

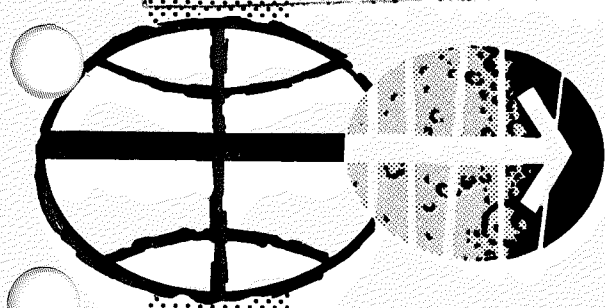
MSC #176



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

**APOLLO
LUNAR SURFACE
EXPERIMENTS PACKAGE
AND
PARTICLES AND FIELDS
SUBSATELLITE
SYSTEM DESCRIPTION
AND
DATA FLOW**

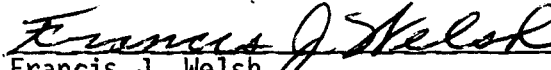
**TRW SYSTEMS
HOUSTON OPERATIONS
TECHNICAL LIBRARY**



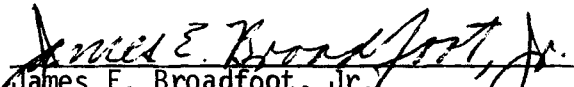
**MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
MAY 1971**

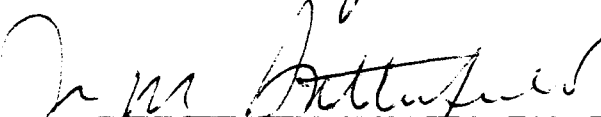
ALSEP AND P&FS
SYSTEM DESCRIPTION
AND
DATA FLOW

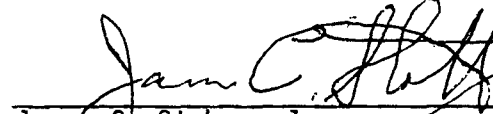
Prepared by:


Francis J. Welsh
Data Systems Integration Section
Communications Data Systems Branch
Flight Support Division

Approved by:


James E. Broadfoot, Jr.
Head, Data Systems Integration Section


James M. Satterfield
Acting Chief, Communications Data Systems Branch


James C. Stokes, Jr.
Chief, Flight Support Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

MAY 1971

PREFACE

The purpose of this book is to provide a reference document for those who require a knowledge of how the Manned Space Flight Network and the Mission Control Center support the Apollo Lunar Surface Experiments Package and the Particles and Fields Subsatellite. To this end a description of the ALSEP and P&FS systems including the experiments is presented along with an explanation of the overall data flow. It is not intended to cover hardware and functions that are used to support Apollo except as they relate to the ALSEP and P&FS data flow. Therefore, areas such as the NASCOM network, FACS, and CCATS will only be touched on lightly.

This book replaces the "ALSEP System Description and Data Flow" book dated December, 1970. Comments and suggestions concerning the contents of this book will be appreciated and should be directed to F. J. Welsh at extension 2451.

TABLE OF CONTENTS

PART I - ALSEP

Para.		Page
	PREFACE	A
	TABLE OF CONTENTS	B
	LIST OF FIGURES	D
	LIST OF TABLES	D
	ALSEP SYSTEM DESCRIPTION	
1.1	INTRODUCTION	1
1.2	ALSEP SUBSYSTEMS	2
1.2.1	EXPERIMENTS	4
1.2.2	ELECTRICAL POWER	12
1.2.3	DATA SUBSYSTEM	12
1.2.4	ALSEP CENTRAL STATION	15
	ALSEP DATA FLOW	
2.1	INTRODUCTION	17
2.2	ALSEP COMMAND DATA FLOW	17
2.2.1	MCC ALSEP COMMAND PROCESSING	17
2.2.2	GSFC ALSEP COMMAND PROCESSING	23
2.2.3	REMOTE SITE ALSEP COMMAND PROCESSING	25
2.2.4	ALSEP FLIGHT ARTICLE COMMAND PROCESSING	31
2.3	ALSEP TELEMETRY DATA FLOW	32
2.3.1	ALSEP TELEMETRY DOWNLINK	32

Para.		Page
2.3.2	REMOTE SITE ALSEP TELEMETRY PROCESSING	34
2.3.3	GSFC ALSEP TELEMETRY PROCESSING	37
2.3.4	MCC ALSEP TELEMETRY PROCESSING	37
2.3.5	ALSEP DIGITAL DISPLAY	43
2.4	ALSEP VS. APOLLO	46

PART II - P&FS

P&FS SYSTEM DESCRIPTION

3.1	INTRODUCTION	47
3.2	SUBSATELLITE DESCRIPTION	48
3.3	EXPERIMENTS	48
3.3.1	S-BAND TRANSPONDER EXPERIMENT	48
3.3.2	PARTICLE SHADOWS/BOUNDARY LAYER EXPERIMENT	49
3.3.3	MAGNETOMETER EXPERIMENT	50
3.4	ELECTRICAL POWER	50
3.5	DATA SUBSYSTEM	51

P&FS DATA FLOW

4.1	INTRODUCTION	52
4.2	P&FS COMMAND DATA FLOW	52
4.3	P&FS TELEMETRY DATA FLOW	55
4.4	P&FS TRACKING DATA FLOW	57

ACRONYMS & ABBREVIATIONS

58

LIST OF FIGURES

FIG.		Page
1	ALSEP COMMAND DATA FLOW	18
2	MCC ALSEP GENERAL DATA FLOW	24
3	REMOTE SITE CONFIGURATION FOR ALSEP	27
4	ALSEP TELEMETRY DATA FLOW	33
5	MCC DETAILED ALSEP DATA FLOW	40
6	P&FS REMOTE SITE CONFIGURATION	53

LIST OF TABLES

TABLE		
1	ALSEP MISSION EXPERIMENT COMBINATIONS	3
2	ALSEP EXPERIMENT OBJECTIVES	13
3	ALSEP DOWNLINK CHARACTERISTICS	35

PART I - ALSEP
SYSTEM DESCRIPTION

1.1 INTRODUCTION

The Apollo Lunar Surface Experiment Package (ALSEP) is a series of scientific experiments and support subsystems which are deployed on the lunar surface during Apollo lunar landings. These experiments are used to investigate and determine the composition and structure of the lunar surface, interior, and environment. The ALSEP is assembled in subpackages which are mounted in and adjacent to the Scientific Equipment (SEQ) bay of the Lunar Module (LM). After landing on the lunar surface, the astronauts remove the ALSEP from the LM, deploy instruments, and subsystems, and activate the power subsystem. The astronauts then verify with the Flight Controllers at MCC that the receiving, processing, transmitting and power supply subsystems are operational.

Although the ALSEP has a design goal to transmit experiment data for one year, the ALSEP experiments are capable of supplying data for an indefinite period. Each ALSEP is a self-contained unit designed to measure lunar physical and environmental characteristics and transmit this data to the Manned Space Flight Network (MSFN) stations around the Earth. The data is then either sent to MCC in real time and/or recorded on magnetic tape. The tapes are used for playback if required, and are then sent to Houston. Upon arrival at MCC, the data is processed, displayed, and collected for dissemination to the Principal Investigators (PI's).

They proceed to analyze the data to derive information on the composition and structure of the lunar body, magnetic field, atmosphere, and the solar wind.

The USB 30-foot stations are the primary sites for continuous receive and record of ALSEP data for the lifetime of each package. It was originally thought that the 85-foot sites would be needed to support the high bit rate data (10.6 Kbps) from the Active Seismic Experiment (ASE). However, ALSEP 4 has shown that the 30-foot cooled sites can receive good ASE data. It is expected that the new bit rate of 3.533 Kbps associated with the Lunar Seismic Profiling Experiment on the Apollo 17 ALSEP (ARRAY E) can also be handled at the 30-foot cooled sites.

Since the sites require no major changes from Apollo configuration, the turnaround time to support ALSEP is no greater than two hours.

Continuous MSC and MSFN support of ALSEP is performed during the first 45 days after deployment. After the initial 45-day support period, real time coverage is required for approximately two hours each day and during the terminator crossings (± 12 hours). ALSEP data will be received and recorded at some element of the MSFN 24 hours a day, for the life of each package.

1.2 ALSEP Subsystems

The ALSEP consists of the following major subsystems: (a) experiment subsystems in varying combinations for each mission (Table 1), (b) the electrical power subsystem, and (c) the data subsystem. The experiment

ALSEP MISSION EXPERIMENT COMBINATIONS

APOLLO MISSION	11	12	13	14	15	16	17
ARRAY DESIGNATION	EASEP ¹	A	B ²	C	A-2	D	E
NUMERICAL DESIGNATION		(1)		(4)	(2)	(3)	
DATE DEPLOYED	7/20/69	11/19/69		2/5/71			
<u>EXPERIMENTS</u>							
PASSIVE SEISMIC	X	X	X	X	X	X	
ACTIVE SEISMIC				X		X	
LUNAR SURFACE MAGNETOMETER		X			X	X	
HEAT FLOW			X		X	X	X
SOLAR WIND SPECTROMETER		X			X		
CHARGED PARTICLE LUNAR ENVIRONMENT			X	X			
SUPRATHERMAL ION DETECTOR		X		X	X		
COLD CATHODE ION GAUGE			X				
LUNAR SEISMIC PROFILING							X
LUNAR SURFACE GRAVIMETER							X
LUNAR EJECTA AND METEORITE							X
LUNAR MASS SPECTROMETER							X
DUST DETECTOR		X					
DTREM				X	X		
³ LASER RANGING RETROREFLECTOR	X			X	X		

NOTE 1: EARLY APOLLO SCIENTIFIC EXPERIMENT PAYLOAD

NOTE 2: ALL ALSEP EXPERIMENTS DESTROYED ON THE APOLLO 13 MISSION

NOTE 3: DISTINCT FROM BUT CARRIED WITH ALSEP EXPERIMENTS: NO DATA UPLINK OR DOWNLINK ASSOCIATED WITH THIS EXPERIMENT

TABLE 1

and support subsystems of the ALSEP are mounted in two subpackages for storage and transportation in the LM. The fuel cask (part of the electrical power subsystem) is attached to the outside of the LM.

1.2.1 Experiment Subsystems

The ALSEP objective of obtaining lunar physical and environmental data is accomplished through employment of various experiment combinations as shown in Table 1.

Passive Seismic Experiment (PSE)

The PSE is designed to monitor lunar seismic activity and at the same time afford the opportunity to detect meteoroid impacts and free oscillations. It may also detect surface tilt produced by tidal deformations which result, in part, from periodic variations in the strength and direction of external gravitational fields acting upon the Moon and changes in the vertical component of gravitational acceleration.

Analyses of the velocity, frequency, amplitude, and attenuation characteristics of the seismic waves provide data on the number and character of lunar seismic events, the approximate azimuth and distance to their epicenters, the physical properties of subsurface materials, and the general structure of the lunar interior.

The PSE is composed of four major physical components. The sensor assembly, leveling stool, and thermal shroud are all deployed together by the astronaut on the lunar surface. A separate electronics assembly is located in the ALSEP central station.

The instrumentation employed to achieve the objectives of the PSE is functionally divided into three long period seismic data channels, one short period seismic data channel, and a sensor assembly temperature monitoring channel. These scientific data channels are supported by sensor assembly heater control, data handling, uncaging, leveling, and power functions.

Active Seismic Experiment (ASE)

The primary function of the ASE is to generate and monitor artificial seismic waves in the three to 250 Hz range in the lunar surface and near subsurface. It can also be used to monitor natural seismic waves in the same frequency range. Like the PSE, the objective of this experiment is to acquire information on the physical properties of lunar surface and near subsurface materials.

Seismic waves will be artificially produced by explosive devices and detected by sensors called geophones. The explosive devices are (1) a "thumper" containing 21 explosive initiators and (2) a mortar package containing four high explosive grenades. The thumper will be used by the astronaut during the deployment of the experiment to provide seismic activity for the geophones to detect. The geophones are electromagnetic transducers which translate high frequency seismic energy into electrical signals. The grenades will be rocket-launched by Earth command near the end of the ALSEP mission (about two years after deployment) and are designed to impact at four different ranges: approximately 500, 1000, 3000, and 5000 feet with individual high explosive charges proportional to their range.

A 20-bit digital word format and a 10,600 bit/sec. data rate will be used in the ASE to ensure accurate encoding and transmission of critical real time event data, and to provide a relatively high frequency seismic data handling capability. The higher bit rate and longer word length are incompatible with the normal ALSEP format and preclude usual data collection from the other experiments during the time the ASE is turned on.

Lunar Surface Magnetometer (LSM)

The LSM provides data pertaining to the magnetic field at the lunar surface by measuring the magnitude and temporal variations of the lunar surface equatorial vector magnetic field. Electromagnetic disturbances originating in the solar wind and subsurface magnetic material near the magnetometer are also detected. This experiment should give some indication of inhomogeneities in the lunar interior.

The LSM consists of three magnetic sensors supported at equal distances above the lunar surface and apart from each other by three fiberglass support arms. The magnetic sensors, in conjunction with the sensor electronics, provide signal outputs proportional to the incident magnetic field components parallel to the respective sensor axes.

Heat Flow Experiment (HFE)

The HFE measures the temperature gradient and the thermal conductivity in the near surface layers of the Moon. The measurements obtained from the experiment enable the average value as well as the direction of the net heat flux to be determined. The knowledge of the lunar heat flux will pro-

vide additional information concerning: (a) a comparison of the radioactive content of the Moon's interior and the Earth's mantle; (b) a thermal history of the Moon; (c) a lunar temperature vs. depth profile; and (d) the value of thermal parameters in the first three meters of the Moon's crust.

The HFE is deployed with the two sensor probes implanted in the lunar surface in three-meter boreholes. These holes are drilled by the astronaut with the Apollo Lunar Surface Drill (ALSD). The two probes are connected by two multiple-lead cables to the HFE electronics package which is deployed separately from the ALSEP central station.

This experiment was part of the ALSEP that was destroyed on Apollo 13. Since this is considered one of the more significant ALSEP experiments, it has been added to the A-2 Array which is assigned to Apollo 15.

Solar Wind Spectrometer (SWS)

The SWS measures energies, densities, incidence angles and temporal variations of the electron and proton components of the solar wind plasma that strikes the surface of the Moon. The experiment also yields data on the properties of the tail of the Earth's magnetosphere.

Seven Faraday cups, designed specifically for the ALSEP program, collect and detect the solar wind electrons and protons. The cups open toward different but slightly overlapping portions of the lunar sky. Therefore, with a knowledge of the positioning of the SWE on the lunar surface, the direction of the bulk of charged particle motion can be deduced. Voltages on modulation grids of the cups are changed in sign and varied so

that the cups will differentiate between electrons and protons and between particles having different energies.

Charged Particle Lunar Environment Experiment (CPLEE)

The CPLEE will provide data pertaining to the solar wind, solar cosmic rays and other particle phenomena by measuring the energy distribution and time variations of the proton and electron fluxes at the lunar surface.

The basic instrument of the CPLEE used to perform these measurements consists of two detector analyzers oriented in different directions for minimum exposure to the ecliptic path of the Sun. Each detector analyzer has six particle detectors. Five of these detectors provide information about particle energy distribution, while the sixth detector provides high sensitivity at low particle fluxes. Particles entering the detector analyzer are deflected by an electric field into one of the six detectors, depending on the energy and polarity of the particles. The CPLEE also includes electronics for recording the particle count and providing data to the data subsystem.

Suprathermal Ion Detector Experiment (SIDE)

The SIDE comprises the suprathermal ion detector and the Cold Cathode Ion Gauge (CCIG). The purpose of the SIDE is to measure the ionic environment of the Moon by detecting the ions resulting from the ultraviolet ionization of the lunar atmosphere and the free streaming and thermalized solar wind. The suprathermal ion detector will measure the flux, number density,

velocity, and energy per unit charge of positive ions in the vicinity of the lunar surface. The cold cathode ion gauge will determine the density of any lunar ambient atmosphere, including any temporal variations either of a random character or associated with lunar local time or solar activity. In addition, the rate of loss of contaminants left in the landing area by the astronauts and LM are measured.

The SIDE consists of a velocity filter, a low energy curved plate analyzer ion detector, a high energy curved plate analyzer ion detector, a cold cathode ion gauge, a wire mesh ground plane, and associated electronics. The outer case of the SIDE houses the CCIG which is removed by the astronaut during deployment. The gauge is connected to the experiment by a short cable. The wire mesh ground plane is a conductive network placed on the lunar surface beneath the experiment to provide an equipotential reference surface for control of local electric fields between the two SIDE ion detectors and the lunar surface.

Cold Cathode Gauge Experiment (CCGE)

The CCGE comprises the cold cathode ion gauge (CCIG) and associated electronics. The purpose of the experiment is to measure the density of the lunar atmosphere. This experiment is almost identical to the CCIG experiment associated with the SIDE.

Laser Ranging Retro-Reflector (LRRR)

The LRRR is a 10 x 10 group of corner reflectors that acts as a target for Earth based laser beams. (The LRRR on Apollo 15 will have 300 corner reflectors instead of 100.) This experiment is in addition to the ALSEP experiments but is considered here since it has been (Apollo 11 and 14) and will be (Apollo 15) carried and deployed with the ALSEP. There is no uplink or downlink communications with the LRRR; it is strictly a passive reflector.

The LRRR experiment will enable precise Earth-Moon distance measurements to be made over a period of several years from which fluctuations in the Earth's rotation rate, shifting of the continents and gravity influences on the Moon can be derived.

NEW EXPERIMENTS

The following four new experiments are to be combined with the HFE to make up the Array "e" package (Apollo 17).

Lunar Ejecta and Meteorite Experiment (LEAM)

The LEAM experiment is designed to measure the physical parameters of primary cosmic dust encountered on the lunar surface and to detect lunar ejecta or secondary spray particles emanating from the site of meteorite impacts. It is also aimed at determining the radiant flux density and speed of particles in meteor streams and to perform a control experiment on the reliability of the accoustical sensor as a cosmic dust sensor.

Lunar Seismic Profiling Experiment (LSP)

The LSP experiment is designed to perform seismic reporting on the lunar surface by generating and monitoring artificial seismic waves in the lunar subsurface (similar to the ASE). The LSP consists of four geophones with cables, a central electronics located in the central station, and up to ten explosive charges. The explosive charges are activated after the astronauts depart from the lunar surface by timers and are detonated through a commanded RF link. Seismic signals are detected by the geophones processed through the LSP central electronics, and along with critical timing data telemetered back to Earth through the ALSEP central station. A unique bit rate of 3.533 Kbps is associated with the experiment, but it will also have the capability to operate at the normal ALSEP data rate (1060 bps).

Lunar Mass Spectrometer Experiment (LMS)

The Lunar Mass Spectrometer experiment is designed to identify and determine the density and composition of the lunar atmosphere in the mass range of 1 to 160 AMU and to determine temporal variations. It will also detect transient changes in composition due to venting of gases from the interior or from man-made sources. It utilizes a magnetic sector field mass spectrometer with a Nier type thermionic electron bombardment ion source.

Lunar Surface Gravimeter Experiment (LSG)

The Lunar Surface Gravimeter experiment is designed to study the lunar gravitational field by measuring the magnitude and the time variation

of the vertical component of gravity at a location on the lunar surface. The LSG shall consist of four basic components: a LaCoste and Romberg mass spring-level system, electronics package, thermal control box, and sun shade. The objective of this experiment is to determine lunar deformation due to tidal forces in order that the internal constitution may be established. Also, the existence of gravitation radiation from intense cosmic sources such as neutron stars could be determined.

1.2.2 Electrical Power Subsystem (EPS)

The EPS generates 63 to 74 watts of electrical power for operation of the ALSEP system and is composed of a radioisotope thermoelectric generator (RTC), a fuel capsule, a power conditioning unit, and a fuel cask. The power is developed by a thermopile system which is heated by a radioisotope fuel capsule. The power is regulated, converted to six required voltages, and supplied to the data subsystem for distribution to the support and experiment subsystems. Analog housekeeping data from the EPS is supplied to the data subsystem for downlink telemetry.

1.2.3 Data Subsystem

The data subsystem receives, decodes, and applies discrete logic commands from the MSFN to the deployed units of ALSEP. These commands are used to perform power switching, thermal control, operating mode changes and experiment control. The data subsystem accepts and processes scientific data from the experiments, engineering status data from itself and all the

ALSEP EXPERIMENTS	ALSEP OBJECTIVES								
	Monitor Lunar Seismic Activity	Generate Artificial Seismic Activity	Detect Artificial Impacts	Determine Meteorite	Determine Lunar Magnetic Field	Study Lunar Gravitational Field	Analyze Solar Wind and Cosmic Rays	Measure Thermal Conductivity of Subsurfaces	Detect Lunar Ionosphere
Passive Seismic	X		X						
Active Seismic	X	X	X						
Lunar Surface Magnetometer				X					
Heat Flow							X		
Solar Wind Spectrometer						X			
Charged Particle Lunar Environment						X			
Suprathermal Ion Detector						X		X	
Cold Cathode Ion Gauge									X
Lunar Seismic Profiling	X	X	X						
Lunar Surface Gravimeter					X				
Lunar Ejecta and Meteorite			X						
Lunar Mass Spectrometer									X

ALSEP EXPERIMENT OBJECTIVES

TABLE 2

subsystems, and transmits the data to the MSFN receiving stations. The data subsystem also performs the function of switching and distributing operating power to the experiment and support subsystems.

The data subsystem on all vehicles except Array "E" is made up of the following components:

- a. Transmitters A + B (redundant)
- b. Diplexer switch
- c. Diplexer filter
- d. Command receiver
- e. Command decoders A + B (redundant)
- f. Timer
- g. Data processors X + Y (redundant)
- h. Power distribution unit
- i. Antenna

The data subsystem timer is designed to provide predetermined switch closures which are used to initiate specific functions within the data subsystem. On Arrays A and C (Apollo 12 and 14) it consists of a Bulova model TE-12 Accutron clock and a long life mercury cell battery. The timer on the A-2 and D Arrays (Apollo 15 and 16) is different in that it is a resettable solid state timer. Since the timers on both ALSEP Array A and C have failed, there will be no automatic shutoff of the transmitter on these packages. The resettable timer on Array A-2 and D will operate on a 97 day cycle and will be reset by command.

The antenna is a modified axial helix designed to receive and transmit

a right-hand circularly polarized S-band signal. This antenna type was selected because it has a relatively high gain (15 db) over a moderately narrow beamwidth (27°).

1.2.4 ALSEP Central Station

The ALSEP Central Station consists of the data subsystem, the power conditioning unit, the electronics subsystem for the PSE and ASE, thermal control provisions, shielding and housing for these subsystems, and a switch panel by which the astronaut can activate the central station if activation cannot be accomplished by ground command. Each ALSEP experiment interfaces electrically with the central station by means of flat, ribbon-like conductor cabling.

Positioned on one corner of the sunshield of the ALSEP 1 central station is the Dust Detector. Its purpose is to obtain data for assessment of dust accretion on the experiments and provide a measure of thermal degradation of thermal surfaces. It consists of three photocells oriented on three sides to face the ecliptic path of the sun. Dust accumulation on the surfaces of the three solar cells will reduce the solar illumination detected by the cells. The outputs of the solar cells as well as the temperature of each one is sent down in the telemetry data.

On Array C (Apollo 14) and the A-2 package (Apollo 15) there is a modified version of the dust detector called the Dust, Thermal, and Radiation Engineering Measurements (DTREM) package. In addition to obtaining data on dust accretion, it also provides information on the lunar radiation environment and the lunar surface brightness temperature. In this case, the three solar

cells are facing vertical, and one of them has been degraded by a known amount of radiation. This cell is used as a standard to measure the degradation of the other two cells.

Both of these systems are controlled by on/off commands from Earth.

2.1 Introduction

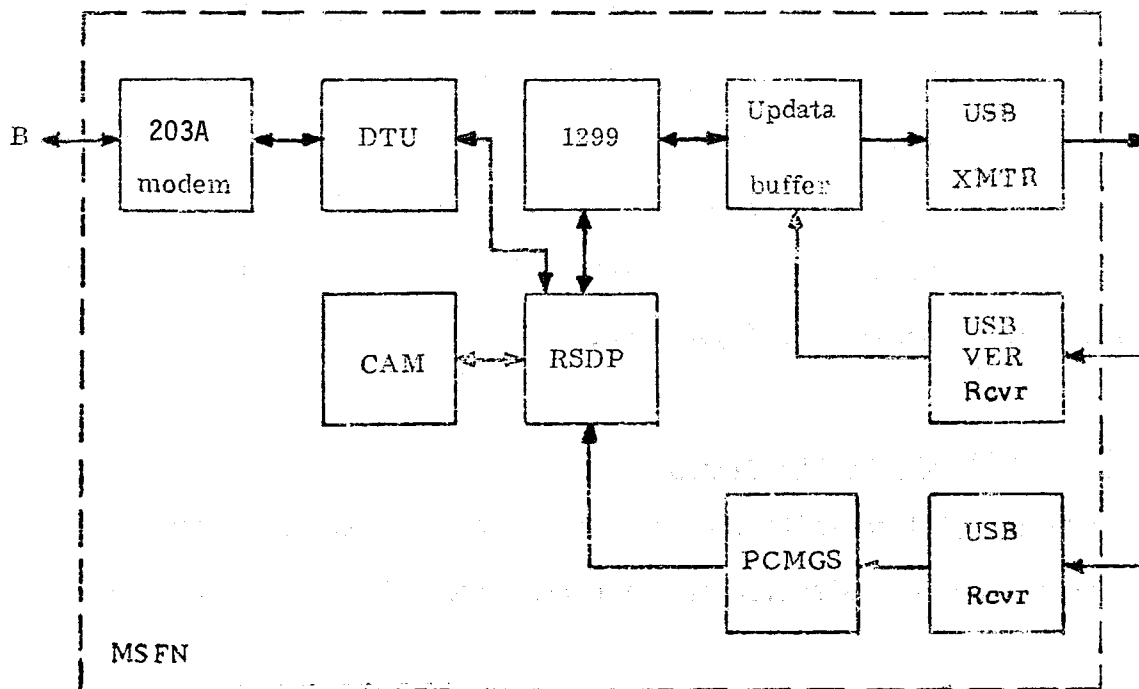
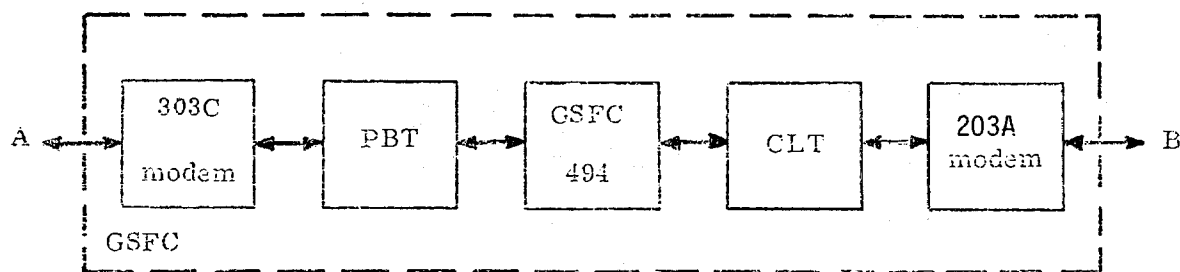
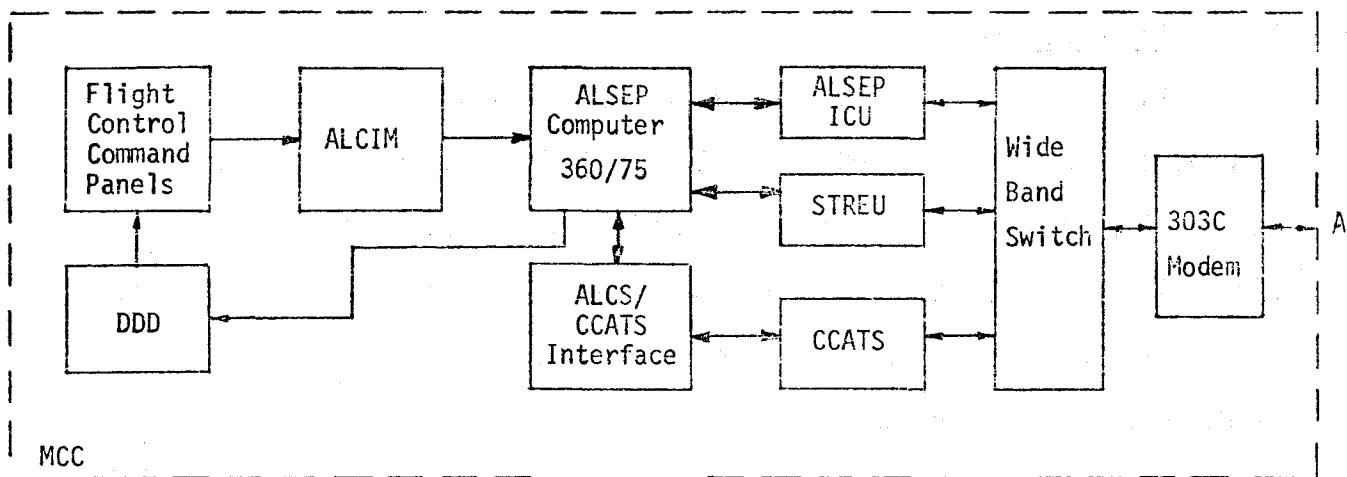
In this section, ALSEP data flow will be explained. Starting with command data generated at MCC, the flow is followed through the MCC to the remote site by way of the Goddard switching center and then up to the vehicle. Similarly, the telemetry data flow is followed from the vehicle to the remote site through to GSFC and the MCC. Processing and displaying the data at MCC will also be treated.

2.2 ALSEP Command Data Flow

The ground command system to be used in support of ALSEP operations is a modified version of the Apollo Universal Command System (UCS). The UCS is a chain of computer systems interlinked to form a closed loop between MCC and the receiving vehicle/package. (The other half of the loop is completed by the telemetry downlink.) The chain is composed of four basic units: (a) The MCC in Houston, (b) The Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, (c) the remote sites situated around the world, and (d) the receiving vehicles/packages. The basic differences between Apollo and ALSEP are MCC routing, format definition, remote site transmission, and console modular configuration.

2.2.1 MCC ALSEP Command Processing

Commands will be initiated from MCC at the appropriate flight control console by thumbwheel selection of three numerical digits, push-button



ALSEP Command Data Flow
Figure 1

selection of vehicle and decoder, and the subsequent depression of an execute push-button indicator (PBI). The three digit selection and the depression of the execute PBI, transmitting CMD data between MCC and a MSFN command site, can be classed as either Command Execute Request (CER) or Computer Execute Function (CEF).

The CER type execute initiates the uplink of Real Time Commands (RTC's) from the Remote Site Data Processor (RSDP) to the particular ALSEP experiment. CEF type executes do not initiate uplink of command functions, but rather instruct the RSDP to perform some specific operation, such as generation and transmission to MCC of an inventory summary message.

ALSEP Computer Input Multiplexer (ALCIM)

The major components of the command subsystem's man/machine interface are the Command Control and the Digital Select Matrix modules on the Flight Controller's console. The instructions to the ALSEP Computer System (ALCS) from these modules are transmitted by way of the ALCIM. One ALCIM is required to support ALSEP and is capable of accepting inputs from a maximum of 128 encoders. The encoders get their inputs from the various console modules. Thus, the CER's are initiated at the console, are sent to an encoder, and are then sent to the ALCIM.

Manual Entry Device (MED)

The MED used with the ALSEP 360/75 is an IBM 2260 Display Station. It is a compact cathode ray tube unit used for display and a keyboard

which allows the user to enter messages in computer storage. Messages are displayed on the screen for verification and editing before being transferred to main storage. The 2260 is connected to the ALSEP computer by way of the 2848 Display Control Adapters and the 2914 Switch.

The ALSEP Network Controller makes use of the 2260 to send CER's to the RS. Examples of these are low speed RTC Inventory requests and Site Status requests. The 2260 can also be used as a backup to send commands (CER's) to the ALSEP flight article.

ALSEP Computer System (ALCS)

The ALCS is comprised of an ALSEP computer, a 2902 Multiplex Line Adapter, and a 2701 Parallel Data Adapter. The output of the ALCIM is simplex serial data in 36-bit words at the rate of 2400 bits per second. This output is supplied to the 2902 Multiplex Line Adapter (MLA) which converts the data from serial to parallel and then through a 2914 switching unit to the ALSEP computer.

The 2902 Multiplex Line Adapter provides for the on-line attachment of peripheral input/output devices to the IBM System 360. Each device is attached to the MLA by an adapter. The MLA is comprised of a common section and 16 adapters. Two adapter types, Serial Input and Serial Output, are designed to operate with the real-time interfaces in the subsystem. The Serial Input adapter receives the serial data from the devices, assembles it into the 8-bit byte format and transfers it to the Central Processing Unit of the computer. The Serial Output adapter disassembles the data from

the System 360 byte format and transfers it to the device bit serially. The interface and adapter circuitry can accept data at rates up to 100 Kbps.

The ALSEP computer is an IBM Model 360/75, one of the five computers of this type in the Real Time Computer Complex area of building 30. The computer accepts the 8-bit bytes from the MLA in parallel form and processes each word in the message to determine the requested functions to be performed.

The ALCS outputs command messages for transmission to the remote sites via GSFC depending upon the current mode of operation, i.e., Apollo mission support with the Communications, Command, and Telemetry System (CCATS) operational or the ALSEP system in a stand-alone configuration. When the CCATS is operational, the ALCS will decode the command data from the ALCIM, perform error protection processing, and arrange the command message in a format acceptable to CCATS. The ALCS provides the source code, destination code, and data format code, and formats the actual command message into a 60-bit subblock which is inserted into a 600-bit clock for transfer to CCATS. Command message transfer to the CCATS is accomplished by way of the ALCS/CCATS Interface Unit (ACIU). The ALCS outputs the data (out of the MLA) in a bit serial mode and clocks the data to CCATS at an effective rate of 2.4 Kbps (81.6 Kbps burst). The ACIU accepts command data from the ALCS and transmits control information to the ALCS.

In the area of command, the CCATS supports the ALCS in the following manner:

- a. Integrates ALSEP commands into CCATS sequential data block transfers to NASCOM.

- b. Provides the ALCS an acknowledgment of the receipt of ALCS command data by CCATS.
- c. Encodes ALSEP commands with a 22- or 33-bit polynomial error protection code.
- d. Processes ALSEP commands as required by the CCATS operational program.
- e. Outputs ALSEP commands in standard NASCOM 600-bit blocks to GSFC at a 50.0 Kbps rate.

From CCATS, the command data goes to the wideband data switch matrix and then to a 303C modem which outputs it on the 50 Kbps lines to GSFC.

During non-mission periods, the ALCS operates in the stand alone configuration. When in this configuration, the command message block is output to the NASCOM WBDL terminal equipment via the ALSEP Interface Control Unit (ICU) or the Serial Transmit, Receive and Encode Unit (STREU). The ALCS develops the entire 600-bit message format including the appropriate sequence number, message number, and acknowledgment sequence number (always zeros), as well as the source code, destination code, data format code, and the actual command message. Output data transfers from the ALCS occur in 32-bit words.

ALSEP Interface Control Unit (ICU)

The ICU is the interface between the ALCS and the Facilities Control System (FACS). The ICU encodes the command data from the ALSEP computer with a 33-bit error protection code. The command comes out of the computer in eight-bit bytes and goes to a 2701 Parallel Data Adapter (PDA) where it is converted to 32-bit parallel words. The ICU accepts the 32-bit words,

applies the 33-bit error protection code, and puts out a 600-bit block in serial form to the Wideband Data Switch and then to a 303C modem.

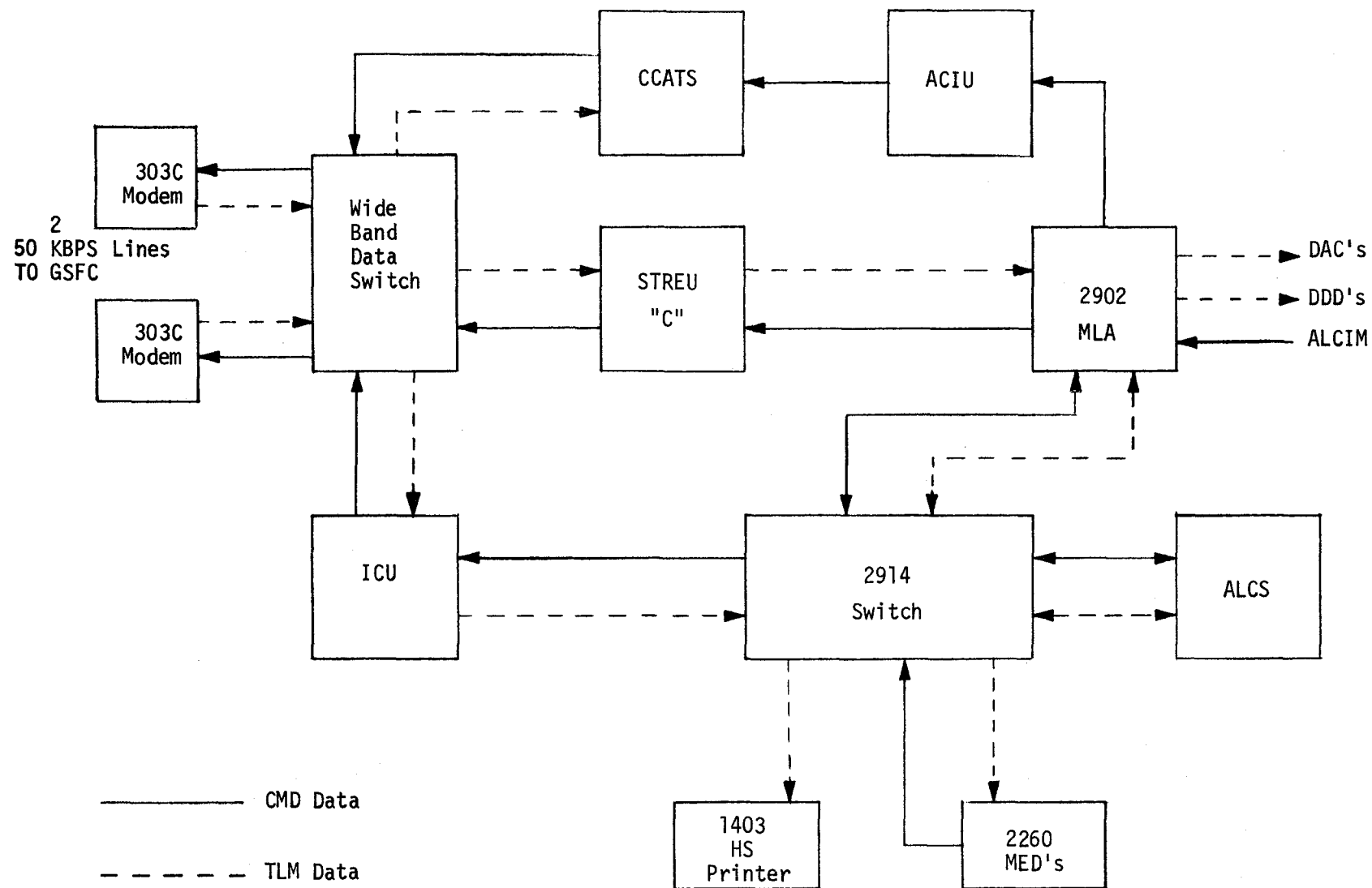
Serial Transmit, Receive, and Encode Unit (STREU)

Another route exists by which the command data can be sent out when the ALCS is in a stand alone configuration. In this case, the eight bit bytes from the ALSEP computer are supplied to the 2902 MLA and are converted to serial data. The 2902 transfers the serial command data to a STREU which applies the error protection code.

The STREU was originally a piece of equipment used for simulation of data flow (STREU "A" + "B" are still used for simulation; only STREU "C" is used for ALSEP). For ALSEP, the STREU acts as a backup for the ICU as well as providing an interface with the second 50 Kbps line. After leaving the STREU, the command data goes to the Wideband Data Switch and then to a 303C data modem.

2.2.2 Goddard Space Flight Center (GSFC) ALSEP Command Processing

The GSFC receives the high-speed 600-bit block via the NASCOM system 50 Kbps wideband data lines from MCC. Each 600-bit block enters GSFC through a 303C modem which routes the command data to a Polynomial Buffer Terminal (PBT). The PBT checks the 33 bits of polynomial error protection on the 600-bit block and if no data error exists, the PBT strips the error protection and transfers the data to the GSFC 494 Communications Processor (CP) computer.



MCC ALSEP General Data Flow

Figure 2

The GSFC CP strips the header portion (first 60 bits) of the NASCOM segment and repacks the first 60 bits of the 480-bit data portion of the NASCOM segment into 10-bit bytes. Preceding the 60 bits of data extracted from the data portion of the NASCOM segment, the GSFC adds two eight bit sync words, one eight-bit Start of Message (SOM) word, one eight-bit Length of Count (LOC) word, and adds one 10-bit End of Message (EOM) following the data.

The CP transfers the high speed data format in parallel to the Communication Line Terminal (CLT). The serial output of the CLT is routed to a 203A modem which transmits the data in a serial stream via the 4.8 Kbps link to the Remote Site.

2.2.3 Remote Site ALSEP Command Processing

The polynomial encoded 60-bit subblock is received serially at the 203A modem of the Remote Site (RS) at a rate of 4.8 Kbps and is routed to the Data Transmission Unit (DTU) which reformats the data and inputs it to the Remote Site Data Processor (RSDP).

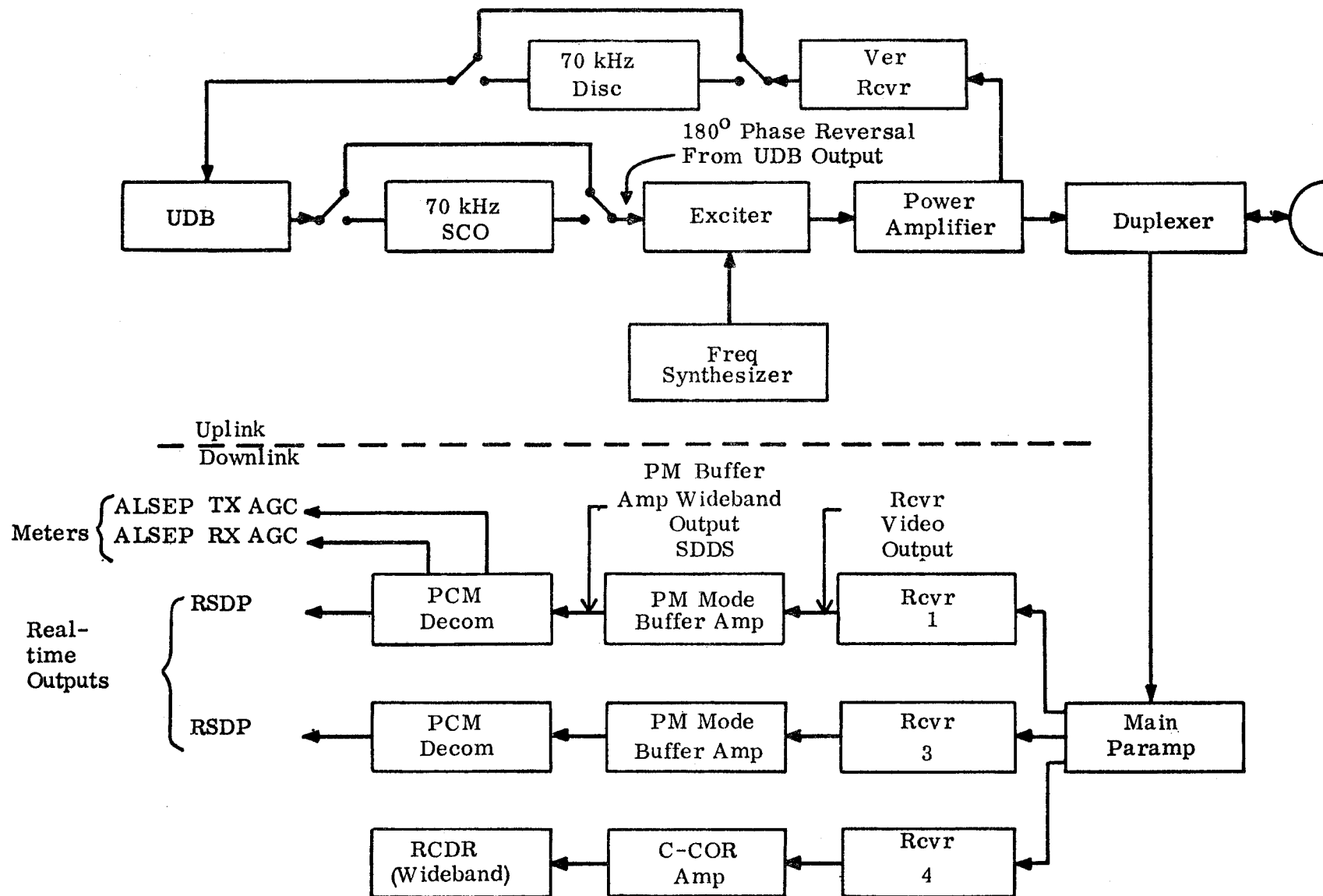
To support ALSEP, the RS utilizes one of the two Apollo 642-B computers. The remaining 642-B acts as a backup. The RSDP contains both the ALSEP and Particles and Fields Subsatellite command and telemetry programs. The existing Apollo configuration of each RS will basically be the same except for different USB frequencies, baseband instead of subcarrier modulation, and the above computer program changes.

Action which results in the uplink of command data or determination of the status of the command data within the RSDP can be initiated at either MCC or the RS. The mode that the RSDP is in determines who can access it. In mode 1, command uplink can be performed only from the RS via Computer Address Matrix (CAM). In mode 2, only high speed data (HSD) requests from MCC will be honored. To change to mode 2, a CAM input must be made. Also, the RSDP can be in either of two other modes. Flight Control (FC) mode or M&O mode.

In the FC mode, which can be entered from mode 1 or 2, inputs from the 1232 I/O console which interfere with uplink processing are inhibited. In the M&O mode, which can only be entered in mode 1, the 1232 I/O console is enabled, all uplink requests are rejected and any request to change to mode 2 is rejected. When the ALSEP program is initialized, it will be in mode 2 and the FC mode.

The RSDP will accept inputs from the CAM and the 1232 I/O console. CAM inputs are used to initiate command uplink requests in mode 1 and FC mode; change command modes; and make command related function inputs. The 1232 I/O console is used to change the MAP waiting time, check core contents, change ALSEP vehicle/decoder addresses, input initialization constraints, designate the prime CAM, and input offline command history parameters.

Before uplink processing of an RTC can be initiated either by CER or CAM entry that RTC must be in the enable condition and no other processing other than a carrier status check may be in progress.



Remote Site Configuration for ALSEP

Figure 3

All RTC's are stored in permanent storage of the RSDP. There are two types of RTC's: normal and critical. Critical RTC's are those which would endanger the astronauts or the proper operation of the ALSEP. Those RTC's which are not deemed critical are called normal RTC's. In general, only normal RTC's are enabled in the RSDP for uplink. Critical RTC's are enabled by CAM entry in mode 1 and M&O mode in groups as they are needed. There are four groups which are defined in Section 3.2 of the ALSEP Command Data Format Control Book. When an RTC is enabled, the structure for that RTC is duplicated from permanent storage into the uplink storage area. RTC's can be cleared from the uplink storage area by RTC CLEAR CAM entry in mode 1 and M&O mode. When an RTC CLEAR is entered, the true data bits of the appropriate normal RTC or critical RTC group are replaced with a dummy data bit pattern in uplink storage. A backup CAM capability exists to insure control of critical RTC's.

When an RTC uplink request is honored either for a CER or CAM entry the data bits for that command are removed from uplink storage and are checked for correctness. Each RTC contains an ALSEP vehicle/decoder address, seven true data bits, the complement of the data bits, and filler "1" bits to make up the 75-bit RTC. The data bits are then formatted twice into the 75-bit command word. (ALSEP commands are not subbit encoded.) These two words are then compared. If both of the above checks pass, the 75 bits are output through the 1299 Switchboard to the Up Data Buffer (UDB) 25 bits at a time. The actual transfer consists of 30 bits. The first five bits are control bits. The UDB samples the 25 bits and enters them into the A REG in parallel for storage and transmission. The five control bits cause the UDB to select the USB

carrier and the USB verification receiver. The data bits are output serially from the A REG to the 1 and 2 KHz Phase Shift Key (PSK) Subsystem which then phase modulates (PM) the baseband carrier (2119 MHz). ALSEP command modulation system differs from Apollo in that the 70 KHz subcarrier is bypassed and the command information is modulated directly on the carrier. (See Figure 3).

Each RTC is transmitted only once. The radiated signal is sampled and routed to the USB Verification Receiver. The signal is demodulated, and the resulting data bits are compared by the RSDP with the original bits. If this RF loop fails, or if the formatting of RTC retrieval test fails, a ground reject is printed out onsite. If the RSDP is in mode 2 a Ground Reject Command Analysis Pattern (CAP) will be transmitted to the MCC. However, if the Message Acceptance Pulse (MAP) is received before the termination of the MAP waiting period and the first two checks were valid, then an RF loop error will not cause a ground reject.

Command executes from MCC to the RS are responded to by CAP's. The CAP is 40 bits in length and consists of 26 data bits and 14 polynomial error protection bits. Each CAP is transmitted from the RS three times in successive telemetry frames. No CAP word is transmitted to MCC when a command is initiated by onsite CAM.

A MAP is a unique bit structure downlinked by the ALSEP indicating that the command was received and decoded properly. The MAP waiting period is variable and depends on the location of the ALSEP and systems delays. Each CER or CAM uplink request contains a MAP or MAP Override indication.

In the MAP case the RSDP must try to receive a MAP from the ALSEP. In the MAP OVRD case no MAP is required. MAP's are transmitted once per received RTC by an ALSEP vehicle.

If the RSDP is in the MAP configuration and a MAP is received during the MAP waiting time and these data bits correspond with the true data bits that were uplinked, a spacecraft verification is printed out onsite. If the RSDP is in mode 2, a spacecraft verification CAP will be transmitted to MCC. If no MAP is received during the MAP waiting time and there is no ground reject, then a spacecraft reject is printed out onsite and if the RSDP is in mode 2, a spacecraft reject CAP is transmitted to MCC.

If the RSDP is in the MAP OVRD configuration then as soon as the last bit has been uplinked a verification is printed out onsite and if the RSDP is in mode 2, a verification CAP is sent to MCC.

Each time a RTC is uplinked command history data is recorded on magnetic tape. This data includes ALSEP ID; octal of stored and radiated RTC; octal of MAP; English of the RTC; MAP, NO MAP, or MAP OVRD; GMT of RTC uplink request; initiating source; and vehicle/decoder indication.

Command histories are available as a high speed printer (HSP) onsite printout and/or TTY punched tape. The type of history and output is specified via the 1232 I/O console. Command histories as well as RTC Inventory Summaries may be transmitted to the MCC via TTY.

The RSDP status can be obtained via either a HSD CEF or CAM entry. This causes a test pattern to be transmitted and verified via comparison on the RF loop return. A RSDP Status CAP will be generated and output to

MCC. The Status CAP contains the status of the RSDP [such as FC or Maintenance and Operations (M&O) modes, mode 1 or mode 2], the status of the Unified S-Band (USB) transmitters, and indicates what critical command groups are enabled.

2.2.4 ALSEP Flight Article Command Processing

Uplink command data transmitted from the MSFN is received at the appropriate ALSEP (based on vehicle/decoder address) by the data subsystem antenna, routed through the diplexer, demodulated by the command receiver, decoded by the command decoder, and applied to the experiment and support subsystems as discrete commands. The discrete commands control experiment and support subsystems operations and initiate command verification functions.

The command receiver demodulates the 2119 MHz carrier and provides the composite 2 KHz and 1 KHz subcarrier to the command decoder. The command decoder demodulator section detects the 2 KHz command data subcarrier and the 1 KHz timing signal and applies both to the redundant digital decoder sections (A + B) of the command decoder. The digital decoder sections identify correct address codes, decode the digital data commands, issue command verification signals to the data processor, and apply command signals to the appropriate experiment and support subsystems.

The central station timer provides timing signals to the command decoder delayed command sequencer which are used to initiate a series of delayed commands to activate certain system operations.

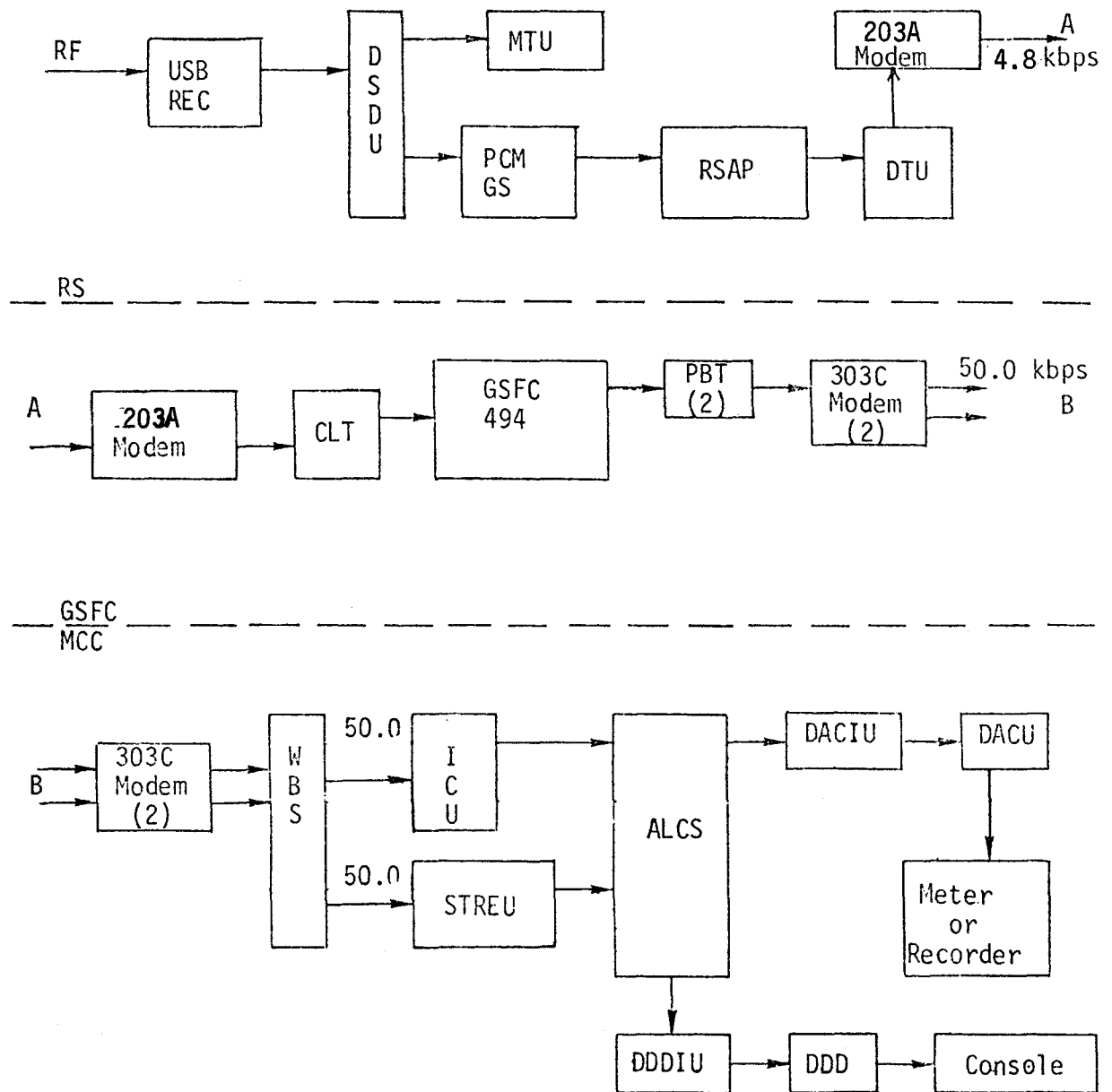
2.3 ALSEP Telemetry Data Flow

This section will cover the ALSEP telemetry flow to include the flight article downlink, the RS reception and formatting by the RSDP, the GSFC handling, and finally MCC processing and display. The telemetry data stream starts at the central station of the ALSEP.

2.3.1 ALSEP Telemetry Downlink

The data processor in the central station of the ALSEP collects and formats both analog and digital data, provides split-phase modulated data used for phase modulation of the downlink RF carrier, and generates timing and control signals. There are two redundant processing channels which process both analog and digital data. The processor is made up of two components: (a) digital data processor, and (b) analog multiplexer/converter. The data processor operates in three modes: (a) normal mode - 1060 bps; (b) slow or contingency mode - 530 bps; and (c) active seismic mode - 10.6 Kbps. The slow mode provides backup operation at one-half the normal data rate. The active seismic mode is provided exclusively for the Active Seismic Experiment and has a separate format. When in this mode, no data from any of the other experiments is downlinked.

The data subsystem transmitter generates an S-Band carrier frequency between 2275 and 2280 MHz which is phase modulated by the split-phase serial bit stream from the data processor. Two identical transmitters are used in each data subsystem to provide redundancy. The transmitter has a power output of 1 watt minimum and a carrier deviation of ± 1.25 radians $\pm 5\%$. The



ALSEP Telemetry Data Flow
Figure 4

particular downlink frequency used by each ALSEP is listed below.

<u>Flight Article</u>	<u>Apollo Mission</u>	<u>Frequency</u>
ALSEP 1 (A)	12 (AS-507)	2278.5 MHz
ALSEP 4 (C)	14 (AS-509)	2279.5 MHz
ALSEP 2 (A-2)	15 (AS-510)	2278.0 MHz
ALSEP 3 (D)	16 (AS-511)	2276.0 MHz
ALSEP ? (E)	17 (AS-512)	2275.5 MHz

2.3.2 Remote Site ALSEP Telemetry Processing

Each 30 foot dual remote site is capable of receiving and recording a telemetry data stream at normal or contingency bit rates from four ALSEP's simultaneously. However, the Remote Site Data Processor (RSDP) can only process two of these data streams at the same time. Telemetry data from a maximum of two ALSEP's can be placed in one HSD format. Combinations of real time and tape playback from separate vehicles can be processed by the RSDP. Real time and tape playback data from the same vehicle cannot be output in the same format. If data from only one ALSEP is available, a fill pattern will be placed in the slots for the missing vehicle. Current GMT is used to time tag live data while the recorded GMT is used for playback data.

DOWNLINK CHARACTERISTICS

<u>Normal Bit Rate</u>	<u>Contingency Bit Rate</u>	<u>ASE Bit Rate</u>	<u>LSP Bit Rate</u>
1060 bits/sec	530 bits/sec	10.6 Kbps	3.533 Kbps
10 bits/word	10 bits/word	20 bits/word	30 bits/word
64 words/frame	64 words/frame	4 subwords/word	4 subwords/word
640 bits/frame	640 bits/frame	5 bits/subword	7 bits/subword
603.77 ms/frame	1.21 sec/frame	32 words/frame	60 words/frame
		640 bits/frame	1800 bits/frame
		.060377 sec/frame	.5095 sec/frame

Most Significant Bit is transmitted first.

$$\text{Normal bit rate} = 10 \text{ bits/word} \times 64 \text{ words/frame} \times \frac{1 \text{ frame}}{.60377 \text{ sec}} = 1060 \text{ bits/sec}$$

$$\text{Contingency bit rate} = 10 \text{ bits/word} \times 64 \text{ words/frame} \times \frac{1 \text{ frame}}{1.21 \text{ sec}} = 530 \text{ bits/sec}$$

$$\text{ASE bit rate} = 20 \text{ bits/word} \times 32 \text{ words/frame} \times \frac{1 \text{ frame}}{.060377 \text{ sec}} = 10600 \text{ bits/sec}$$

$$\text{LSP bit rate} = 30 \text{ bits/word} \times 60 \text{ words/frame} \times \frac{1 \text{ frame}}{.5095 \text{ sec}} = 3.533 \text{ bits/sec}$$

Table 3

The ALSEP telemetry is received by the USB antenna and routed to one of the USB receivers where it is demodulated. The data output of the receiver is then amplified and supplied to a magnetic tape recorder and a PCM Ground Station. The ground station acquires sync on the PCM bit stream

and forms a 30-bit parallel data link with the RSDP. Each 30-bit word consists of a 10-bit downlink word plus other bits which indicate the status or type of the data word.

During Phase III monitoring (receive and record only), certain parameters are stripped out of the data stream at the ground station for on-site display. These measurements are displayed on chart recorders to monitor predefined limits. In addition, Command Verification Word (CVW) monitoring is performed to detect any spurious commands that might have entered the ALSEP vehicle.

The RSDP receives the parallel data transfer and builds up a five frame buffer for each vehicle. When these buffers are full the RSDP begins to fill another set of five-frame buffers, and the data bits in the first set of buffers are transferred to an output buffer which consists of three HSD frames.

Each HSD frame consists of 240 10-bit words. One HSD frame is output per second. To do this the RSDP outputs each format in parallel 10-bit words to the Data Transmission Unit (DTU) which serializes the data and transmits the data through a 203A data modem to GSFC via one 4.8 Kbps line.

The HSD output format for either normal or contingency bit rate data is made up of three HSD frames. The HSD format for ASE bit rate consists of one HSD frame. The RSDP at normal bit rate periodically transfers a fill frame to the output buffer to compensate for the time difference between input and output rates. In contingency bit rate, every other frame transferred to the output buffer contains fill data. When ASE data

is being processed the RSDP reduces the downlinked sample rates to either 106, 17, or 2 samples per second and outputs this reduced data in a fixed format to the MCC (refer to the ALSEP TMDFCB for format definition). Command Analysis Patterns (CAP's) are output in every HSD frame.

2.3.3 GSFC ALSEP Telemetry Processing

The GSFC switching center receives ALSEP highspeed telemetry data from the RS on a single voice data circuit at 4800 bps. The first 48 bits of each data frame in the format will be the standard NASCOM routing header; it is used by the 494 processor to perform the reformatting necessary for transmission to the MCC on the wideband data circuit. All telemetry data processing performed at the GSFC switching center in support of ALSEP is identical to the processing that is performed for Apollo except for recognizing different source/destination codes and different data format codes.

Destination codes are used to route telemetry data to MCC only, GSFC only, or both.

2.3.4 MCC ALSEP Telemetry Processing

Wide-Band Data lines (50 Kbps) and teletype lines are used for data communication between the GSFC switching center and the MCC. The Wide-Band Data (WBD) link is utilized for transmission of ALSEP telemetry. (Teletype lines are used for transmission of RTC inventories and command histories.) This data will enter MCC subsystems, CCATS and/or ALSEP subsystems, via the Facilities and Control System (FACS) area.

A 303C Modem provides the interface with each of the WBD lines and routes the data to the WBD switch matrix. This switch matrix provides the necessary switching and drive capability to route the data to the CCATS and/or the ALSEP Interface Control Unit (ICU) and the Serial Transmit, Receive and Encode Unit (STREU).

When CCATS is operational and supporting an Apollo mission, it receives all data from GSFC and distinguishes between mission data and ALSEP data using the destination or format code contained in the standard NASCOM 600-bit block header. CCATS disregards ALSEP data and only processes Apollo mission telemetry inputs. In addition, it acknowledges ALSEP telemetry inputs from GSFC.

Similarly, the ICU and the STREU during an Apollo mission each receive all the data coming in on one 50 Kbps line. They distinguish between ALSEP and mission data, disregard mission data, and throughput only ALSEP data to the ALCS.

During non-mission periods, when the ALCS is in the stand alone configuration, either the ICU or the STREU will receive the data from the one WBD line in use.

Besides providing data recognition capability, the ICU checks for good polynomial error protection code and forwards only good ALSEP data to the ALCS in 32-bit parallel words via the 2701 PDA. (It can also operate in a mode in which it passes good and bad data and indicates the quality by setting a bit.) The 2701 PDA converts the 32-bit words to 8-bit bytes for use by the ALSEP computer. The ICU also adds an 8-bit field, that is

used for status information, to each 600-bit message making a total of 608 bits transmitted to the ALCS.

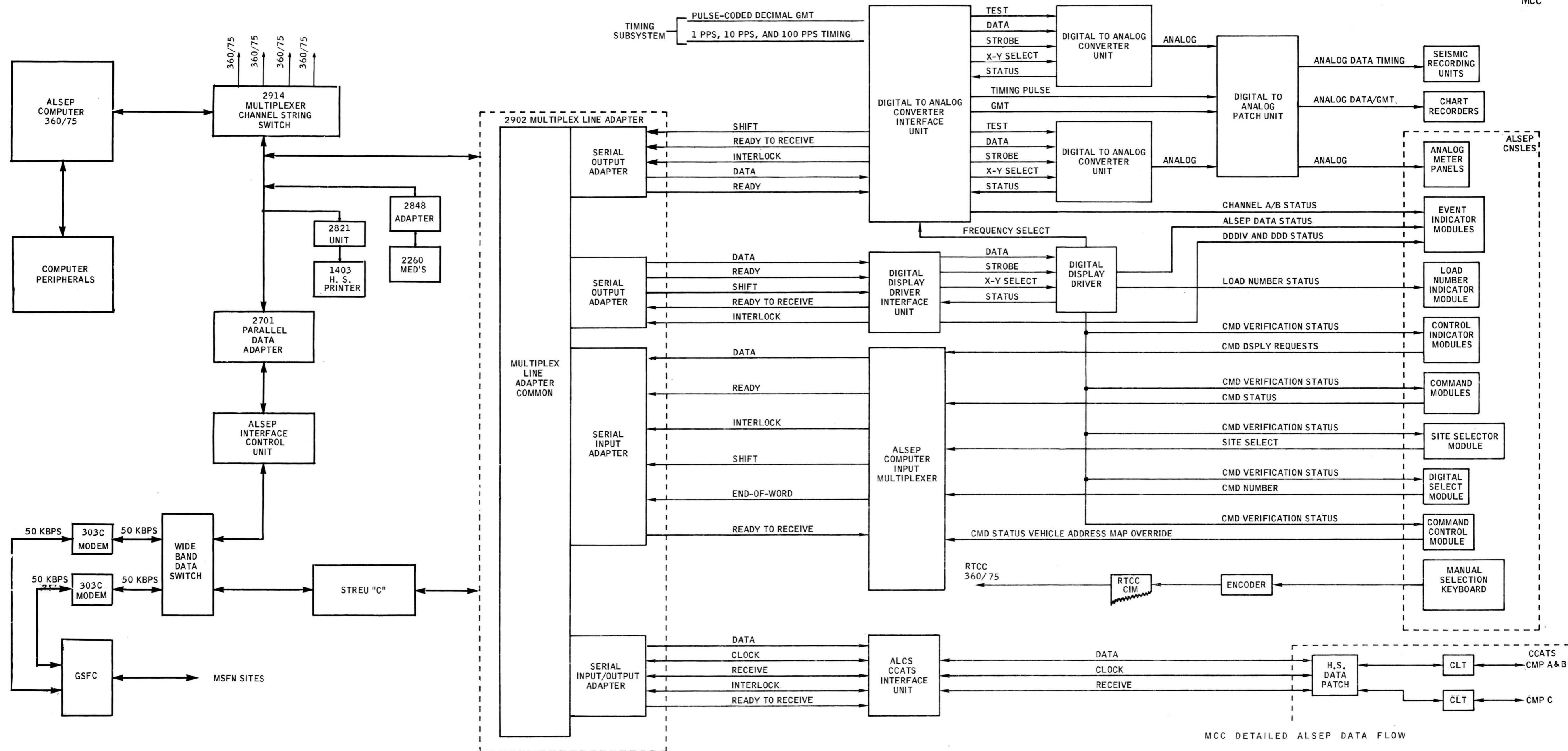
The STREU, in addition to providing data recognition, checks for good polynomial error protection code and forwards both good and bad ALSEP data to the ALSEP computer via the 2902 MLA. The STREU strips the 33 bits of error protection code from the 600-bit block and adds 8 fill bits plus one more bit to indicate good or bad data.

ALSEP Computer Telemetry Processing

The ALSEP computer processes only data segments containing the ALSEP destination code. Processing is performed for a maximum of two separate ALSEP's simultaneously (except when ASE data is received). In the event that data is received from two sites for the same ALSEP, the computer processes the data from just one site. It decommutates the ALSEP frame data after the required header information processing. The telemetry data will be sorted and buffered as a function of the specified display requirements. The ALSEP computer decodes a flag indicator within each segment trailer to determine if the segment data is valid or invalid (as decided by the ICU and STREU polynomial decode function). The computer also performs CAP processing.

When operating in the stand alone configuration, the ALCS does not provide message acknowledgments for messages received directly from GSFC. However, acknowledging is done by CCATS when it is active.

The ALCS does all of the real time ALSEP telemetry data processing with the exception of some data reduction that the remote site must do on



MCC DETAILED ALSEP DATA FLOW

FIGURE 5

the Active Seismic Experiment (ASE) data. The ALCS performs data processing necessary to display the data to the appropriate personnel. Analog parameters are routed to the Digital-to-Analog Converter Interface Unit (DACIU) which in turn selects the proper Digital-to-Analog Converter Units (DACU). The DACU converts the digital input to an analog signal and outputs it to the proper analog strip chart recorder, seismic recorder, or meter. These DACU's interface with the end devices through the Analog Patch Rack. The ALCS also processes events. These events are routed to the Digital Display Driver Interface Unit (DDDIU) which selects the proper Digital Display Driver (DDD). The DDD drives the display device to the proper indication.

ALSEP Analog Display

The DACIU provides the interfacing, address decoding, and data distribution required between the ALCS and the Digital-to-Analog Converter Units (DACU). The ALCS outputs 32-bit words to the DACIU at 13.568 Kbps on a single IBM 2902 Serial Output Adapter. The DACIU can recognize and process data for a ten or eight bit DAC. The first 12 bits of the 32-bit transfer word are the DAC address. The first six of the 12 are X address and the second six are Y address. The next ten bits are a sync word. If the word is for a 10-bit DAC, the next ten bits are DAC data; otherwise, the next two bits are fill and the last eight are DAC data. The DACIU uses the 12 X and Y select bits to select the appropriate DAC over 32X and 32Y select lines. The ten information bits are output over ten parallel data lines to the selected DAC.

The DAC's provide the means to drive analog meter, analog strip chart recorders and seismic recorder displays. The DAC input is the output of the DACIU. Transfer words to the 8-bit DAC's are on lines three through ten of the ten line parallel interface. The DAC converts the input bits to a zero to ten volt level which is accurate to one part in 256 for 8-bit DAC's and one part in 1024 for 10-bit DAC's.

The Analog Patch Rack provides a central point for routing analog data within the MCC. The Analog Patch Rack has as inputs all of the available DAC outputs. All analog devices, meters, and records are wired as outputs from the patchboard.

The Drum Recorders are used to record the analog parameters which correspond to seismic experiments. There are eight Drum Recorders which are used to support two ALSEP's. The recorders receive their inputs from the 10-bit DAC's via a variable low pass filter. The speed of the recorder is fixed, but can be changed by replacing the speed control gears.

The five analog strip chart recorders are used to simultaneously record both analog parameters and time signals. Each recorder can record up to eight analog parameters and two events. The speed is variable from 0.025 mm/sec to 100.0 mm/sec.

The analog meter panels provide the capability for monitoring pre-selected analog parameters. Each meter has a zero to ten volts range. There are two panels with 4 meters each.

2.3.5 ALSEP Digital Display

The DDDIU provides the interfacing and data distribution facilities required between the ALCS and the computer driven DDD's of the ALSEP Display Control System. The ALCS formats transfer data into blocks of 36-bit words as they are needed. The first 12 bits are a DDD set address and the remaining 24 bits represent lamp illumination information to the DDD set. Thus each 36-bit word is completely addressed to allow selective updating of any digital display indicator set. These words are transferred at 40.8 Kbps from the 2902 serial data subchannel to the DDDIU.

The DDD's provide the means to drive Digital Readout Displays, Event Indicators, and ON/OFF Indicators. The input to the DDD's is the output of the DDDIU. There are 160 available addresses, in four racks, 24 bits per address, representing 3,840 individual lamp drivers.

The Cable Termination Cabinet (CTC) provides the means to route the DDD outputs to the selected display devices in the ALSEP console subsystem. In addition, it provides the patch capability to output selected ALSEP events to display devices located on MCC MOCR consoles.

ALSEP Video Distribution

The ALSEP video distribution equipment provides the facilities for routing video information in the four ALSEP D/TV converters and the ALSEP opaque television to various users throughout the MCC. In addition, it distributes video from the existing MCC video sources to the overhead utility monitors and ALSEP consoles.

ALSEP Timing Equipment

The ALSEP Timing Equipment generates the Serial Decimal Time (SDT) that is required by the analog strip chart recorders. The ALSEP Timing Equipment receives remote site GMT from the ALCS via the DACIU. The ALCS transfers the remote site GMT in three consecutive 32-bit words through an IBM 2902 to the DACIU at 13.568 Kbps. The DACIU addresses each word before sending them to the ALSEP Timing Equipment. The timing equipment uses the minute hacks from the remote site GMT and internal counters to generate SDT. If no remote site GMT is received the timing equipment will accept and throughput Master Instrumentation Timing Equipment (MITE) generated SDT. In either case one complete time word is output over a ten second interval to the analog chart recorders.

ALSEP Experiments Printer

The ALSEP Experiments Printer is used for hardcopy recording and printout of preselected computer data. It is the same as an IBM 1403-N1 Printer.

ALSEP Console Equipment

The ALSEP Computer Controller Console (84) in room 112 provides voice communication, site selection, console status reporting, and control of the ALCS program. The front panel contains two voice comm panels, a console-mounted speaker, a status report module, a command module, a site selector module, 5 switch modules, a load number indicator module, and 9 event indicator

modules (one of the event indicator modules is used to monitor P&FS tracking data.) This console also serves as the ALSEP Network Controller Console.

The ALSEP Interface Controller Console (85) in room 242 provides voice communications, analog displays, digital displays, selection and status of critical components, and selection of video source for overhead video monitors. The front panel contains a voice comm panel, three event indicator modules, two analog meter panels, a switch module, and a speaker assembly.

The ALSEP Lunar Surface Program Office (LSP0) Console (87) in room 314A provides voice communications, monitoring of ALSEP data on display devices, and console status reporting. The front panel of the console contains two video (Apollo data only) monitors, two comm panels, a console-mounted speaker, two event indicator modules, and a status report module.

The ALSEP/P&FS Console (88) in room 314B provides the flight controller with voice communications, selection of chart recorders analog parameters, monitoring of ALSEP digital data, selection of printer format, and formatting of ALSEP/P&FS commands. The front panel of the console contains 4 video (Apollo data only) monitors, 3 voice comm panels, 7 event indicator modules, a speaker assembly, 2 MSK's, 6 switch modules, a digital select module, a command control module, and a stop clock.

The ALSEP Principal Investigators Console (89) in room 314A provides voice communication, video monitoring of ALSEP data, and console status reporting. The front panel contains two vertical-mounted keysets, two video monitors, a console-mounted speaker, and a status report module.

2.4 ALSEP vs. APOLLO

Listed below are the main differences between ALSEP and Apollo operations.

- a. The ALSEP command and telemetry programs are contained in one 642B computer at the RS while Apollo uses one computer for each.
- b. ALSEP does not have on-line command history capability.
- c. A single high speed data line is used from the RS.
- d. Telemetry data words for ALSEP are ten bits instead of eight.
- e. ALSEP commands are not subbit encoded.
- f. ALSEP does not use command loads.
- g. There is no automatic retransmission via UDB of ALSEP commands.
- h. ALSEP has no need for an intercomputer channel since only one 642B is used.
- i. ALSEP has a category of RTCs designated "critical."
- j. ALSEP uses baseband modulation for both uplink and downlink, whereas Apollo uses subcarriers.
- k. ALSEP uses a noncoherent uplink/downlink signal combination.

PART II - P&FS
SYSTEM DESCRIPTION

3.1 Introduction

The Particles and Fields Subsatellite (P&FS) to be carried in the Scientific Instrumentation Module (SIM) on Apollo 15 and 16 is a small lunar satellite containing three experiments. It is placed in lunar orbit by being ejected from the SIM bay while the CSM is in a TBD circular orbit. It will send back information on the lunar gravitational field, the Earth's magnetosphere, and magnetic fields in the vicinity of the moon. The expected lifetime of the P&FS is one year and will require periodic MCC support in accordance with the following plan:

- a. Deployment plus 33 - 37 days
 - continuous 24 hour support
 - tracking every 3rd revolution; 2nd site tracking every 3rd day for 5 hours.
- b. 33 - 37 days plus 3 months
 - one site for 5 hours each day
 - second site tracking every 3rd day
- c. Remainder of vehicle lifetime
 - every 3rd day 2 sites for 5 hours

ALSEP and P&FS support will be combined and accomplished from the same MSFN site whenever possible. P&FS data will be received and recorded at some element of the MSFN for every lunar orbit during the life of the satellite.

3.2 Subsatellite Description

The P&FS is 31 inches long, has a hexagonal cross-section with 12-inch sides and weighs 80 lbs. It consists of charged particle detectors, a magnetometer, a data storage unit, a solar cell battery power system, and an S-band communication subsystem. The subsatellite has three booms each of which automatically deploys at launch to 5 feet. The magnetometer is mounted at the end of one boom, whereas the other two booms are provided to achieve the desired balanced spin stabilization characteristics. Command Module crew controls are provided to launch the subsatellite as well as to retract the deployment mechanism into the SIM bay. The P&FS will be electrically inert until launch has been initiated. At launch the battery will be automatically connected to the subsatellite load to permit the transmitter to be turned on by MCC command.

3.3 Experiments

The three experiments associated with the subsatellite are the S-band Transponder Experiment (S-164), the Particle Shadows/Boundary Layer Experiment (S-173), and the Magnetometer Experiment (S-174).

3.3.1 S-Band Transponder Experiment

The purpose of the S-Band Transponder Experiment is to obtain long-term doppler tracking data in lunar orbit in order to describe the lunar gravitational field. It requires no hardware or supporting equipment other than the transponder that is part of the subsatellite S-band communications

subsystem.

Low altitude tracking data will be used in conjunction with high altitude data to provide a description of the size and shape of the Mass Concentrations (MASCONS) previously discovered by the Lunar Orbiter flights. Correlation of gravity data with photographs and other scientific records will give a more complete picture of the lunar environment and support future lunar activities.

3.3.2 Particle Shadows/Boundary Layer Experiment

The purpose of the Particle Shadows/Boundary Layer Experiment is to obtain data on wave particle interactions occurring within the solar wind boundary layer as the solar wind flows over the moon. This data will yield information relative to plasma flow and electric fields associated with the solar wind and the earth's magnetotail. It is hoped that from this experiment scientists can find or rule out the existence of a magnetic field component normal to the magnetopause. Such a component bears directly on the question of openness of the magnetosphere. Also, it may be possible to identify which field lines surrounding the neutral sheet in the magnetotail connect on both ends to the earth and which go far beyond the earth, perhaps entering interplanetary space.

On the basis of present evidence, the interaction of the solar wind with the Moon occurs very close to the lunar surface. The boundary layer for this interaction extends from the lunar surface outward to some distance which is as yet unknown, but which is estimated to be on the order of 100 km.

The characteristics of the boundary layer are determined by the properties of the plasma as well as those of the moon. Thus, the study of the interaction region will yield information on the external plasma, the interior of the moon, the surface and the lunar ionosphere.

3.3.3 Magnetometer Experiment

The purpose of the Subsatellite Magnetometer Experiment is to obtain data on the lunar magnetic field and the earth's magnetosphere. Measurements of magnetic fields in the transient and steady state boundary layers should provide indirect information on the lunar ionosphere and transient lunar atmosphere. In the cavity directly behind the moon, the properties of the plasma and magnetic field are very different from those of the solar wind flowing in the adjacent regions. At the boundary between this downstream cavity and the solar wind there are strong gradients in the density and velocity of the plasma. The lunar orbit of the P&FS will traverse this layer in two places. Thus, one of the main purposes of this experiment is to obtain data on the microscopic behavior in this region.

3.4 Electrical Power

The electric power subsystem is designed to provide the capability of continuous operation of the satellite in lunar orbit with maximum eclipse times. It is made up of a primary/secondary system with an array of solar cells as primary source of power and a rechargeable silver-cadmium battery as the secondary source which sustains operation during the eclipse portion

of the orbit.

The size of the solar array is the basic limitation on the electrical power system capability. The spacecraft size is limited by the available envelope within the SIM. Should power in excess of the capability of the solar array be required, then it would be necessary to periodically curtail operations so that the battery could be recharged.

3.5 Data Subsystem

The Data Subsystem is made up of data processing and storage equipment (DPSE) and the command decoder. The DPSE consists of an analog multiplexer, an A/D converter, a digital multiplexer and formatter, an encoder and modulator, a floating point accumulator, a memory, and a clock. The primary functions of the DPSE are:

- a. Multiplex scientific and engineering data into a single data stream for application to the memory or directly to the transmitter.
- b. Perform analog-to-digital conversion for the analog inputs.
- d. Generate all timing signals for the spacecraft and scientific experiments from a crystal controlled clock.

The command decoder is designed to operate with a signal structure derived from the Apollo command format. The decoder is divided into three functional blocks: The FM discriminator, subbit detector, and digital processor.

DATA FLOW

4.1 Introduction

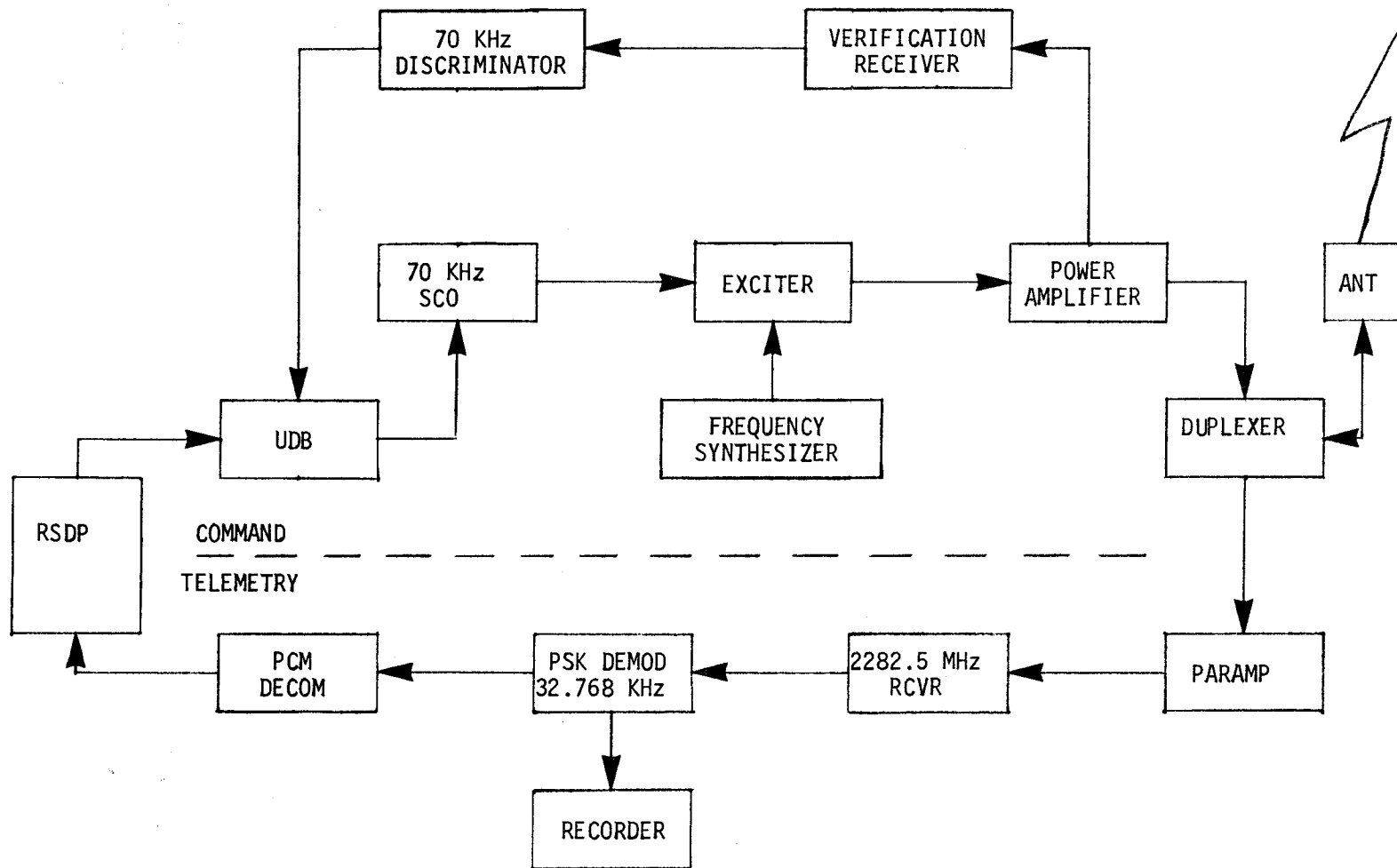
The Particles and Fields Subsatellite data flow will be supported for the most part with the same facilities and in much the same manner as ALSEP data. One major exception to this is the need to collect tracking data on the P&FS. Periodically high speed tracking data from two or more sites will be collected and logged on the ALSEP computer.

At the remote site a combined computer program in the 642-B will be used to support both ALSEP and P&FS command and telemetry processing. One 4.8 Kbs line from each site can handle both ALSEP (2.4 Kbps) and P&FS (2.4 Kbps) telemetry formats. The difference between ALSEP and P&FS in commanding lies in the fact that the Up Data Buffer must route the command modulation to a 70 KHz subcarrier for the P&FS whereas this subcarrier is bypassed for ALSEP.

In this section P&FS command, telemetry, and tracking data flow will be explained. Much of the information presented in the section on ALSEP data flow applies to the P&FS, and, therefore, only the differences will be dwelled on here.

4.2 P&FS Command Data Flow

Commands to the Subsatellite will be sent from the same consoles at MCC as those used to send commands to the ALSEP vehicles. The data path through MCC and GSFC is the same as that used by ALSEP command data. At the remote site the command data is received at the 203A data modem at a 4.8 Kbps rate and is routed to the data transmission unit which reformats the data and inputs it to the RSDP.



P&FS REMOTE SITE CONFIGURATION

FIGURE 6

The RSDP assigned to support ALSEP and P&FS has a combined program that handles command and telemetry processing for both vehicles. The command data for the P&FS is formatted just like Apollo command data. The uplink format contains 12 bits--three bits for vehicle address, three bits for system address, and six true data bits. Also like Apollo the P&FS uplink format requires subbit encoding prior to actual uplink. (ALSEP command data is not subbit encoded.)

After the RSDP has subbit encoded the 12 bit command (5 subbits per data bit) the data is transferred to the Up Data Buffer (UDB) 25 subbits at a time. On each transfer to the UDB logic five control bits are inserted, thus making the RSDP output a 30-bit word. The UDB takes the 25 data subbits and enters them in parallel for storage and subsequent transmission. The output of the UDB is transmitted serially through the 1 and 2 KHz PSK subsystem which then frequency modulates a 70 KHz subcarrier which in turn phase modulates the 2101.8 MHz carrier.

The subsatellite S-band receiver outputs the 70 KHz subcarrier to the command decoder equipment which consists of a FM discriminator, a subbit detector, and a digital processor. The FM discriminator, recovers the composite audio command signal. The subbit detector demodulates the PSK data by means of a correlation detector and provides subbit synchronization derived from a phase-lock-loop which tracks the 1000 Hz synchronization subcarrier. The digital processor verifies the command message and routes the command. Included in the operation of the digital processor is the decoding of the message bits from the subbit code. The decoded information consists

of RTC's for control of various subsatellite functions.

4.3 P&FS Telemetry Data Flow

The P&FS downlink consists of the 2282.5 MHz carrier with a 32.768 KHz telemetry subcarrier phase modulated on it. Whenever an uplink carrier is present the downlink carrier is phase-coherent at 240/221 times the uplink frequency. When the uplink is not present, the 2282.5 MHz is generated internally. A coherent uplink/downlink carrier only mode is available upon command for doppler tracking which shall operate only when an uplink signal is present.

The 32.768 KHz telemetry subcarrier is bi-phase modulated by the 128 bps bit stream which is encoded in a serial, IRIG NRZ-M PCM data format. Telemetry data is transmitted either real-time or via data storage readout. There are two storage rates available--8 bps and 16 bps--but only one read-out rate--128 bps.

The subsatellite can be commanded to operate in any of the following modes:

- a. Real-time mode: Status and experiment data are sampled and transmitted in real-time at 128 bps.
- b. Data storage normal: Experiment data sampled and stored at 8 bps; the memory is filled in 6144 seconds.
- c. Data storage fast: Experiment data is sampled and stored at 16 bps; the memory is filled in 3072 seconds.

d. Memory readout: Stored data is read out and multiplexed with status data and transmitted at 128 bps.

e. Automatic cycle mode: Subsatellite automatically cycles through the real time mode (448 seconds). The memory readout mode (512 sec.), and the data storage normal mode (6144) seconds). This takes a total time of 7104 seconds or approximately the time of one lunar orbit. Upon completion the cycle automatically repeats.

The P&FS telemetry data downlink characteristics are:

128 bits/second

8 bits/word

32 words/frame

1 frame/2 sec.

8 frames/data cycle

16 words/sec.

Telemetry data is transmitted in 8 bit words. When the data gets into the RSDP it is repacked into 10 bit words. The output format is similar to the ALSEP high speed data frame, i.e., 2400 bits/sec., 10 bits/word, and 240 words/frame.

The RSDP can process one P&FS bit stream along with two ALSEP data streams in any combination of normal and contingency bit rates, or one ALSEP high bit rate stream. It will output P&FS and ALSEP data simultaneously on one 4.8 Kbps line (two 2.4 Kbps formats).

At MCC the ALSEP Computer System (ALCS) is utilized to process P&FS telemetry. The P&FS telemetry data undergoes the same type of processing

in the ALCS as the ALSEP data. The ALCS is capable of handling two ALSEP data streams at normal or contingency bit rates and one P&FS data stream or one high bit rate ALSEP data stream by itself.

4.4 P&FS Tracking Data Flow

The subsatellite will be tracked periodically throughout its lifetime in order to determine the Moon's effect on its orbit. Immediately after activation during the mission low speed doppler tracking data will be processed by the Mission Operations Computer (MOC) to determine its initial orbit. Normally, however, high speed doppler tracking data will be transmitted from the remote sites and will be logged in the ALSEP Computer System (ALCS). All tracking data will be doppler only with no ranging.

Except for right after activation there will be no R/T processing of P&FS tracking data. The high speed data from two sites can be monitored (by interrogating certain data bits) at the ALSEP Computer Controller/Network Controller Console (84). Although several sites can input to the ALCS log tape, only the data from two sites can be monitored.

Processing of the tracking data will occur in non-real time by using an off line program to delog the tape. The data will then be used to generate a vector. The RTCC will then use this vector to formulate ephemeris data.

ACRONYMS AND ABBREVIATIONS

ACIU	ALSEP CCATS Interface Unit
ADCS	ALSEP Display Control Subsystem
AICU	ALSEP Interface Control Unit
AIS	ALSEP Interface Subsystem
ALCIM	ALSEP Computer Input Multiplexer
ALCS	ALSEP Computer Subsystem
ALSEP	Apollo Lunar Surface Experiment Package
APP	Antenna Position Programmer
ASE	Active Seismic Experiment
CACC	Communications and Configuration Console
CAM	Computer Address Matrix
CAP	Command Analysis Pattern
CCATS	Communications, Command, and Telemetry Subsystem
CCC	Computer Control Console
CCGE	Cold Cathode Gauge Experiment
CEF	Computer Execute Function
CIM	Computer Input Multiplexer
CLT	Communications Line Terminal
CMD	Command
CP	Communication Processor
CPLLE	Charged Particle Lunar Environment Experiment
CPU	Central Processing Unit
CRT	Cathode Ray Tube
CTC	Cable Termination Cabinet
DAC	Digital-to-Analog Converter
DACIU	Digital-to-Analog Converter Interface Unit
DACU	Digital-to-Analog Converter Units
DASF	Direct Access Storage Facility
DDD	Digital Display Driver
DDDIU	Digital Display Driver Interface Unit
DPSE	Data Processing and Storage Equipment
DSC	Dynamic Standby Computer
DSDU	Decommuration System Distribution Unit
DSM	Digital Select Matrix
DTREM	Dust, Thermal, and Radiation Engineering Measurements (Package)
DTU	Data Transmission Unit
EAO	Experiment Activity Office
EASEP	Early Apollo Scientific Experiment Payload
EOM	End of Message
FACS	Facility Control Subsystem
FC	Flight Controller
GS	Ground Station
GSFC	Goddard Space Flight Center

Acronyms and Abbreviations (continued)

HFE	Heat Flow Experiment
HSD	High Speed Data
ICU	Interface Control Unit
I/O	Input/Output
LM	Lunar Module
LOC	Length of Count
LRRR	Laser Ranging Retro-Reflector
LSM	Lunar Surface Magnetometer Experiment
LSP	Lunar Seismic Profiling Experiment
LSP0	Lunar Surface Project Office
MAP	Message Acceptance Pulse
MCC	Mission Control Center
MITE	Master Instrumentation Timing Equipment
MLA	Multiplex Line Adapter
MOC	Mission Operations Computer
MOCR	Mission Operations Control Room
MSC	Manned Spacecraft Center
MSFN	Manned Space Flight Network
MSK	Manual Selection Keyboard
MTU	Magnetic Tape Unit
NASCOM	NASA Communications
PBI	Push Button Indicator
PBT	Polynomial Buffer Terminal
PCM	Pulse Code Modulation
PCMGS	PCM Ground Station
PDA	Parallel Data Adapter
PFSK	Printer Format Select Keyboard
PM	Phase Modulation
PSE	Passive Seismic Experiment
PSK	Phase Shift Key
RF	Radio Frequency
RS	Remote Site
RSDP	Remote Site Data Processor
RSS	Resettable Solid State (Timer)
RTC	Real Time Command
RTCC	Real Time Computer Complex
RTG	Radioisotope Thermoelectric Generator
SCO	Subcarrier Oscillator
SCS	Standard Communications Subsystem
SCU	System Configuration Unit
SDDS	Signal Data Demodulator System
SDT	Serial Decimal Time
SEQ	Scientific Equipment
SIDE	Suprathermal Ion Detector Experiment

Acronyms and Abbreviations (Continued)

SOM	Start of Message
STREU	Simulation/Serial Transmit, Receive, and Encode Unit
SWS	Solar Wind Spectrometer
TBD	To Be Determined
TLM	Telemetry
TTY	Teletype
UCS	Universal Command System
UDB	Up Data Buffer
USB	Unified S-Band
VSM	Video Switch Matrix
WBD	Wide Band Data

