts the number of CCT's required per experiment.

5.2.4 POSC Support Requirements. The support provided by the POSC can be divided into the following phases:

- Launch site tests
- Crew and mission simulations
- Premission operations
- Mission operations
- Postmission operations.

A summary of the support duration and the data categories required during each of these support phases is presented in table 5.2-9.

During the 7-day mission operations phase, it is anticipated that the POSC will provide real-time support, 24 hours per day. All data categories will be required during this time. In addition, 2 days of premission support and 2 days of postmission support are also anticipated. However, this support will be limited in that all categories of data will not be required. The voice, telemetry, command, and miscellaneous data categories will be required for the premission operations period; whereas, voice, telemetry, and the miscellaneous data will be required for the postmission operations period. These data categories will be required on a 24 hour per day basis. This type of support schedule will ensure that all premission activities are accomplished, the experiment data collection is successfully completed, and all ATL related data is returned and stored at LRC.

In addition to the mission related operation activities, certain tests and simulations must be supported by the POSC. It is estimated that the POSC will have to support four tests and

TABLE 5.2-8

COMPUTER COMPATIBLE TAPE REQUIREMENTS

EXPERIMENT	RECORD LENGTH (BYTES)*	RECORD LENGTH (INCHES)**	NO. RECORDS PER 2400' CCT	RECORD LENGTH (BITS)	NO. RECORDS PER MISSION	NO. 2400' CCT'S PER MISSION
NV-1	3696	2.61	11034	29568	1201500	109
NV-2	3872	2.72	10588	30976	243000	23
NV-3	3072	2.22	12972	24576	1296000	100
EO-1	3600	2.55	11294	28800	15	1
EO-2A	3600	2.55	11294	28800	2400	1
EO-2B	3280	2.35	12255	26240	115200	10
EO-3	3006	2.17875	13218	24048	5787409	438
S190A	3600	2.55	11294	28800	1707	1
EO-4	3616	2.56	11250	28928	53523	5
EO-5	3616	2.56	11250	28928	1702	1
EO-6	3180	2.2875	12590	25440	16982	2
EO-7	8786	5.79125	4973	52716	39469713	7937
EO-8	8786	5.79125	4973	52716	39469713	7937
EO-9	3632	2.57	11206	29056	90000	9
PH-1	3312	2.37	12151	26496	3000	1
PH-2	3616	2.56	11250	28928	425	1
PH-3	3600	2.55	11294	28800	5760	1
PH-6	3584	2.54	11338	28672	322	1
MB-1	3654	2.58375	11146	29232	4	1
MB-3	3808	2.68	10746	30464	1	1

*EIGHT DATA BITS PER BYTE EXCEPT FOR EO-7 AND EO-8 WHICH HAVE SIX DATA BITS PER BYTE

**INCLUDES 0.3 INCH INTERRECORD GAP

TABLE 5.2-8 (CONT'D)

EXPERIMENT	RECORD LENGTH (BYTES)*	RECORD LENGTH (INCHES)**	NO. RECORDS PER 2400' CCT	RECORD LENGTH (BITS)	NO. RECORDS PER MISSION	NO. 2400' CCT'S PER MISSION
MB-4	3420	2.4375	11815	27360	5	1
MB-5	3560	2.525	11405	28480	4	1
CS-2	3500	2.4875	11577	28000	86	1
EN-3	3612	2.5575	11260	28896	17	1

*EIGHT DATA BITS PER BYTE EXCEPT FOR EO-7 AND EO-8 WHICH HAVE SIX DATA BITS PER BYTE

**INCLUDES 0.3 INCH INTERRECORD GAP

TABLE 5.2-9

SUPPORT CHARACTERISTICS

SUPPORT PHASES	SUPPORT DURATION	DATA CATEGORIES					
		VOICE	TELEMETRY	TRAJECTORY	COMMAND	VIDEO	MISCELLANEOUS
TESTS	4 DAYS, AV. 10 HRS/DAY	X	X		X	X	X
SIMULATIONS	12 DAYS, 12 HRS/DAY	X	X		X	X	X
PREMISSION OPERATIONS	2 DAYS, 24 HRS/DAY	X	X		X		X
MISSION OPERATIONS	7 DAYS, 24 HRS/DAY	X	X	X	X	X	X
POSTMISSION OPERATIONS	2 DAYS, 24 HRS/DAY	X	X				X

12 simulations. The data categories required for this support are voice, video, telemetry, command, and the miscellaneous data. An average of 10 hours of support is required for each pad test and each simulation will require approximately 12 hours of support.

A timeline illustrating the active support periods of the POSC is shown in figure 5.2-1. Although the ATL missions are baselined as 7-day missions, POSC support will be required over a 2 month period. Time that is not utilized for simulations will be utilized to complete mission related hardware and software configuration changes as required prior to the start of the premission operations phase. These types of changes are mission peculiar changes and are handled on a mission-to-mission basis. It should also be noted that two of the launch site tests occur during the premission operations phase. During this time period, both phases must be supported simultaneously.

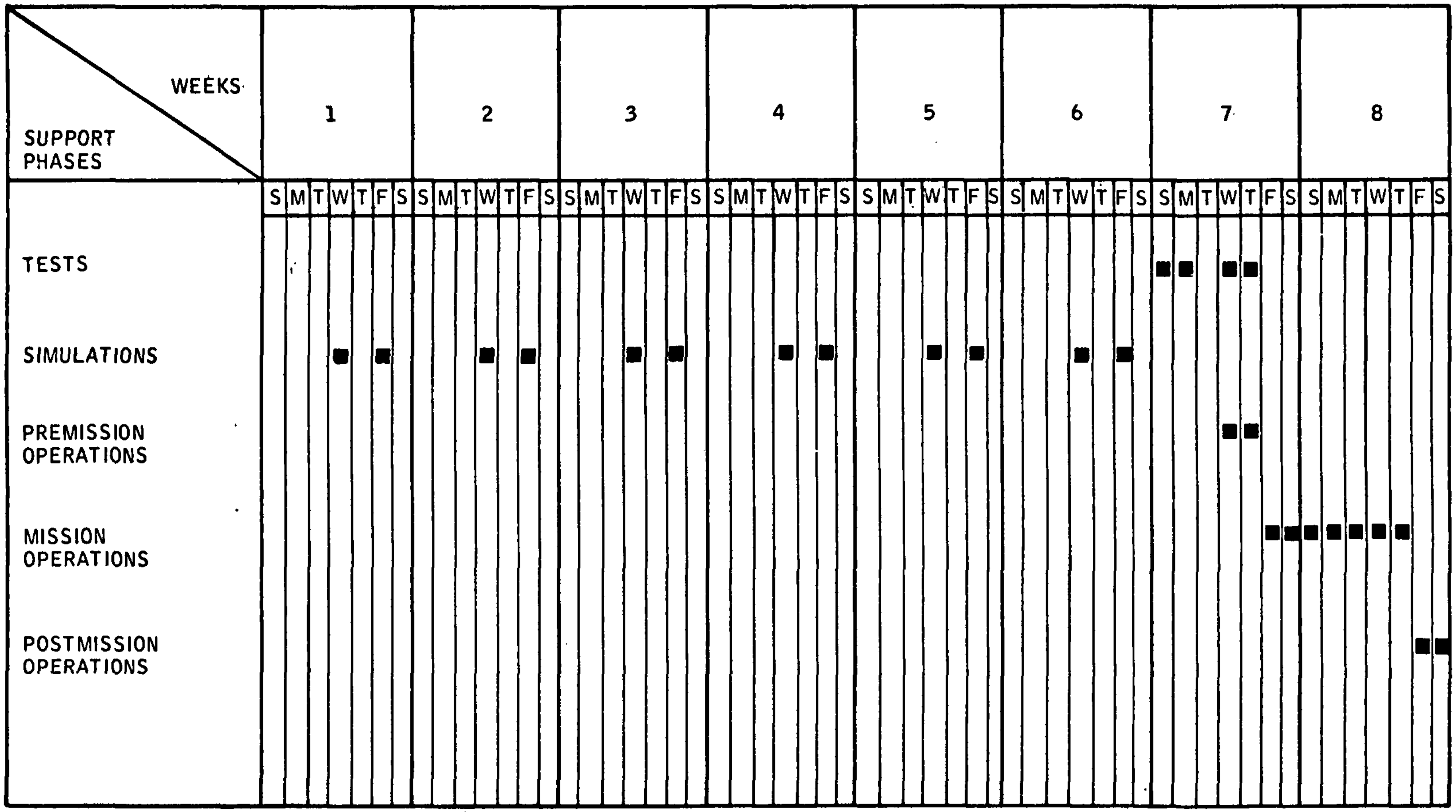


Figure 5.2-1 POSC Support Timeline

SECTION 6

CONFIGURATION CONCEPT DEVELOPMENT

The purpose of Task III was to develop a cost effective configuration to meet the requirements defined in Task II. Performance requirements for the configuration are driven by the imaging experiments, EO-3 and EO-7/8. In the nonimagery classification, the communication and navigation experiments are driving factors. The remaining experiments are relatively simple to handle for reformatting purposes.

6.1 SUBTASK 3.1, CONFIGURATION CONCEPTS

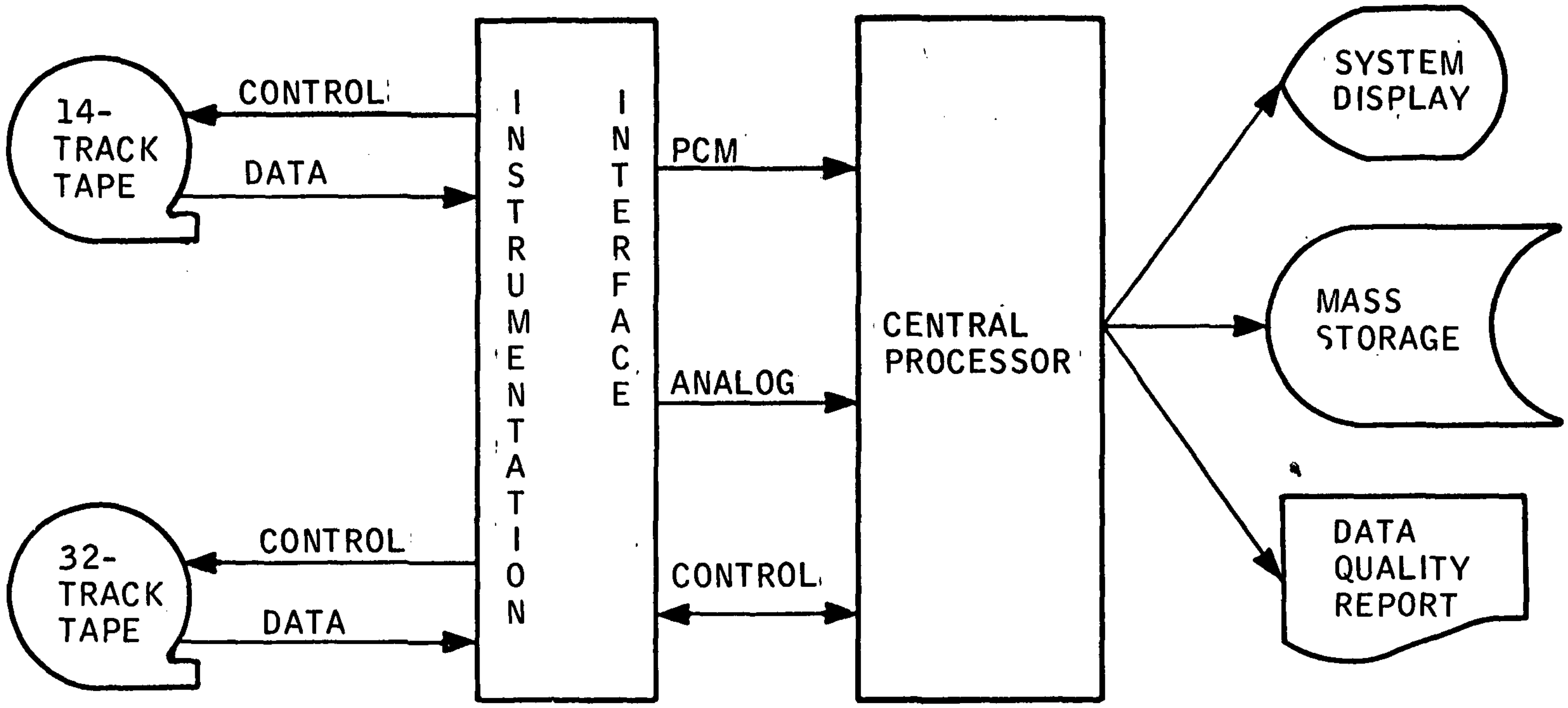
The major drivers in configuring the Data Reformatting System are the experiments shown below:

Experiment	Throughput Rate	Computations/Second
EO-3	181,218 Bytes/Second	5,074,104
EO-7/8	225,769 Bytes/Second	6,321,532
NV-1	92,400 Bytes/Second	2,587,200
NV-3	110,592 Bytes/Second	3,096,576

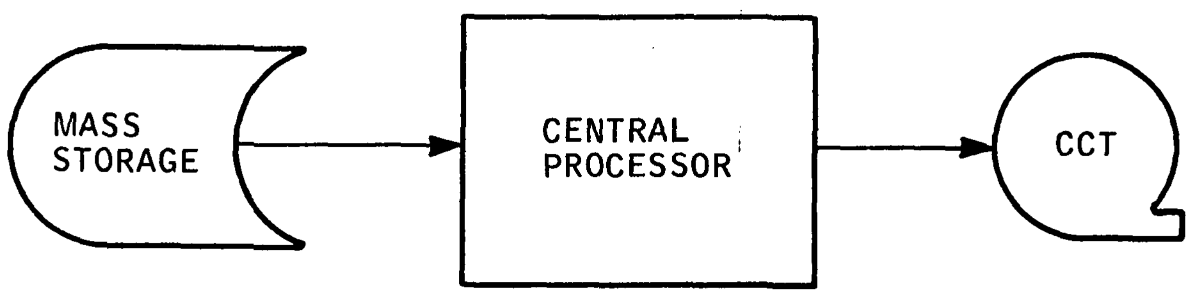
The data rates and computational requirements for the remaining experiments are low enough to be processed by a system similar to the Dynamic Data Transcription System at LRC.

Three basic concepts can be considered as possibilities for reformatting the experiment data.

A. Concept I, Software Reformatting. A total software reformatting concept would require a two-pass operation for the experiments shown above. This concept would involve one pass for inputting the data from instrumentation tape and storing it on a mass storage device. Pass 1 would simply transfer the data from the instrumentation tape to a demand-response type mass storage device. With this type of device the data can be reduced to lower input rates on Pass 2. Pass 2 would then input the data from the mass storage device at a rate which would permit software modules to reformat the data and generate computer compatible tapes. Figure 6.1-1 is a functional description of this concept.



PASS 1 - INSTRUMENTATION TAPE TO MASS STORAGE



PASS 2 - MASS STORAGE TO CCT

Figure 6.1-1 DRS Concept I

B. Concept II, Hardware Reformatting. This concept would permit all experiments to be reformatted in a one-pass operation. It would require a sophisticated instrumentation tape interface which could decommutate and reformat the data from the experiments shown above. The hardware interface would contain 800K bytes of memory for reformatting EO-3. In addition, the interface would contain the formatting logic required to assemble the serial input in the desired output format to permit the data to be written directly to CCT from the input buffers. This would reduce the time required by software reformatting. Figure 6.1-2 is a functional description of this concept.

C. Concept III, Combined Concepts. This concept would provide one-pass processing for all experiments except EO-3. EO-3 would be a two-pass operation due to the large amount of buffering which would be required for completing the reformatting in one pass (814,464 bytes).

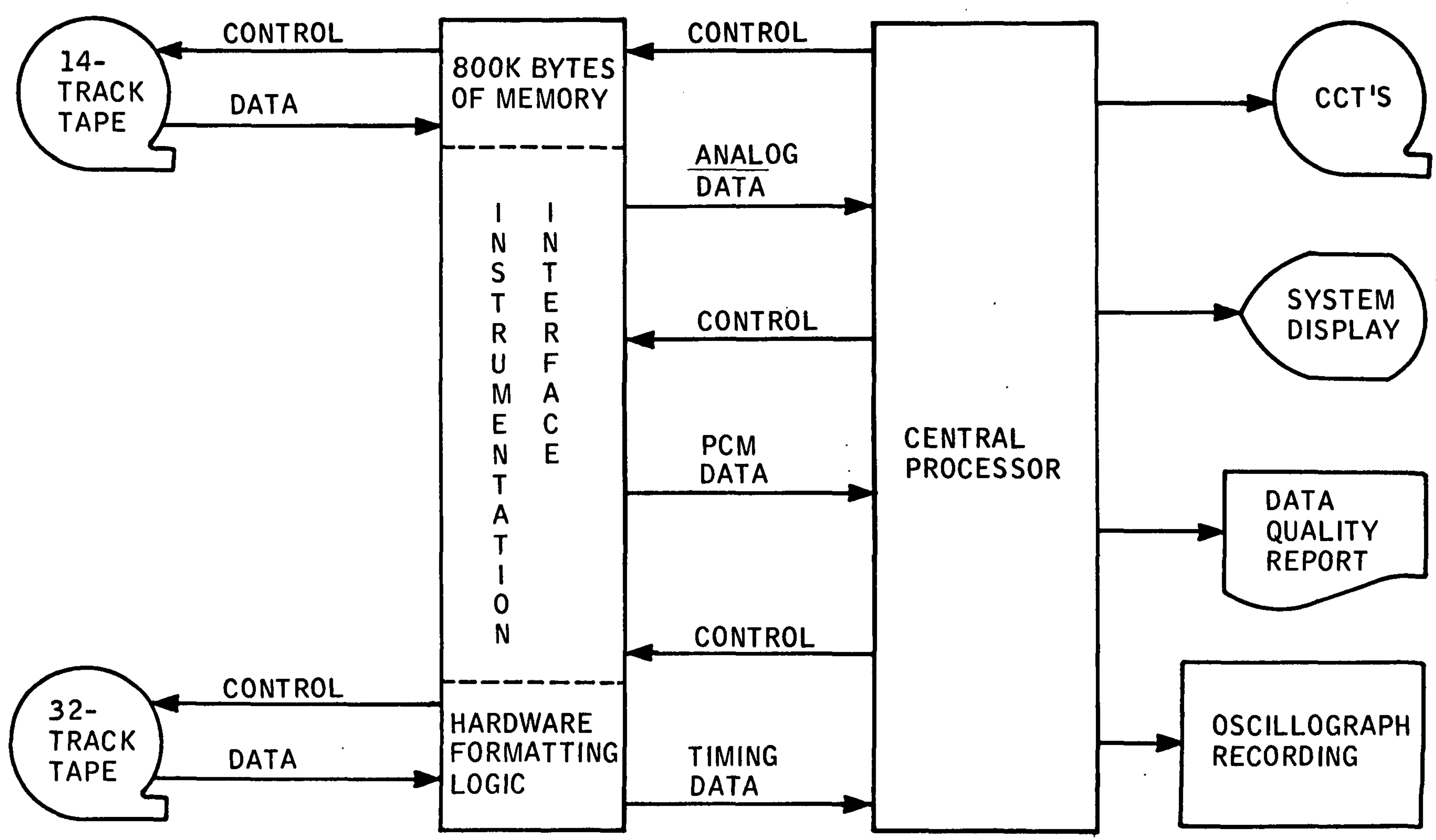


Figure 6.1-2 DRS Concept II

6.2 SUBTASK 3.2, TRADE-OFF ANALYSIS

This subtask consists of the analysis performed on the three candidate configurations to select the optimum system.

6.2.1 Processing Times. Processing times were calculated for each experiment in each configuration. These figures are shown in table 6.2-1. For the majority of experiments there are no differences in processing times for the three configurations. The greatest difference occurs with the system drivers. All times given in table 6.2-1 are actual equipment times and do not include setup or rerun times

The following shows how processing times were calculated for each of the basic concepts to be considered for reformatting the experiment data.

A. Concept I, Software Reformatting. This concept as described in paragraph 6.1, involves a two-pass operation. The first pass would be at tape speed and would require the same time as shown under configuration 2 in table 6.2-1. The second pass would be the reformatting and CCT generation pass. To perform this operation as a software function requires a computation rate of approximately 500,000-600,000 computations/second. Using the computational requirements from Task II, the rate at which the data can be played back on the second pass can be calculated. Total processing time is then equal to the combined times of pass 1 and pass 2. Shown below is a sample calculation for EO-3.

Pass 1 - 1.66 hours of data recorded @ 120 inches/second (IPS) and played into the system @ 7-1/2 IPS = 26.56 hours

Pass 2 - Computations/second @ 7-1/2 IPS = 5.074,104. To complete pass 2, reduce rate by a factor of 9 to achieve the 500,000-600,000 computations/second

$$26.56 \times 9 = 239.04 \text{ hours}$$

Total processing time for Pass 1 + Pass 2 = 265.60 hours.

TABLE 6.2-1

CONFIGURATION PROCESSING TIMES

EXPERIMENT	PROCESSING TIME HOURS		
	CONFIGURATION 1	CONFIGURATION 2	CONFIGURATION 3
NV-1	66.75	13.35	13.35
NV-2	10.80	10.80	10.80
NV-3	60.00	10.00	10.00
EO-1	20.00	20.00	20.00
EO-2A	40.00	40.00	40.00
EO-2B	40.00	40.00	40.00
EO-3	265.60	26.56	265.60
S190A	1.66	1.66	1.66
EO-4	84.00	84.00	84.00
EO-5	13.35	13.35	13.35
EO-6	10.00	10.00	10.00
EO-7/8	3840.00	320.00	320.00
EO-9	10.00	10.00	10.00
PH-1	5.00	5.00	5.00
PH-2	1.33	1.33	1.33
PH-3	6.66	6.66	6.66
PH-6	1.66	1.66	1.66
MB-1	72.00	72.00	72.00
MB-3	3.00	3.00	3.00
MB-4	9.00	9.00	9.00
MB-5	20.00	20.00	20.00
CS-2	.16	.16	.16
EN-3	120.00	120.00	120.00

B. Concept II, Hardware Reformatting. As can be seen in table 6.2-1, this concept significantly reduces the processing times for the system drivers. The processing time is equal to the data acquisition time multiplied by the playback reduction factor. For the majority of the experiments the processing time is equal to the data acquisition time.

C. Concept III, Combined Concepts. This concept is identical to Concept II with the exception of EO-3 which uses the two-pass operation.

   EO-7/8 must be reformatted in a one-pass operation. If one assumes a system operation of 16 hours a day, 5 days a week, the total processing time available/year is 4160 hours. To process EO-7/8 for one mission under a two-pass configuration would require almost 1 year at 16 hours/day, 5 days/week.

6.2.2 Cost Factors. Considering different cost factors of the three candidate systems, the only differences between the systems are mass storage costs versus interface costs. Analysis of these costs show the full interface capability of configuration 2 is more cost effective as well as more timely. The additional core and engineering needed to provide the capability given in configuration 2 amounts to approximately $50,000. A mass storage device to replace this function would require a minimum of $200,000. Based on the analysis of processing times and cost factors, the recommendation of this study is configuration 2.

Reference figure 6.2-1 for the DRS floor layout.

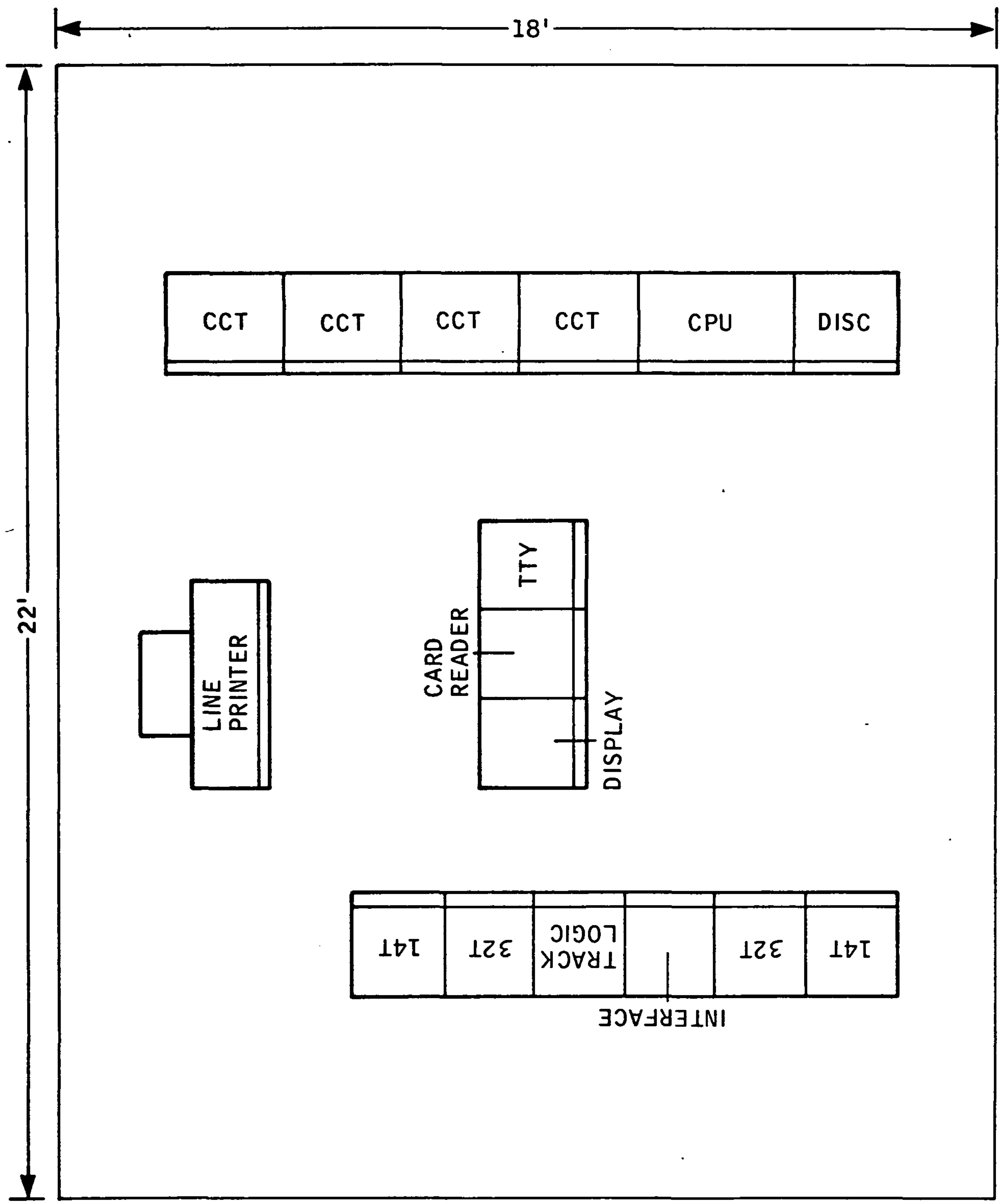


Figure 6.2-1 DRS Floor Plan

6.3 SUBTASK 3.3, DRS PREFERRED CONFIGURATION CONCEPT

Based on processing and cost analyses, the recommended configuration for the DRS is configuration 2 as shown in figure 6.1-2. The two main subsystems of this configuration are 1) the instrumentation interface and 2) the CPU and associated peripherals.

The costing of the DRS configuration consists of hardware, engineering, and documentation. The costs will not include any inflation or tax factors. The total cost of system implementation is shown in table 6.3-1.

6.3.1 Instrumentation Interface. Table 6.3-2 shows the major items and cost of the instrumentation interface. The interface contains the track logic as defined in the functional requirements and the buffering for reformatting EO-3. Two recorders of each type were costed to provide copying capability for the instrumentation tape.

6.3.2 Central Processor. Table 6.3-3 shows the major items and cost of the CPU and peripherals.

6.3.3 Software Configuration. The two main software projects are as follows.

A. DRS Operating System. It is made up of four main components. These are system software, image processing software, non-image processing software, and data quality software. The cost of this software is shown in table 6.3-4.

B. Checkout Validation System. This system will assist with the integration and checkout of ATL experiments and generate and validate test data for system checkout. The cost of this software is shown in table 6.3-5.

6.3.4 Operational Support. Three areas of support will be required for the DRS and POSC operation. These areas are:

A. Operations. Two shifts of operations and maintenance support for the operational system would be required for each shift. Personnel would include the following:

- Operations Supervisor - Responsible for the operational area; coordinates all operational activities and interfaces with the production and software groups

- Operator/Technician - Responsible for operation, setup and maintenance of the instrumentation tape interface and assists with computer operation

TABLE 6.3-1

TOTAL COST OF THE DRS

HARDWARE COSTS	
INSTRUMENTATION INTERFACE	$542K
CENTRAL PROCESSOR AND PERIPHERALS	180K
SOFTWARE COSTS	
DRS OPERATING SYSTEM	244K
CHECKOUT/VALIDATION SYSTEM	141K
TOTAL DRS COST	1,107K

TABLE 6.3-2

INSTRUMENTATION INTERFACE

DESCRIPTION	COST
32-TRACK RECORDER 2 @ 100,000	$200K
14-TRACK RECORDER 2 @ 50,000	100K
INTERFACE LOGIC AND BUFFER	135K
ENGINEERING	52K
DRAFTING	11K
DOCUMENTATION	44K
TOTAL COST	$542K

TABLE 6.3-3

CENTRAL PROCESSOR

DESCRIPTION	COST
MINI-COMPUTER < 1 USEC CYCLE TIME, 16-BIT WORD SIZE, 64K CORE STORAGE*	$ 46K
CARD READER - 300 CPM*	5K
ALPHANUMERIC CRT	4K
LINE PRINTER - 132 COLUMN, 300 LPM*	10K
MAGNETIC TAPE UNITS - 200 IPS, 9-TRACK, 800/1600 CPI DENSITY - 4 @ 17,600	72K
MAGNETIC TAPE CONTROLLER	8K
MASS STORAGE - 40 MEGAWORD CAPACITY, 28 MSEC AVERAGE ACCESS	35K
TOTAL COST	$180K

*ITEMS ARE IN DYNAMIC DATA TRANSCRIPTION SYSTEM AT LRC AND COULD BE USED TO SUPPORT DRS.

TABLE 6.3-4

DRS OPERATING SYSTEM COST

TOTAL DEVELOPMENT TIME	6-1/2 MAN YEARS
LEAD PROGRAMMER (1)	2,000 HOURS
SENIOR PROGRAMMER (4)	8,000 HOURS
PROGRAMMER (2)	3,000 HOURS
TOTAL	13,000 HOURS

SYSTEM SOFTWARE COST	=	$222K
DOCUMENTATION	=	22K
TOTAL OPERATING SYSTEM COST	=	$244K

TABLE 6.3-5

GENERALIZED CHECKOUT/VALIDATION SYSTEM COST

TOTAL DEVELOPMENT TIME	4 MAN YEARS	
LEAD PROGRAMMER (1)	1,500	HOURS
SENIOR PROGRAMMERS (2)	3,000	HOURS
PROGRAMMERS (2)	3,000	HOURS
TOTAL	7,500	HOURS

CHECKOUT/VALIDATION COST	=	$128K
DOCUMENTATION	=	13K
TOTAL SYSTEM COST	=	$141K

- <u>Computer Operator</u> - Responsible for CPU and peripheral operation, tape labeling, and coordination of tapes with the tape librarian

- <u>Tape Librarian</u> - Maintains tape library; responsible for logging tapes in and out of the system.

B. <u>Production Control</u>. Two people per shift for two shifts per day would be required. Personnel would include the following for each shift:

- <u>Data Coordinator</u> - Sets up all production runs for the system and coordinates receipt and delivery of all data

- <u>Production Analyst</u> - Responsible for data quality; analyzes results of each run; and assists in trouble-shooting data problems.

C. <u>System Software</u>. A team of three programmers for system maintenance and modification would be required to assist Production and Operations in problem solving.

The cost of the support effort is illustrated in table 6.3-6. These costs are broken out as annual costs using 1896 hours available per year.

TABLE 6.3-6

SUPPORT COSTS

OPERATIONS	$170K
OPERATIONS SUPERVISOR (2)	
OPERATOR/TECHNICIAN (2)	
COMPUTER OPERATOR (2)	
TAPE LIBRARIAN (2)	
EQUIPMENT TECHNICIAN (1)	
PRODUCTION CONTROL	113K
DATA COORDINATOR (2)	
PRODUCTION ANALYST (2)	
SYSTEM SOFTWARE	90K
LEAD PROGRAMMER	
SENIOR PROGRAMMER	
PROGRAMMER	
ANNUAL SUPPORT COST =	$373K

6.4 POSC COSTS

Each data category outlined in the requirements for the POSC was analyzed to derive the minimal configuration for meeting the requirement. The hardware configuration components are as follows:

A. Voice. One IO PBI TLM remote keyset would meet the specified requirements.

B. Telemetry, Trajectory, and Command. This data could be handled by one 56 kb/s line from JSC to LRC. Minimal type hardware necessary to support these functions include the following:

- 56 kb/s CPU Interface. This interface would accept data from the 56 kb/s data line and perform frame sync and poly checking. After the verification of each message, the message would be routed to the central processor.

- Central Processor. This processor would be the same one used by the DRS.

- Displays. Displays consist of two table top type alphanumeric displays for the purpose of displaying telemetry and trajectory data.

- Video. There will be only one video receiver. The assumption is the video data will be processed at JSC and then transmitted to LRC.

Reference figure 6.4-1 for a functional diagram of POSC.

The software costs were generated based on the following assumptions.

- The major effort will be formatting data for and driving the displays.

- The data received from the 56 kb/s interface will require little or no processing.

- The operating system will be vendor supplied.

- The basic modules required will be for telemetry, trajectory, command and display.

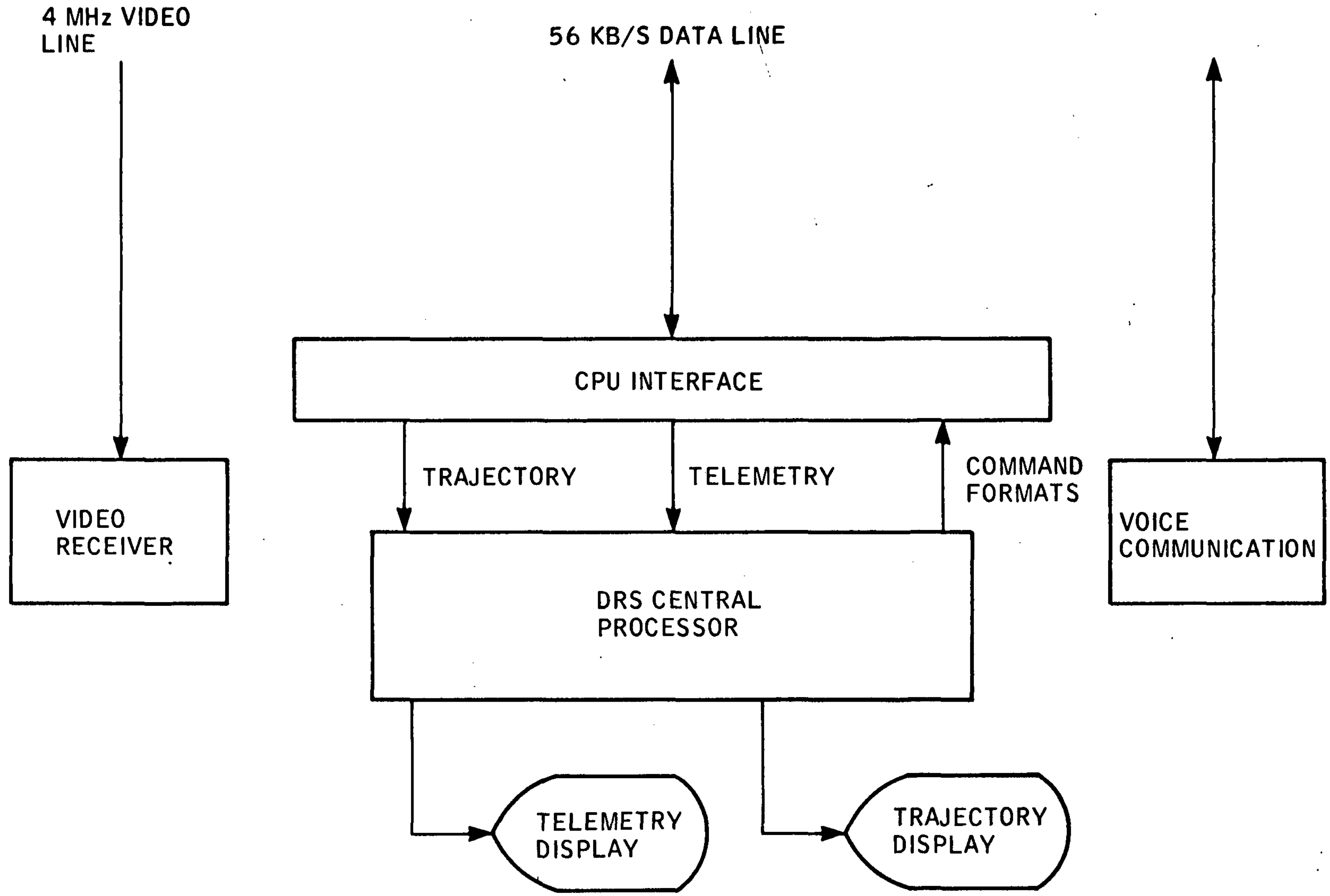


Figure 6.4-1 POSC Functional Diagram

The command philosophy assumed by this study effort is command execution will take place at JSC. This POSC configuration will permit the transfer of command data from LRC to JSC for storage prior to the actual command execution.

Costs for the elements are illustrated in tables 6.4-1, 6.4-2, and 6.4-3. Included in the cost tables are the current lease rates for each type of data line.

The costing data for the POSC were generated assuming minimal processing functions. These processing functions include:

- Set up and control of the 56 kb/s interface
- Formatting the telemetry and trajectory data for display
- Interactive capability for calling new displays and selecting command formats
- Command format transfers to JSC.

Limitations of the POSC include:

- Incoming data must have been preprocessed so that the data stream contains only ATL data
- Only two displays could be operating simultaneously
- No real-time statistical processing
- No multitask processing such as nonreal time programs operating in background modes during real time processing.
- No graphic display capability.

TABLE 6.4-1

HARDWARE COSTS

VOICE	
10 PBI TLM REMOTE KEYSET	$6K
300 BAUD MODEM AND CIRCUIT	900/MONTH
VOICE CIRCUIT	850/MONTH
TELEMETRY, TRAJECTORY, COMMAND	
TOTAL 48 KB/S	
56 KB/S CIRCUIT (1)	9,500/MONTH
VIDEO	
LOCAL CHARGES	2,000/MONTH
LINE CHARGES	1,050/HOUR
STATION CHARGES	160/HOUR
CPU (SAME AS DRS)	
DISPLAYS (2 @ 4K)	8K
VIDEO RECEIVER	3K
56 KB/S INTERFACE	110K

TABLE 6.4-2

SOFTWARE COST

DESCRIPTION		COST
LEAD PROGRAMMER (1500 HOURS)		
SENIOR PROGRAMMER (3 @ 1500 HOURS)		
SOFTWARE COST		102K
DOCUMENTATION		11K
	TOTAL COST	113K

TABLE 6.4-3

POSC SYSTEM COST

HARDWARE COST	
VOICE	6K
TELEMETRY, TRAJECTORY, COMMAND	118K
VIDEO	3K
SOFTWARE COST	113K
TOTAL IMPLEMENTATION COST	240K
LINE CHARGES	
VOICE	1,750/MONTH
56 KB/S CIRCUIT	9,500/MONTH
VIDEO	2,000/MONTH
	1,210/HOUR

SECTION 7

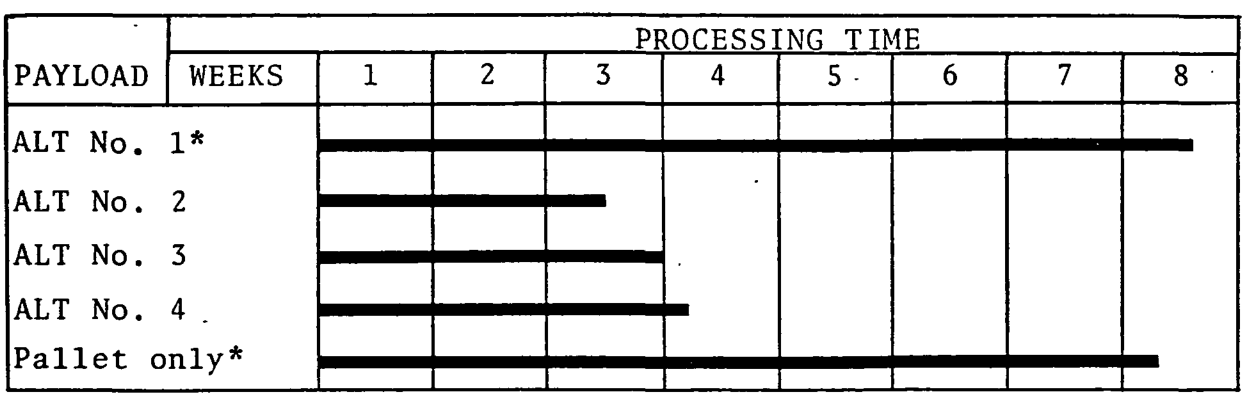
SUMMARY

The experiment analysis and ground processing requirements generation performed in this study clearly show that the main drivers to the ground processing configuration are the imagery experiments. The following illustrates the critical parameter restrictions which these experiments place on the Ground Processing System.

EXPERIMENT	MINIMUM THROUGHPUT RATE	COMPUTATIONAL REQUIREMENTS	STORAGE REQUIREMENTS
EO-3	1.4 Mb/s	5.0×10^6 comp/sec	1.6×10^4 bytes
EO-7/8	1.8 Mb/s	6.3×10^6 comp/sec	8.0×10^5 bytes

Trade analyses of possible configurations which could meet the requirements of the imagery experiments show that a sophisticated instrumentation tape interface controlled by a minicomputer system is the most cost effective. In addition, this configuration would provide the fastest turnaround time for reformatting the data.

Five payload groupings were supplied to the study team by Langley Research Center. Processing times for these payloads were calculated using the preferred configuration as shown below. The processing time was calculated based on 16 hours/day, 5 days/week.



*EO-7/8 part of payload

The processing times reflect actual CPU and interface time and do not include any set-up or rerun time. These times clearly reflect the impact of EO-7/8 to the Ground Processing System. The cost of the system is given in section 6 of this document.

In addition to examining the data processing costs for the post-flight processing, costs are provided for various elements of a Payload Operations Support Center (POSC). These costs (contained in section 6 of this document) are broken out into three main areas: 1) voice; 2) telemetry, command and trajectory; and 3) video.

The POSC was assumed to be a monitoring type center with the actual command and control of the mission being done by LRC personnel located at JSC.

Areas of future study which have been identified by this analysis include:

A. Data Analysis System Study. Ground processing analysis should be continued. This would give the requirements and configuration needed to complete the ground processing of the ATL experiment data. Before total ground processing costs can be evaluated, the analysis processing must be examined.

B. Imaging Radar Processing Study. A detailed processing study is necessary to determine processing techniques and capabilities to optimize the processing of the Image Radar Data. These techniques and capabilities will enhance the cost-effective development of the LRC Data Management System.

C. ATL Command and Control Study. A study should be to made to develop a detailed requirements document for ATL command processing including interagency responsibilities, command types, and formats.