A STUDY TO DETERMINE AN EFFICIENT DATA FORMAT AND DATA SYSTEM FOR A LIGHTWEIGHT DEEP SPACE PROBE

SUMMARY FINAL REPORT

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ILLUSTRATIONS

1. INTRODUCTION

This report summarizes the results obtained from a "Study to Determine an Efficient Data Format and Data System for a Lightweight Deep Space Probe". This study was conducted for NASA/ARC under contract NAS2-3254 during the period from October 1965 to October 1966. This study has resulted in the definition and overall design of a Central Data System (CDS) for a spin stabilized deep space probe.

The CDS consists of an input data sampler and a central processor. Digital and analog data is received by the CDS from the experiments and from the spacecraft performance sensors. This data is sampled by the input data sampler and processed by the central processor into a highly efficient format for storage or transmission. Data processing is programmable and under the control of a stored program. The CDS processes discrete commands and processor program instructions from ground transmissions. The CDS design is based on a group of eight solar experiments chosen for the study by mutual discussion and agreement with NASA/ARC. These are:

1) Micrometeoroid (NASA/GSFC)
2) Flux Gate Magnetometer (TRW)
3) Cosmic Ray Detector (University of Chicago)
4) Plasma Probe (NASA/ARC)
5) Radio Propagation (Stanford)
6) Fast Neutron Detector (TRW)
7) Very Low Frequency (TRW)
8) Cosmic Ray Detector (University of Minnesota).

Each of these experiments was studied in detail to determine their interface requirements in terms of the number of inputs to be sampled by the CDS, input signal characteristics,* required data processing, timing requirements, and sensor control signals.

A number of solar orbital missions, ranging from 0.2 to 1.8 astronomical units (AU) were studied and their trajectories plotted to

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*Research Report No. 2, dated 29 August 1966.

determine the communications link requirements. Eight transmission bit rates were established to provide adequate communication coverage. The rates are:

1) 2048 bps
2) 1024 bps
3) 512 bps
4) 256 bps
5) 128 bps
6) 64 bps
7) 32 bps
8) 16 bps.

The CDS design is based upon the results of the studies which defined the experiment characteristics and communication link requirements. The resultant CDS design provides a system with the following overall characteristics:

1) Universal design for many missions.
2) One time development and qualification cost.
3) Capability to process a variable number of experiment inputs (time-shares common data processing circuits).
4) Capability to process sampled data (compress data to reduce bits required to transmit information - approximating a data reduction of 10 to 1).
5) Ability to provide continuous data sampling during non-communication periods by the use of a bulk store unit.
6) Compatibility with the JPL deep space net (DSN).

A simulation philosophy has been established during the course of this study. This simulation philosophy has been developed to aid in the logic design of the CDS and evaluation of the CDS performance. It has been concluded that a simulation is desirable during the design phase of the CDS.

2. SYSTEM DESCRIPTION

2.1 GENERAL REQUIREMENTS

The CDS design is based upon the following basic concepts:

1) Each data point is sampled at a fixed, high rate and is processed and formatted by a programmable central processor.

   - The CDS samples synchronous data (geared to spacecraft spin rate) and asynchronous data (real-time dependent only, i.e., micrometeoroid events). Asynchronous experiment data is formatted and transmitted only when required and is interleaved with synchronous data, thereby maintaining high transmission efficiency.
   - Synchronous data points are sampled 64 times per spacecraft revolution in a fixed sequence. (Each spacecraft revolution is divided into 64 equal segments or sectors.)
   - Normal transmission is independent of input data sampler requirements thus permitting variable data compression and reduction prior to transmission.
   - High transmission efficiency formats are used (no fill-in bits are required and data is compressed, i.e., log scaled minimum-maximum determination, averaging, etc.).
   - Frame size is programmable to optimize data formats.

2) The CDS utilizes a standard input signal interface (three basic types):

   - Pulse data (counting)
   - Analog (pulse height and linear)
   - Bi-level (status signals).

3) The input data sampler is expandable up to 64 data points in a given sector.

4) The CDS has five programmable modes of operation:

   - Transmission of realtime data interleaved with stored data
   - Transmission of realtime data only
   - Transmission of high rate engineering data only
   - Self test mode
   - Data store mode.

5) The CDS has three fixed modes of operation:

   - Processor program verification (contents of program memory are transmitted to ground)
   - Fixed realtime transmission (limited capability) synchronized by either actual or simulated sun pulse
   - Stored data transmission only.

6) The CDS can store data during periods of noncommunication for later transmission.

   - Thirteen hours of stored data are compressed and transmitted (interleaved) with 11 hours of compressed realtime data. This is to provide continuous data sampling during any 24-hour period.

7) A command system is provided for uplink transmission of discrete commands and processor program instructions. All transmitted commands are self-verified prior to execution.

8) Convolutional coding* is used to improve transmission capability.

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*Convolutional coding scheme developed by Dr. Dale R. Lumb, NASA/ARC.

9) Design and operational flexibility:

- Provide system flexibility from mission to mission by utilizing standard experiment interfaces and programmable operation
- Provide the capability for in-flight program modification to optimize system operation to unexpected conditions.

2.2 CDS OPERATION

The basic CDS design consists of the following elements:

- Input data sampler (IDS)
- Input data buffer (IDB)
- Processor
- Output buffer (OB)
- Bulk store unit
- Fixed realtime transmission logic
- Convolutional coding logic
- Command processor.

A simplified block diagram of the CDS is shown in Figure 2-1. The solid lines in the figure illustrate data flow; the dotted lines illustrate control signals.

The CDS samples input data from experiment packages and from spacecraft performance sensors in the form of three basic types of signals (analog, pulse, and bi-level data). All analog data is encoded to 8-bit accuracy by one time shared analog-to-digital converter.

Each synchronous data source, dependent upon spacecraft rotation, is sampled 64 times per spacecraft revolution and stored for processing by the central processor. The processor selects the desired samples from the IDB, performs the required data compression (i.e., log scaling, minimum-maximum determination, averaging, etc.), and formats the processed data for transmission. All processor operations are controlled by a stored program. The size of the output format is programmable to permit efficient utilization of the selected data bit rates.

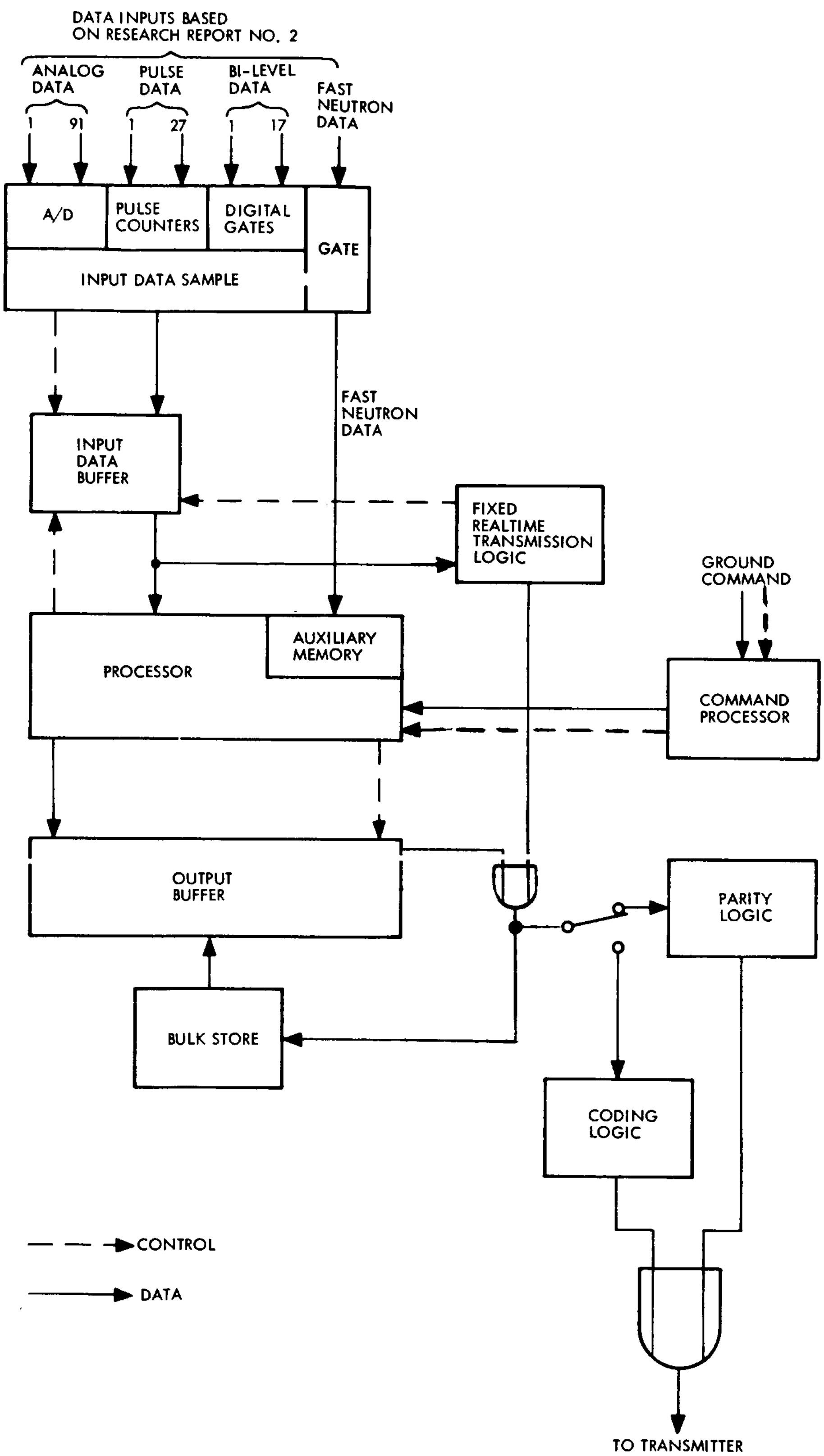

Figure 2-1. Simplified CDS Block Diagram

The CDS timing and synchronization has been designed to provide an input data sampler whose operation is essentially independent of transmission link requirements. That is, experiment data is sampled by the IDS and stored within the IDB until the processor is ready to select data for processing. The processed data is formatted and placed into one of the two output buffers for transmission. The only timing requirement is that data must be processed at a high enough rate to insure that sufficient data will be available for continuous uninterrupted transmission.

This independence of data sampling to transmission link requirements permits variable data processing to be performed prior to transmission. For example, as the allowable transmission bit rate decreases due to the earth-spacecraft distance, the processor will select fewer samples to be transmitted per spacecraft revolution. More data compression also will be performed on data that is transmitted, thus minimizing information transmitted with the available transmission bit rate.

The CDS has five programmable modes of operation (Figure 2-2). Only one mode of operation is permissible at any given time. The realtime interleaved with stored data refers to the operation in which the spacecraft is in communication with the DSIF stations. This is expected for a duration of approximately 11 hours a day. During this time, the CDS will alternately transmit one frame of realtime data and one frame of stored data from the bulk store unit. The realtime data only mode transmits only realtime data (no bulk store data). This mode provides twice the realtime data rate as the realtime/bulk store mode. The data store mode refers to storing data into the bulk store; this mode is expected to be required approximately 13 hours a day. High rate engineering only refers to the transmission of spacecraft performance and experiment status data at a high rate during launch phases or during times of suspected spacecraft malfunction. A self test mode is provided to evaluate CDS performance during the course of the mission.

Each programmable mode requires an individual program; however, common subroutines are shared among all programs. That is, the processor program memory is organized with one section or bank containing subroutines and the other bank containing the main programs. Whenever a main program requires a subroutine, the main program

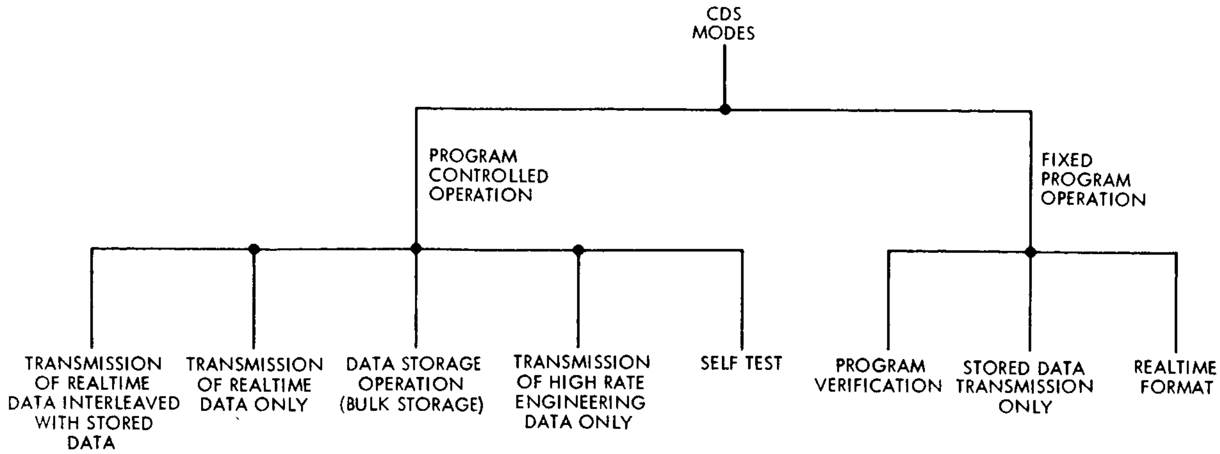

Figure 2-2. CDS Modes of Operation

branches off into the subroutine. After performing the subroutine a jump is made back to the main program.

The three fixed operational modes are designed to bypass the processor. They are used to transmit a limited quantity of scientific and engineering data during periods when the processor program is being modified and during times when a processor malfunction is suspected. The input data sampler operates in its normal sequence during this mode of operation. However, instead of the processor selecting data samples from the IDB, samples are selected from the IDB by a fixed programmer. The selected data is directly formatted by the use of a combiner and is fed to either the convolutional coding circuitry or to a simple parity generator. The output from the CDS modulates the telemetry transmitter.

2.3 INPUT DATA SAMPLING

The basic requirements of the IDS are to:

- Sample analog, biphase, and pulse data
- Analog-to-digital encode analog inputs
- Store sampled data into the IDB for later processing by the processor.

A fixed programmer provides the signals required to sample all inputs in a fixed sequence. Bi-level data is sampled and stored directly into the

IDB. Pulse data is accumulated within counters and then stored within the IDB. Analog data is sampled and encoded into an 8-bit binary number for entry into the IDB.

As stated earlier, all high rate data is sampled 64 times per spacecraft revolution. This is accomplished by dividing each spacecraft revolution into 64 equal segments called sectors. Each sector is also divided into 64 segments called words.

Figure 2-3 illustrates the characteristics of a single spacecraft sector. As shown, analog inputs are sampled, encoded, and stored within the IDB during word times 1 through 20. Pulse data is sampled for one sector and stored within the IDB during word times 21 through 34. Low rate data is sampled once per spacecraft revolution in word 35. Subcommutated data is sampled once per 64 spacecraft revolutions in word 36.

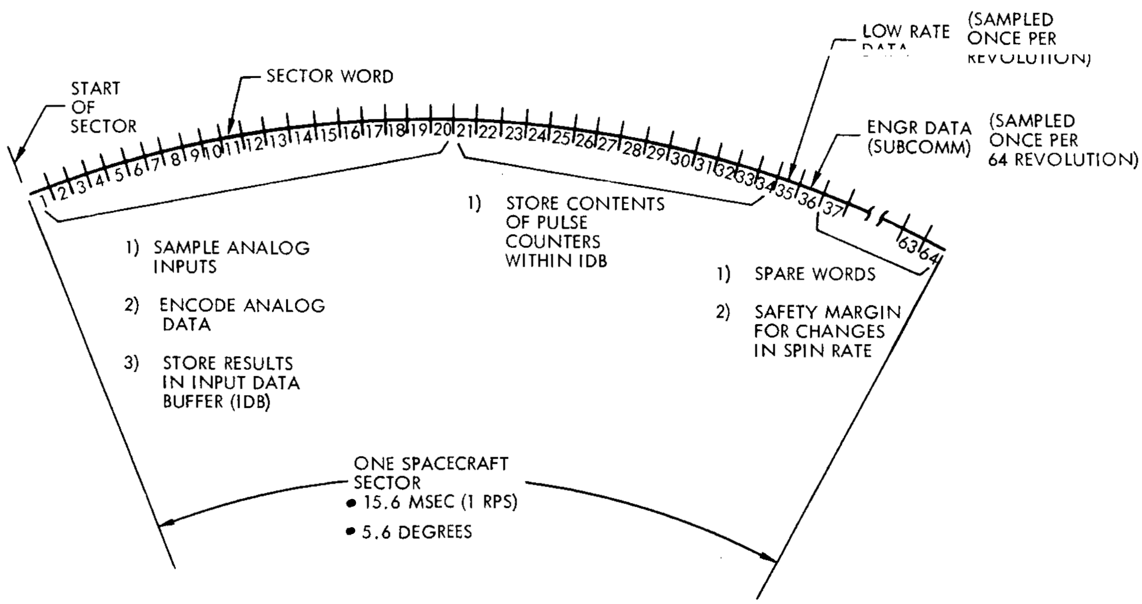

Figure 2-3. Spacecraft Sector Detail Diagram

2.4 DATA PROCESSING AND FORMATTING

Data processing is defined as those operations performed on sample data by the processor prior to transmission. Processing operations include:

- Selection of specific data from the IDB and the auxiliary memory
- Data processing
- Data formatting.

These operations are programmable and are under the control of a processor instruction memory.

The processor is capable of performing specific data compression such as log scaling, averaging, determining minimum and maximum values of n samples, and any other data operation which can be performed by basic addition, subtraction, and shifting left and right. At lower bit rates, the processor will reduce the number of bits per frame by selecting fewer samples per spacecraft revolution and by performing more data compression such as log scaling data, finding minimum-maximum values, etc. Formatting of processed data is automatically performed in the transfer of data from the processor to the output buffers. During the transfer operation the processor will perform the following formatting steps:

1) Select the frame synchronization bits from the processor instruction memory and enter them into the appropriate output buffer memory locations.

2) Enter subcommutator, bit rate, and format identification into appropriate output buffer locations.

3) Store processed data into programmed output buffer locations. Store sector identification bits to identify data with its sector sampling address where required, i.e., minimum-maximum.

4) Determine the size of each frame according to the processor program.

5) Format and store each frame of data to permit continual uninterrupted realtime transmission of data alternately from the two output buffers.

A typical processor program flow diagram is shown in Figure 2-4.

A typical format for 1024-bps transmission bit rate is shown in Figure 2-5. This is one example of any number of possible formats which are possible by programming. The format is divided into four basic sections:

- Frame identification
- High rate data
- Low rate data
- Subcommutated data.

Table 2-1 lists the processing algorithms and total transmission bits for each experiment for the eight transmission bit rates. Various formats can be derived from Table 2-1. A format ID identifies all formats for the CDS modes of operation shown in Figure 2-3.

2.5 WEIGHT AND POWER SUMMARY

The weight and power assessment for the CDS is based upon the use of low power integrated circuit logic such as the Fairchild 9000 series. The Fairchild 9000 series integrated circuits were selected due to their low power consumption and their off-the-shelf availability.

Table 2-2 summarizes the weight and power requirements for the CDS.

2.6 CDS RELIABILITY ASSESSMENT

The CDS reliability is calculated based upon component failure rates suggested by NASA/ARC. Pioneer VI component failure rates were suggested for use in calculating CDS reliability to allow a comparative analysis between the CDS and the Pioneer VI system reliability using the same ground rules.

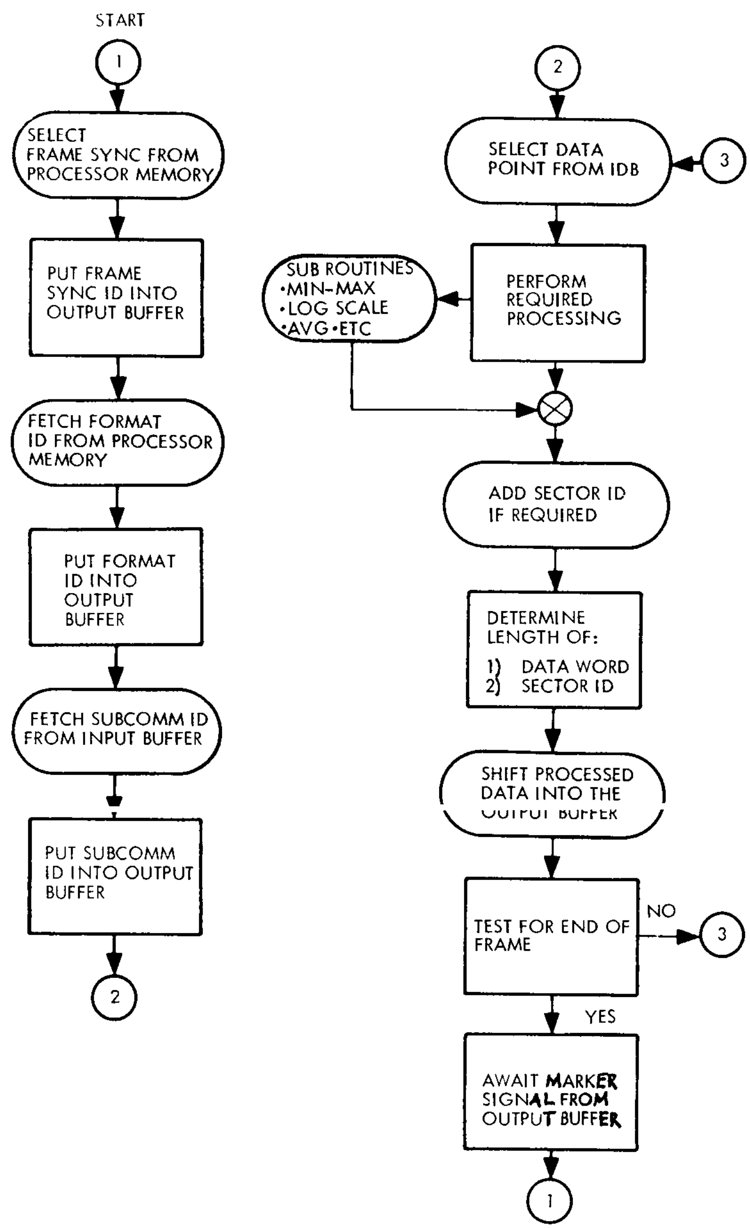

Figure 2-4. Flow Diagram of Processing and Formatting Operation

FRAME IDENTIFICATION				HIGH RATE DATA						LOW RATE DATA 64 BITS	SUB COMM (8/Bits/Frame)
FRAME SYNCH	SUB-COMM ID	FORMAT ID	BIT RATE	MAG	C COS	PIA	RAP	VLF	W COS	(see below)	(see below)
24 Bits	6 Bits	4 Bits	3 Bits	192 Bits	312 Bits	125 Bits	112 Bits	24 Bits	213 Bits		

LOW RATE DATA 64 BITS

START TIME OF SAMPLING CYCLE (ET_1)	8
START SECTOR ADDRESS OF SAMPLING CYCLE	8
PLASMA VOLTAGE & CHANNEL ID	8
EXP. NORMAL CALIBRATE STATUS, MIC RAP, VLF & FAN ID	6
Bits	30

MIC*	
A&B MATRIX	8
ENERGY & MOM	8
TOF	4
SUN ASPECT	7
A, B & M EVENTS	3
MIC ELAPSED TIME	4
Bits	34

RAP**	
S_1	10
S_2	6
S_3	6
S_4	6
S_6	6
Bits	34

FAN**

BLOCK OF 34 BITS

VLF*	
X_c	6
Y_c	6
Z_c	6
M_1	6
M_2	6
Filter	4
Bits	34

SUB COMM (8/Bits/Frame)

ENG DATA-48 words

BI-LEVEL- 2 words

INCLUDES

ET_2 (one word)

ωt (one word)

MAG (one word)

Range

Offset

Orientation

ET_3

54 8-BIT WORDS

Note:

MIC	Micrometeroid
VLF	Very Low Frequency
RAP	Radio Propagation
MAG	Magnetometer
MOM	Momentum
TOF	Time of Flight
C COS	Chicago Cosmic Ray
ET	Elapsed Time
ωt	Spin Rate
Total Bits	1087 Bits

*MIC Data replaces VLF Data when a MIC event occurs

**FAN data replaces RAP da[illegible] when Fast neutron is active

Figure 2-5. Typical Format (1088-Bit Format Size)

Table 2-1. Experiment Processing Algorithms and Data Bits

Experiment*	2048 / 1024 Bit Rates: Algorithms	2048 / 1024 Bit Rates: Bits Per Frame	512 / 256 / 128 Bit Rates: Algorithms	512 / 256 / 128 Bit Rates: Bits Per Frame	64 / 32 / 76 Bit Rates: Algorithms	64 / 32 / 76 Bit Rates: Bits Per Frame
Magnetometer	Select eight samples per rev	192	Select four samples per rev	96	Select one sample per rev	24
Chicago cosmic ray	Select four samples per rev +16 sector ID bits. Sample subsequent sectors each sampling period.	312	Select two samples per rev +8 sector ID bits. Sample subsequent sectors each sampling period.	164	Select one sample per rev log scale, 4 sector ID bits required. Sample subsequent sectors each sampling period.	65
Plasma probe	Select 16 samples per rev +13 bits for max flux	125	Select four samples per S/C rev +13 bits for max flux	41	Select one sample. Determine max value of flux	20
Radio propagation	Select 16 samples per sec	112	Calculate min-max value of S_5	24	Calculate min-max value of S_5	24
Very low frequency	Select one sample (X_c, Y_c, Z_c)	24	Select one sample (X_c, Y_c, Z_c)	18	Select one sample (X_c, Y_c, Z_c)	18
Webber cosmic ray	Select four samples per rev, log scale, trans 16 sector bits. Sample subsequent sectors each sampling period.	213	Select two samples per rev, log scale, trans 8 sector bits. Sample subsequent sectors each sampling period.	156	Select one sample per rev, log scale, trans 4 sector bits. Sample subsequent sectors each sampling period.	78
Micrometeoroid	Transmit 34 bits only when event occurs in low rate data group	34**	Transmit 34 bits only when event occurs in low rate data group	34**	Transmit 34 bits only when event occurs in low rate data group	34**
Fast neutron	Collect data for one hour 20,700 bits and transmit in 34-bit blocks in low rate data group.	34**	Collect data for one hour 20,700 bits and transmit in 34-bit blocks in low rate data group.	34**	Collect data for one hour 20,700 bits and transmit in 34-bit blocks in low rate data group.	34**
Low rate data	See Figure 3-10	64	See Figure 3-10	64	See Figure 3-10	64
Subcomm	See Table 3-2	8	See Table 3-2	8	See Table 3-2	8
TOTAL		1050		571		301

*Refer to Research Report No. 2 for details on experiment processing requirements.

**These data bits contained within 64 low rate data bits.

Table 2-2. CDS Weight and Power Summary

Subsystems	Power (watts)	Weight (pounds)
Input data sampler logic	2.2	1.5
Processor logic	2.2	1.5
Command processor*	low average power - unit turned off when not used	0.5
Power converter	--	3.0
Memories		
1) Two input data buffers (12K bits each)	0.43	2.5
2) Two output buffers (1.2K bits each)	0.16	2.0
3) One auxiliary memory (30K bits)	0.10	2.5
4) Two processor memories (18K bits each)	0.26 for one	3.0
Total	5.35 (8.9 watts raw power)**	16.5

*Peak power = 1.7 w.

**Total Power In, assuming 60% converter efficiency is:
$P_{in} = 5.35/0.6 \cong 8.9$ watts.

CDS reliability is calculated for three mission times: 1 year, 1.5 years, and 2 years. The mission phase reliabilities for these three time periods are listed below. These members are based on an 80 percent data retrieval.

	With Tape Recorder (Bulk Store)			Without Tape Recorder (Bulk Store)			Pioneer VI* •DTU •DEC •DSU •CDU
	Mission Time			Mission Time			Mission Time
	1 Year	1.5 Years	2 Years	1 Yr	1.5 Yrs	2 Yrs	0.5 Yr
CDS	0.28	0.14	0.07	0.67	0.54	0.43	-
Pioneer VI	-	-	-	-	-	-	0.68

*DTU - Digital Telemetry Unit
DSU - Data Storage Unit
DEC - Command Decoder
CDU - Command Distribution Unit

The reliability numbers listed in the first three columns of the table reflect the low reliability of the bulk store, magnetic tape unit. The magnetic tape unit considered for the CDS has the following reliabilities:

- 1 year mission - 0.411
- 1.5 year mission - 0.264
- 2 year mission - 0.169.

As indicated, the CDS reliability is much greater than the magnetic tape unit. Therefore, either redundant tape units or a more reliable bulk store unit should be investigated for use within the CDS.

3. CDS EVALUATION AND COMPARISON TO PIONEER VI

3.1 INTRODUCTION

A requirement of the study contract is to compare the CDS design to a baseline system. The Pioneer VI data handling subsystem was chosen as the baseline system by mutual agreement between TRW Systems and NASA/ARC.

3.2 PIONEER VI DATA HANDLING SUBSYSTEM DESCRIPTION

The Pioneer VI data handling subsystem is made up of a digital telemetry unit (DTU), a data store unit (DSU), and a command decoder. A redundant command decoder and a redundant programmer is used within the DTU in the Pioneer VI system. A system block diagram is shown in Figure 3-1. The six experiment sensors are shown along with their individual processing blocks and storage blocks.

The DTU processes all inputs into a PCM time multiplex format which biphase modulates a 2048-Hz subcarrier. This subcarrier is the output of the DTU which modulates the transmitter. The inputs to the DTU consist of digital data from the experiment packages and bi-level and analog from the spacecraft performance sensors. The DTU receives only digital data from the experiment package since all data processing and A/D conversion is accomplished by the individual experiments (except for the radio propagation).

Signals from the command decoder select different bit rates and modes of operation via uplink transmission from the tracking stations. The range of the telemetry transmission bit rates is from 8 to 512 bps in five steps. Any one of the five bit rates may be commanded for each of four transmission formats.

The DTU also provides various timing and gating pulses to the experiments as required.

If more detailed information is required on the Pioneer VI data handling system, refer to NASA/ARC PC documents (PC-046.01).

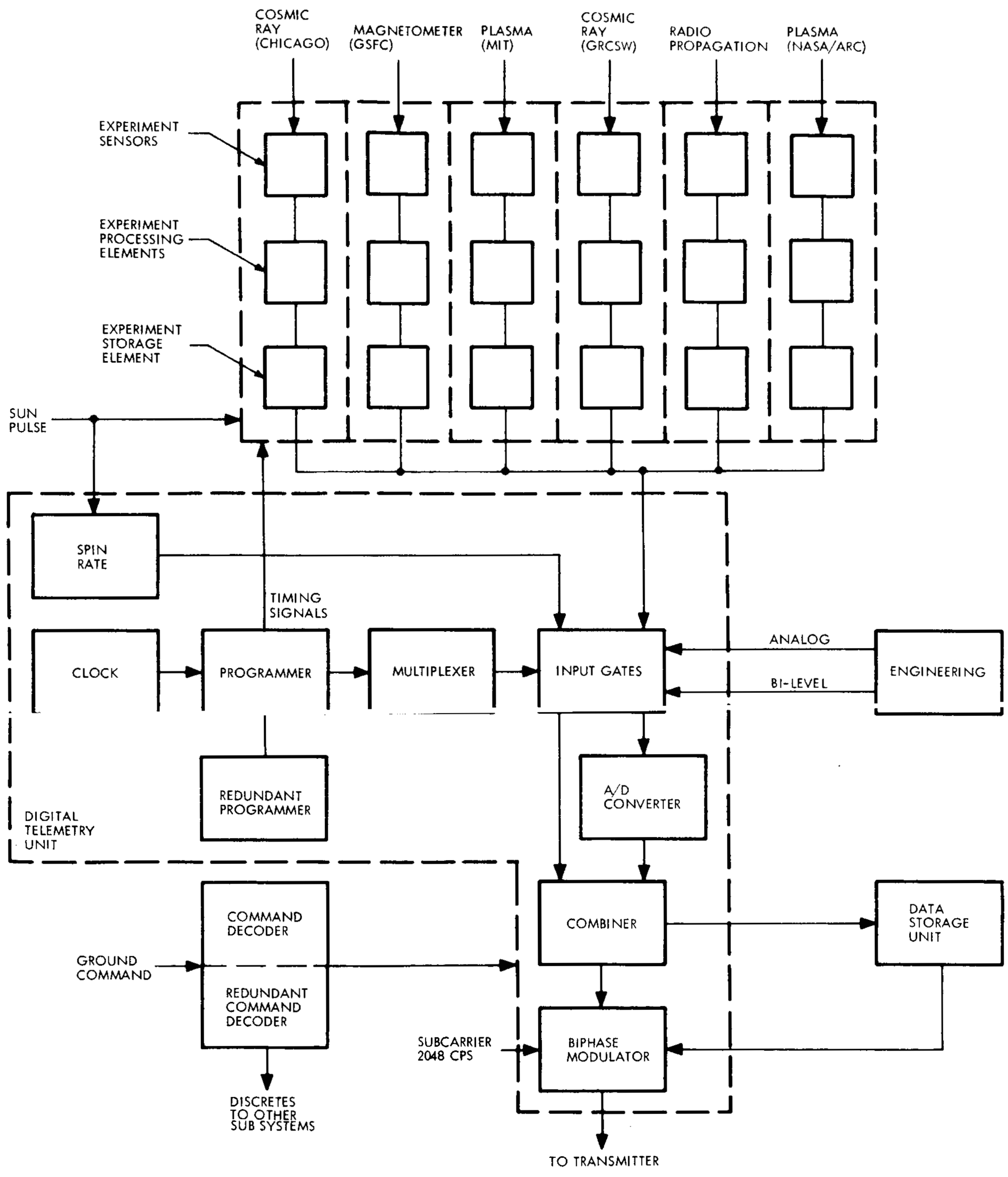

Figure 3-1. Pioneer VI Data Handling Subsystem Block Diagram

The DSU provides 15, 232 bits of storage during noncommunication periods with the DSIF stations. When transmission of stored data is commanded, the output of the DSU is read out by the DTU.

3.3 TABLE COMPARISON OF CDS AND PIONEER VI DATA HANDLING SUBSYSTEM

Table 3-1 summarizes the characteristics of the CDS and the Pioneer VI data handling system.

Table 3-1. Comparison of CDS and Pioneer VI Data Handling System

	Pioneer VI	CDS
Number of inputs processed and transmitted	15 digitals 71 analogs 66 bi-levels 1 spin rate Additions cannot be made without redesign due to the fixed formats used.	27 pulse data, 91 analog, 17 bi-levels. Additional inputs may be accommodated by adding sampler gates and reprogramming the processor instruction memory to process additional signals.
Sampling rate (assuming 1 rps spin rate)	Max of 2.3 samples/experiment/second	64 samples/exp/sec
Number of formats	4 (fixed)	Programmable, typically 8 programmable, 2 fixed
Format size	224 bits (fixed)	Programmable, typically 2K bits, 1K, 0.5K, and 0.25K bits
Spacecraft word size	(fixed) 6 bits + one parity (7-bit word size)	Programmable, word size variable
Transmission bit rates	512 256 64 16 8	2048 64 1024 32 512 16 128
Modes of operation	Realtime Telemetry store Duty cycle store Memory readout	Program controlled: Transmission of realtime interleaved with stored data Transmission of realtime data only Data storage operation during noncommunication periods (bulk storage)

Table 3-1 (Continued)

	Pioneer VI	CDS
		Transmission of high rate engineering data only Self test Fixed operations: Program verification Realtime format Data storage readout
Ground commands	128	128
Number of experiments	6 (fixed)	8 (more can be added)
Reliability	0.68 for 6 months	0.67 for 1 year 0.54 for 1.5 years 0.43 for 2 years (excludes bulk store tape unit)
Data storage (bits)	Data handling system - 15,232 Experiments - 2292 Total - 17,524 bits	56,000, includes 2 input data buffers, 2 output buffers, and the auxiliary memory. Bulk store $\approx 2 \cdot 10^7$ bits.
Weight (lbs)	Data handling - 10.6 lbs Decoder - 6.0 lbs 6 experiments - 34.7 lbs Total - 51.3 lbs	CDS 16.5 lbs 8 experiments 11.0 lbs minus CDS processing circuits (does not include bulk store) 27.5 lbs
Power (watts)	Data handling - 4.4 w 6 experiments - 7.3 w Decoder - 1.4 CDU negligible Total - 13.10	CDS (total) 8.9 w 8 experiments 11.0 w Total 19.9 w

Table 3-1 (Continued)

	Pioneer VI	CDS
Elapsed time counter (spacecraft clock)	Variable recycling time dependent on bit rate (8 minutes to 8 hours)	Central spacecraft clock (recycling time 194 days, 1 second resolution) elapsed time transmitted within each frame
Spacecraft sector generator	Generated by individual experiment package	1 central sector generator
Analog encoding accuracy (quantitization level)	$2^6 = 64$ levels	$2^8 = 256$ levels

Table 3-1 (Continued)

	Pioneer VI	CDS
Ground stations	DSIF	DSIF
Failure modes	1 redundant programmer 1 redundant command decoder	Failure mode bypass capabilities by reprogramming CDS to bypass failed component (in processor instruction memory, IDB, processor, etc.)
Data transmission efficiency	As many as 40% of bits transmitted consists of fill-in bits - (format A 512 bps)	No fill-in bits required
Data processing	Fixed processing within each experiment	Programmable by central processor: Log scaling Min-max Max Averaging
Number of sectors sampled per spacecraft revolution	Fixed by experiments 16 max	64 sectors for each synchronous experiment
Number of A/D required	6 within experiments 1 in DTU	2 (1 redundant)
Bulk storage	15,232 bits (core)	2×10^7 bits (tape)
Data sampling sequence	Dependent on particular experiment data processing timing (not constant)	Constant intervals

4. RECOMMENDATIONS AND CONCLUSIONS

The results of the study indicate that a CDS is practical for use in a lightweight deep space probe in terms of meeting the requirements for weight, power, and flexibility. The principle advantages over a fixed hardwired system are:

- Higher information rate for a given bit rate
- A fixed hardware design is usable for many missions.

Because of the favorable results obtained in meeting the goals of the study and the improvements it provides over the Pioneer VI type system, it is recommended that the CDS design be carried out through a detailed logic and circuit design. Specifically, it is recommended that the following areas be further studied for possible inclusion within the detailed logic design:

1) Reduce required average power by use of power gating techniques.

2) Use one central memory system as opposed to separate memories (i.e., processor instruction memory, auxiliary memory, input data buffer, and output buffer).

3) Use CDS memories interchangeably. For example, use the auxiliary memory in place of one or both input data buffers.

4) Standardize memory sizing in terms of word length, modularization packaging, etc.

5) Extend data reduction capabilities and techniques. Increase the computational capability of the processor to perform more extensive data reduction (i.e., statistical analysis).

6) Use the processor to perform convolutional coding.

7) Use an NDRO processor instruction memory.