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GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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Greenbelt, Maryland

CONTENTS

1. INTRODUCTION

On October 14, 1965, OGO-2, the first of three planned Polar Orbiting Geophysical Observatories, was launched into an orbit with the following characteristics:

Inclination	87.4°
Perigee	413 Km
Apogee	1510 Km
Anomalistic Period	104.3 Minutes

OGO-2 is an extremely versatile second generation satellite capable of high bit rates possessing an on-board tape recorder and, until 10 days after launch having complete attitude control. It is a "street car" or observatory type satellite with a complement of twenty experiments measuring many different geophysical phenomena as can be seen from the following list of experiments (S-50 Experiment Bulletin No. 18; Ludwig, 1966).

Exp. No.	Experimenter	Organization	Experiment Description
1	Haddock	U. Michigan	Radio Astronomy measurements at 2.5 and 3.0 mc/s.
2	Helliwell	Stanford U.	VLF measurements in the frequency range .2-100 Kc.
3	Morgan and Laaspere	Dartmouth	Study of VLF emissions and whistlers between .5 and 10 Kc.
4	(Experiment Number Not Used)		
5	Holzer and Smith	UCLA and JPL	Investigation of magnetic field fluctuations in the low audio frequency range using a search coil magnetometer.
6	Heppner, Cain, and Farthing	GSFC	Measurement of earth's magnetic field and associated long period (> 2 cps) fluctuations.

Exp. No.	Experimenter	Organization	Experiment Description
7	Neher and Anderson	CIT and JPL	Comparison of ionization over the polar region with that measured by ionization chambers carried on space probes.
8	Simpson	U. Chicago	Determination of 0.3 mev/nucleon to approximately 30 mev/nucleon by means of a scintillation telescope.
9	Webber	U. Minnesota	Measurement of the energy spectrum and charged particle composition of galactic and solar cosmic rays.
10	Van Allen	S. U. Iowa	Measurement of the net downflux of corpuscular radiation in the auroral zones and over the polar caps.
11	Hoffman, Davis, Konradi, & Williamson	GSFC	Measurement of low energy trapped radiation; 10-100 Kev electrons and 100 Kev to 4.5 Mev protons.
12	Blamont and Reed	U. Paris and GSFC	Airglow measurements in the 6300 A°, 5577 A°, 3914 A°, and near UV region.
13	Mange, Chubb, and Friedman	NRL	Lyman-Alpha and UV airglow measurement between 1230-1350 A°.
14	Barth and Wallace	JPL and Yerkes Observatory	UV spectrometer for airglow measurements between 1100-3400 A°.
15	Jones and Schaefer	U. Michigan	Massenfilter mass spectrometer for neutral and ion composition measurement, ranges 0-6 and 0-40 AMU.
16	Taylor and Brinton	GSFC	Bennett ion spectrometer to measure 1-45 AMU.
17	Newton	GSFC	Bayard-Alpert density gage.
18	Alexander, McCracken, Berg, and Secretan	GSFC	Measurements of micrometeorites mass, velocity and charge.

Exp. No.	Experimenter	Organization	Experiment Description
19	Bourdeau	GSFC	Measurements of ionospheric composition and solar UV flux, retarding potential analyzer.
20	Hinteregger	AFCRL	Scanning spectrometer to monitor solar emission in the 200-1600 A° region.
21	Kreplin, Chubb, and Friedman	NRL	Ionization chamber to determine solar x-ray emission in the .5-3A°, 2-8A°, 8-16A°, & 44-60A° bands.

Figure 1 is a drawing of the spacecraft showing the relative locations of the various experiments. The main body is 1.7 m. long, .78 m. high, and .81 m. wide. The long booms extend over 6.0 m. from the main body (Ludwig, 1963).

The Orbiting Geophysical Observatories are designed with a complex on-board digital telemetry system, minimizing the electronics required in the individual experiments. This telemetry system contains two redundant equipment groups each capable of feeding its output to either the on-board tape recorder or to the wide-band transmitter in real time operation. Using both equipment groups, simultaneous real time and recorder operation is possible. In addition, a separate transmitter is capable of being modulated with five subcarriers, making it possible to obtain analog as well as digital information. This is called the Special Purpose Telemetry System.

The magnetic field experiment, number six in the above list, was designed to measure the total (scalar) magnetic field in the range from 15,000 gammas to 64,000 gammas to an accuracy of ±2 gammas. Due to a higher orbit than orginally planned, the instrument was required to operate in a field weaker than its design range; it performed extremely well down to a field of 13,000 gammas. The accuracy achieved is between $\pm .83\gamma$ and $\pm .125\gamma$ with a resolution of $\pm .43\gamma$

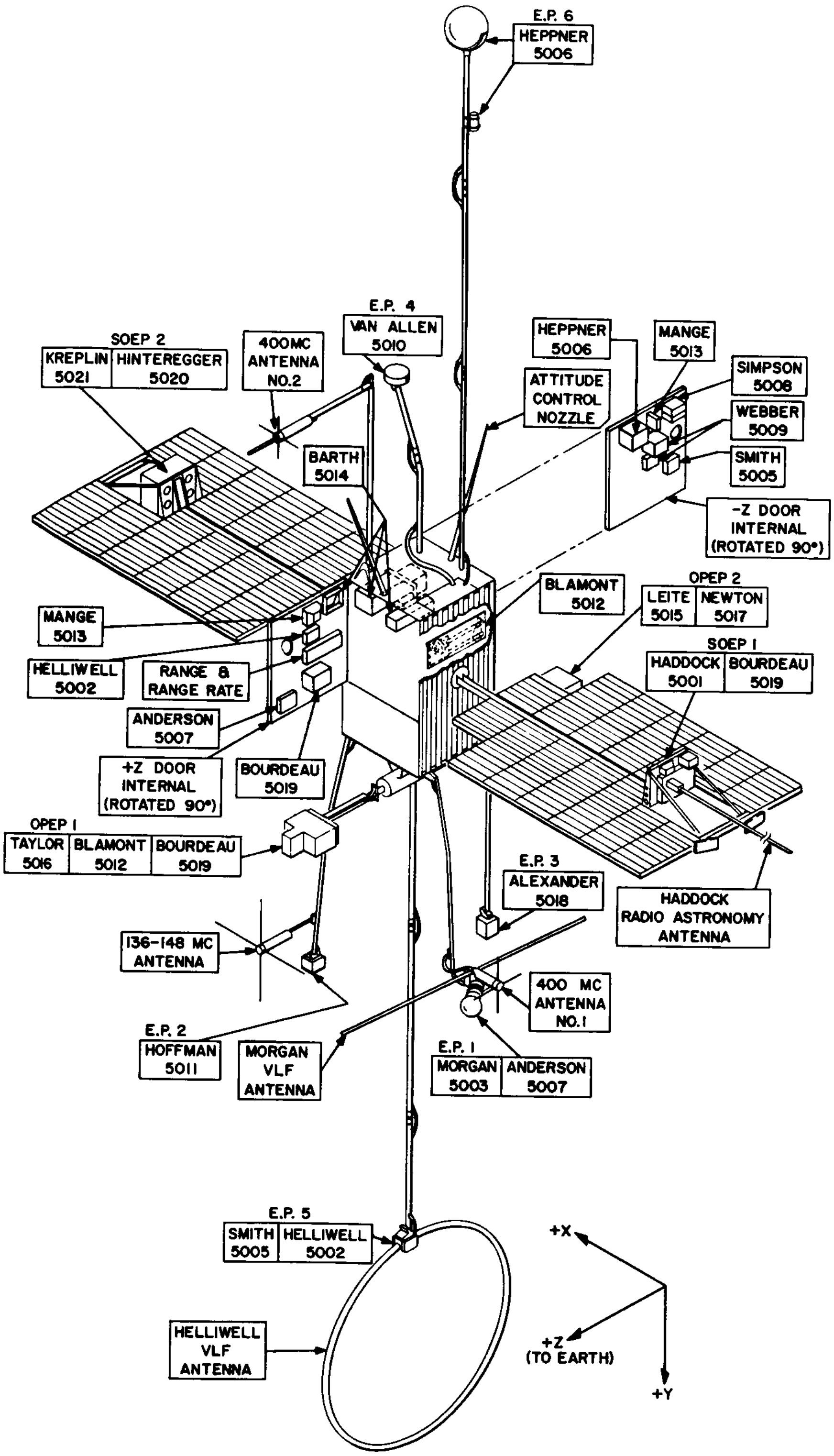


Figure 1 - POGO Experiment Configuration (Caughey and Quann, 1965)

(Farthing and Folz, 1966). Since this experiment measures the scalar field and not the vector field, the data were unaffected by the loss of attitude control early in the lifetime of the satellite (Cain, Langel, and Hendricks, July 1966). The instrument performed flawlessly from launch until early July when the failure of a power supply caused loss of the special purpose telemetry and partial loss of the digital PCM data (Farthing and Folz, 1966). The extent of the data coverage will be discussed subsequently. This report details, as far as is practical, the process of reduction of OGO-2 magnetic field data from the original data acquisition and recording (of PCM data only; no discussion of special purpose data is included) to the preparation of the final data set used for analysis by the original experimenter and also delivered to the NASA Space Sciences Data Center for use by other scientists. We hope hereby to instill a confidence in the final data in all potential users so that they will not feel a necessity for reverting to the original data records and also to create an awareness of possible idiosyncrasies which may still exist in the final data.

To one traveling it for the first time, the road of data reduction may be long and hard, filled with many surprises and pitfalls. We hope that our effort may serve as a guide to those embarking on this journey in the future. With this in mind we have attempted to point out those techniques which have not worked out as planned as well as those which have been successful. We have some definite ideas about how we would go about the data reduction game (differently) if we were to begin afresh, and also about how to best utilize the new generation of computer hardware just now being made available. A brief section is included on these subjects.

2. THE SPACECRAFT TELEMETRY SYSTEM

OGO-2 uses a split-phase PCM/PM digital telemetry system (Glaser, 1962), in which each telemetry word contains nine bits; 128 nine-bit words are included in the basic main frame. In addition to the main frame, three subcommutators are provided, each containing 128 nine-bit words and operating at 1/128 the rate of the main commutator. The subcommutator outputs are assigned to words 97, 98, and 99 of the main commutator.

Figure 2 shows the contents of the 128 word main frame (NASA-GSFC OP-Plan 10-65). The numbers in the center of the squares indicate the experiment to which the word is assigned, the numbers in the small box in the upper left-hand corner of each major square indicate the word number. Note the four groups of three words which begin each of the four groups of 32 words making up the main frame. Words 1-3 are called "frame sync words" and consist of a constant bit pattern used for synchronization in the Analog to Digital (A/D) conversion process at GSFC, words 33-35 are used to telemeter the contents of the spacecraft clock register, words 65-67 are spacecraft identification (ID) words giving the mode of operation of the digital equipment, and words 97-99 contain the outputs from the subcommutators. A group of 128 main commutator frames (one subcommutator cycle) is called a "sequence."

In order to allow a limited number of experiments to achieve higher data rates thirty-two (32) telemetry formats are provided in addition to the main frame. These formats consist of 32 nine-bit words which can be assigned independently of the main frame words and which can be combined into a 29 word frame in 32 separate combinations called flexible formats. These flexible formats are designated by numbers from 1 to 32. This 29 word frame then operates

HORIZONTAL MATRIX LINES	K101	K102	K103	K104	K105	K106	K107	K108	K109	K110	K111	K112	K113	K114	K115	K116
R11	1 [000] SYNC WORD #1	2 [001] SYNC WORD #2	3 [002] SYNC WORD #3	4 [003] 5 X-AXIS HI GAIN DATA	5 [004] 13 +Z - LYMAN ALPHA DATA	6 [005] 2 0.2 TO 1.6 KC DATA	7 [006] 2 1.6 TO 12.5 KC DATA	8 [007] 2 12.5 TO 100 KC DATA	9 [010] 9 S DETECTOR EVENTS COUNT	10 [011] 20 COLLIMATOR POSITION	11 [012] 20 PM TUBE A STATUS DATA COUNT	12 [013] 20 PM TUBE A DATA COUNT	13 [014] 16 10^{-9} CURRENT DATA	14 [015] 5 Y-AXIS GAIN HI DATA	15 [016] 16 10^{-10} CURRENT DATA	16 [017] 16 10^{-11} CURRENT DATA
R12	17 [020] 8 V1 PULSE HEIGHT DATA	18 [021] 8 V EVENT TYPES & RATES	19 [022] 7 OPERATING MODE & EVENTS COUNT	20 [023] 5 Z-AXIS GAIN HI DATA	21 [024] 2 SIGNAL PHASE 14.7 TO 26.1 KC DATA	22 [025] 2 SIGNAL AMPLITUDE 14.7 TO 26.1 KC DATA	23 [026] 16 10^{-12} CURRENT DATA	24 [027] 5 X-AXIS GAIN LO OR HI DATA	25 [030] 20 COLLIMATOR POSITION	26 [031] 20 PM TUBE B STATUS, DATA COUNT	27 [032] 20 PM TUBE B DATA COUNT	28 [033] A14 OPEP SINE	29 [034] 12 OPEP HIGH DATA OUTPUT	30 [035] 17 COLLECTOR CURRENT DATA	31 [036] 16 10^{-13} CURRENT DATA	32 [037] 8 V3 HIT RATE
R13	33 Δ [040] ACCUMULATED TIME (SECS) 2^{24} – 2^{18}	34 [041] ACCUMULATED TIME (SECS) 2^{17} – 2^{9}	35 [042] ACCUMULATED TIME (SECS) 2^{8} – 2^{0}	36 [043] 5 Y-AXIS GAIN LO OR HI DATA	37 [044] 13 ULTRAVIOLET DATA	38 [045] 13 UV DETECTOR MODE, AMPLIFIER GAIN	39 [046]	40 [047] 5 Z-AXIS GAIN LO OR HI DATA	41 [050]	42 [051] 19 UV FLUX DATA	43 [052] 19 ION AND ELECTRON DATA	44 [053] 19 VOLTAGE AND MODE MONITOR	45 [054] 16 10^{-9} CURRENT DATA	46 [055] 5 X-AXIS DATA HI GAIN	47 [056] 16 10^{-10} CURRENT DATA	48 [057] 16 10^{-11} CURRENT DATA
R14	49 [060] 9 (S+C) HEIGHT PULSE DATA	50 [061] 9 (S) HEIGHT PULSE DATA	51 [062] 11 HOR EVENTS DETECTOR COUNT	52 [063] 11 VERT EVENTS DETECTOR COUNT	53 [064] 11 VERT ENERGY DETECTOR FLUX	54 [065] 11 HOR ENERGY DETECTOR FLUX	55 [066] 16 10^{-12} CURRENT DATA	56 [067] 5 Y-AXIS DATA HI GAIN	57 [070] 6 SENSOR A FREQ COUNT 2^{7} TO 2^{0}	58 [071] 6 SENSOR A FREQ COUNT 2^{8} TO 2^{0}	59 [072] 6 SENSOR B AMPLITUDE OSC	60 [073] 12 OPEP MEDIUM DATA OUTPUT	61 [074] 21 0.5-3 Å DATA	62 [075] 5 Z-AXIS GAIN HI DATA	63 [076] 16 10^{-13} CURRENT DATA	64 [077] 21 2-8 Å DATA
R15	65 [100] SUBCOM WORD NUMBER THIS FRAME	66 [101] XMITTED EG	67 [102] OTHER EG	68 [103] 5 X-AXIS GAIN LO OR HI DATA	69 [104] 1 2.0 MC NOISE COSMIC DATA	70 [105] 1 2.5 MC NOISE COSMIC DATA	71 [106] 1 ANT IMPEDANCE SINE PHASE	72 [107] 1 ANT IMPEDANCE COS PHASE	73 [110]	74 [111] 10 COMM POS, DATA COUNT, PARITY BIT	75 [112] 10 PARITY BIT DATA COUNT	76 [113] 12 OPEP LOW DATA OUTPUT	77 [114] 16 10^{-9} CURRENT DATA	78 [115] 5 Y-AXIS GAIN LO OR HI DATA	79 [116] 16 10^{-10} CURRENT DATA	80 [117] 16 10^{-11} CURRENT DATA
R16	81 [120] 8 H AND V RATES	82 [121]	83 [122] 7 OPERATING MODE & EVENTS COUNT	84 [123] 5 Z-AXIS GAIN LO OR HI DATA	85 [124] 2 SIGNAL PHASE 14.7 TO 26.1 KC DATA	86 [125] 2 SIGNAL AMPLITUDE 14.7 TO 26.1 KC DATA	87 [126] 16 10^{-12} CURRENT DATA	88 [127] 5 X-AXIS DATA HI GAIN	89 [130]	90 [131] 12 MAIN BODY MIRROR POSITION & CALIB MODE	91 [132] 12 OPEP LOG DATA OUTPUT	92 [133] 12 OPEP MIRROR POSITION & CALIB MODE	93 [134] 12 MAIN BODY LOG DATA OUTPUT	94 [135] 17 COLLECTOR CURRENT DATA	95 [136] 16 10^{-13} CURRENT DATA	96 [137] 11 ABSORBER WHEEL POSITION
R17	97 [140] SUBCOM 1 DATA WORD HERE	98 [141] SUBCOM 2 DATA WORD HERE	99 [142] SUBCOM 3 DATA WORD HERE	100 [143] 5 Y-AXIS DATA HI GAIN	101 [144] 12 MAIN BODY MEDIUM DATA OUTPUT	102 [145] 12 MAIN BODY HIGH DATA OUTPUT	103 [146] 12 MAIN BODY LOW DATA OUTPUT	104 [147] 5 Z-AXIS DATA HI GAIN	105 [150]	106 [151] 19 UV FLUX DATA	107 [152] 19 ION AND ELECTRON DATA	108 [153] 19 VOLTAGE AND MODE MONITOR	109 [154] 16 10^{-9} CURRENT DATA	110 [155] 5 X-AXIS GAIN LO OR HI DATA	111 [156] 16 10^{-10} CURRENT DATA	112 [157] 16 10^{-11} CURRENT DATA
R18	113 [160] 9 (S+C) HEIGHT PULSE DATA	114 [161] 9 (S) HEIGHT PULSE DATA	115 [162] 11 HOR DETECTOR EVENTS COUNT	116 [163] 11 VERT DETECTOR EVENTS COUNT	117 [164] 11 VERT DETECTOR ENERGY FLUX	118 [165] 11 HOR DETECTOR ENERGY FLUX	119 [166] 16 10^{-12} CURRENT DATA	120 [167] 5 Y-AXIS GAIN LO OR HI DATA	121 [170] 6 SENSOR B FREQ COUNT 2^{7} TO 2^{0}	122 [171] 6 SENSOR B FREQ COUNT 2^{8} TO 2^{0}	123 [172] 6 SENSOR B OSC AMPLITUDE	124 [173] A15 OPEP COSINE	125 [174] 13 -Z ALPHA LYMAN DATA	126 [175] 5 Z-AXIS GAIN LO OR HI DATA	127 [176] 16 10^{-13} CURRENT DATA	128 [177]

Figure 2 - OGO-2 Main Telemetry Format
Equipment Groups 1 and 2

at the same bit rate as the main frame with the 29 flexible-format words replacing the last 29 words in each of the four 32 word groups in the main frame. For example, Table 1 shows the word sampling sequence for flexible format 12, one of those most frequently used:

Table 1

Word Configuration of Flexible Format 12

X	X	X	20	21	22	23	24
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
9	10	11	12	13	14	15	16

The 32 words shown replace 32 words in the main frame, except the groups of three discussed previously. Flexible format word 10 appears twice in the 32 word format and will therefore recur eight times in the main frame when operating in FF12 mode. Figure 3 shows the sampling rate in the main frame from the various experiments when operating in the various flexible format modes.

Basic formatting and timing is handled in the digital data handling assembly (ddha) (Glaser, 1962) which contains two redundant groups of digital equipment. Two tape recorders are carried, each with a capacity of 43.2 million bits, and the two equipment groups are designed such that while output is being recorded on an on-board tape recorder, the other output may be fed to the transmitter for real time operation to a ground station. The tape recorder operates at a main

EXPERIMENT NO.	INPUT NO.	SAMPLES PER MAIN FRAME																															
5009	1	28	56		12					12		4		12		4	4												4				
5009	2	28	60		12					12		4				4													4	12			
5019	3	28			12					12		4			12	4	4												4				
5019	4	32			16					16		8				8													8		12		4
5011	5			28	16						12	8		12		8	4												8				4
5011	6			28	16						12	8				8													8	12			4
5014	7			28	16						12	8			12	8	8												8				4
5013	8			32	16						16	8				8													8		12		4
5017	9					28	56		12	16		8	8	12			8															4	4
5006	10					28	60		12	16		8	8																	12		4	4
5006	11					28			12	16		8	8		12		8															4	4
5002	12					32			16	16		8	8																		12	8	4
5015	13							28	16		16	8	8	16			8															8	4
5015	14							28	16		16	8	8																	16		8	4
5014	15							28	16		16	8	8		16		8															8	4
5015	16							32	16		16	8	8																		16	8	4
501[illegible]	17												4	16		8	8	28	56		12					12		4					4
5012	18												4			8		28	60		12					12		4		16			4
5006	19												4		16	8	8	28			12					12		4					4
5006	20												8			8		32			16					16		8			16		4
5012	21												8	16		8	8			28	16						12	8					4
5012	22												8			8				28	16						12	8		16			4
5014	23												8		16	8	8			28	16						12	8					4
5012	24												8			8				32	16						16	8			16		4
5016	25													16			8					28	56		12	16		8	8			8	4
5016	26																					28	60		12	16		8	8	16		8	4
5016	27														16		8					28			12	16		8	8			8	4
5016	28																					32			16	16		8	8		16	8	4
5020	29													16			8							28	16		16	8	8			8	4
5020	30																							28	16		16	8	8	16		8	4
5014	31														16		8							28	16		16	8	8			8	4
5002	32																							32	16		16	8	8		16	8	4
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
		FORMAT NUMBER																															

Figure 3 - OGO-2 Flexible Format Assignments Chart (Caughey and Quann, 1965)

frame rate of 4000 bits/sec (4 kbs) and can record for three hours; the two recorders have a total storage capability of six hours. The recorders read out to ground at 128 kbs enabling them to play back to ground in about 12 minutes when both are filled to capacity. The ddha can also operate at 64 kbs and 16 kbs, upon ground command, when in the real time mode.

The ddha provides accurate timing pulses (stability better than one part in 10^5, Farthing and Folz, 1966 and Ludwig, 1963) to the experiments at rates of 10 pps and 1 pps. The 1 pps signal is counted within the ddha and the (cumulative) count is stored in the spacecraft clock register. This clock register is interrogated by the telemetry system once each main frame.

3. MAGNETOMETER AND ASSOCIATED INSTRUMENTATION

The magnetic field data originates with the output of an optically pumped, self-oscillating, rubidium vapor magnetometer (Farthing and Folz, 1966) (using Rb^{85}). The resulting frequency (in cps) is equal to 4.66737 times the scalar magnitude of the ambient magnetic field (in gammas). This frequency is sampled on alternate half seconds by two electronic scalers, designated Scaler A and Scaler B. The sequence of events is as follows (see Figure 4):

a) One second timing pulse from spacecraft occurs.

b) Scaler A samples data for approximately 1/2 second (determined by counting the 10 pps signal).

c) While Scaler A is sampling data, Scaler B is available for readout to both equipment groups. The information readout will be the count accumulated during the previous half second.

The output from each scaler consists of an accumulated count of up to 18 bits. Scaler A output appears in main frame words 57 and 58 and flexible

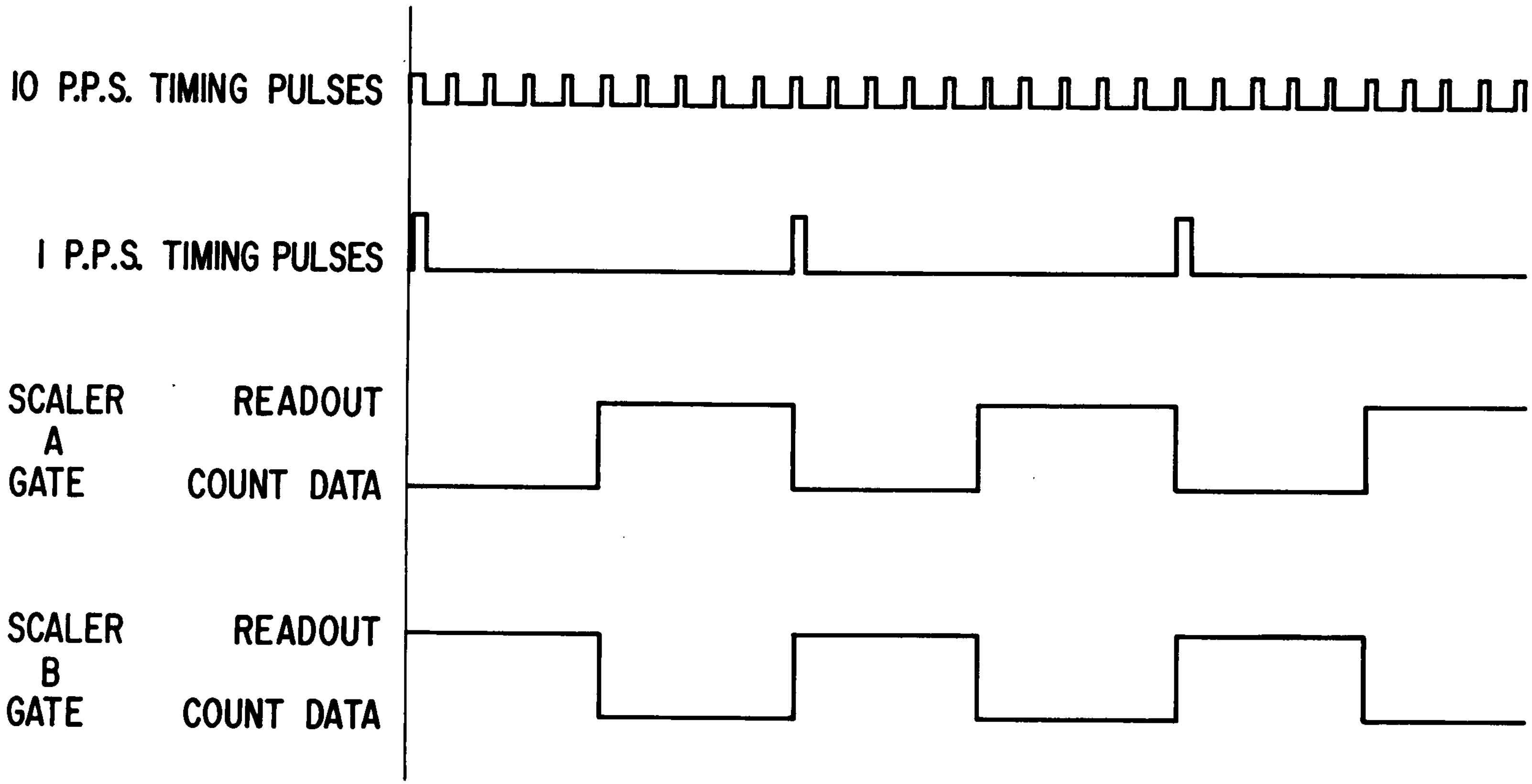


Figure 4 - Timing Sequence for Data Digitization

format words 10 and 11; Scaler B output appears in main frame words 121 and 122 and in flexible format words 19 and 20. Since the spacecraft operates at 4 KBS, 16 KBS, or 64 KBS and the main frame consists of 1152 bits (128 nine-bit words), the main frame will be read out in .288, .072, and .018 seconds respectively and the spacecraft sequence durations (see Section 2 for definition of a spacecraft sequence) will be 36.864, 9.216, and 2.304 seconds. Because of the rate difference between the half second sampling times and the times between readouts, the same data point may be read out in more than one frame. At 4 KBS it is possible to have either one or two complete readouts (or one complete and one partial). At 16 and 64 KB main frame, and for flexible formats at all bit rates, more than six readouts will occur for each data point. When the experiment is interrogated during the half second allocated to counting the value readout will be zero.

In addition to the digitized field data, various engineering data is telemetered to ground from the experiment. These include the amplitude of the magnetometer signal, temperatures at critical points in the instrument, power and heater status and the band selection of an electronic comb filter used to increase the signal to noise ratio of the magnetometer signal before scaling. These occupy main frame words 59 and 123, and words 6, 50, 51, 52, 70, 114, 115, and 116 of one of the subcommutators.

4. DATA REDUCTION BEFORE DATA REACHES THE EXPERIMENTER*

Data from the spacecraft is recorded on analog tape at two primary and four secondary ground stations:

*Caughey and Quann, August 1965.

Station Location	Code Name	Code	Function	Antenna	WWV Delay
Gilmore Creek, Alaska	ULASKA	19	Primary	85 ft.	17.9 ms
Rosman, No. Carolina	ROSMAN	20	Primary	85 ft.	3.6 ms
Johannesburg, S. Africa	JOBURG	16	Secondary	40 ft.	45.7 ms
Quito, Ecuador	QUITOE	5	Secondary	40 ft.	16.1 ms
Santiago, Chile	SNTAGO	8	Secondary	40 ft.	28.7 ms
Winkfield, England	WNKFLD	15	Mobile	14 ft.	20.8 ms

Each analog tape contains seven tracks of information; two of these contain the PCM spacecraft data, two contain WWV (received) based time (this is corrected at GSFC for transmission time by the amounts shown above), one contains a 10 kc signal to aid digitization and time interpolation, and one contains the recorded WWV signal.

The raw analog tapes are sent to the Telemetry Computation Branch at GSFC where several significant steps (Figures 5 and 6) are performed. The more important of these are:

1. Analog to digital conversion.
2. Editing. This includes quality control checks and all necessary time corrections.
3. Decommutation. Separation of data by experiment.
4. Reformat for the IBM 7094-7040 DCS computer (applies to this experiment only).

The format of the tapes coming to us includes the following:

A. The first file on each tape is a summary of the data on that tape.

B. The data is organized into files with the following characteristics:

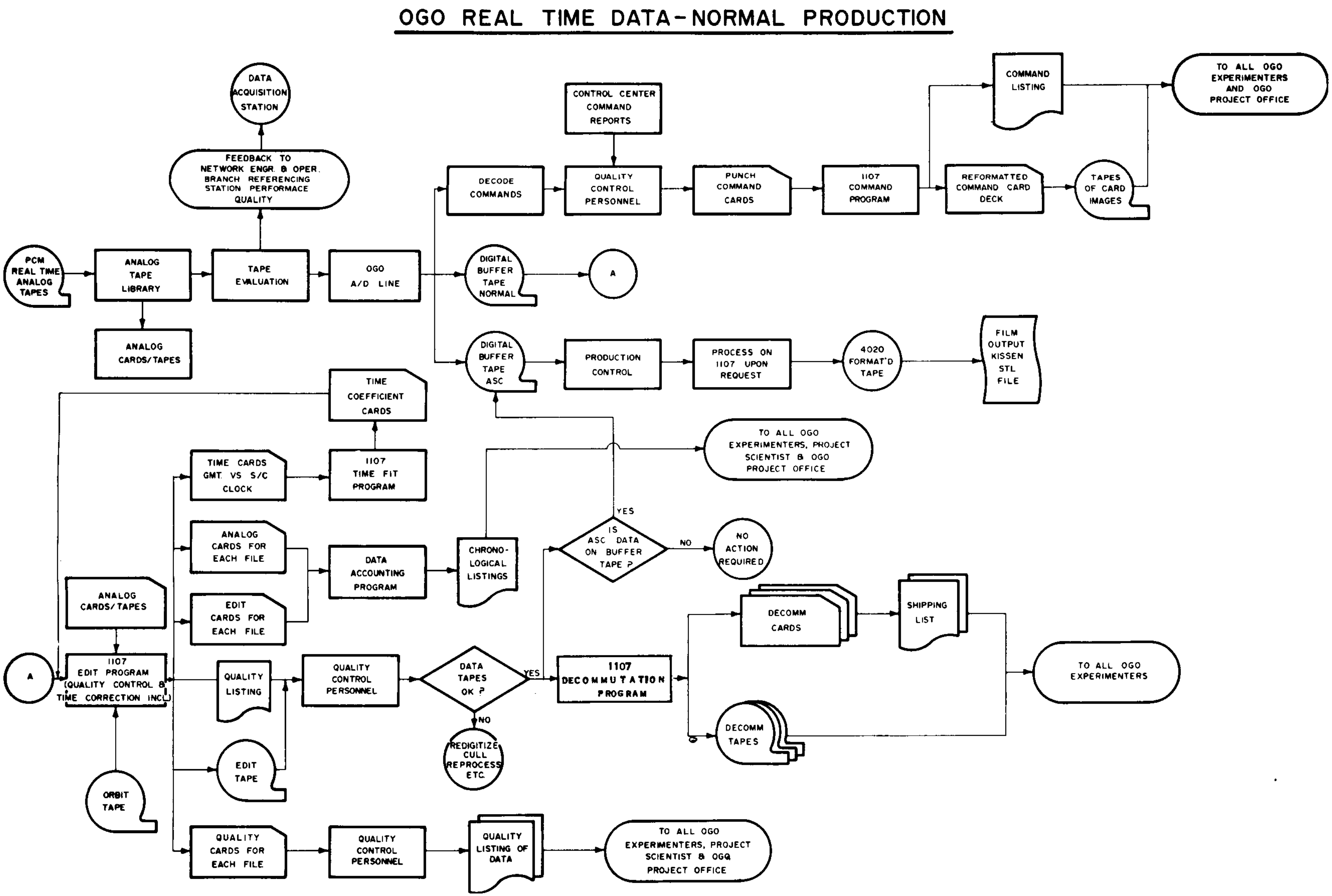


Figure 5 - OGO-2 Real Time Data - Normal Production by Telemetry Computation Branch (Caughey and Quann, 1965)

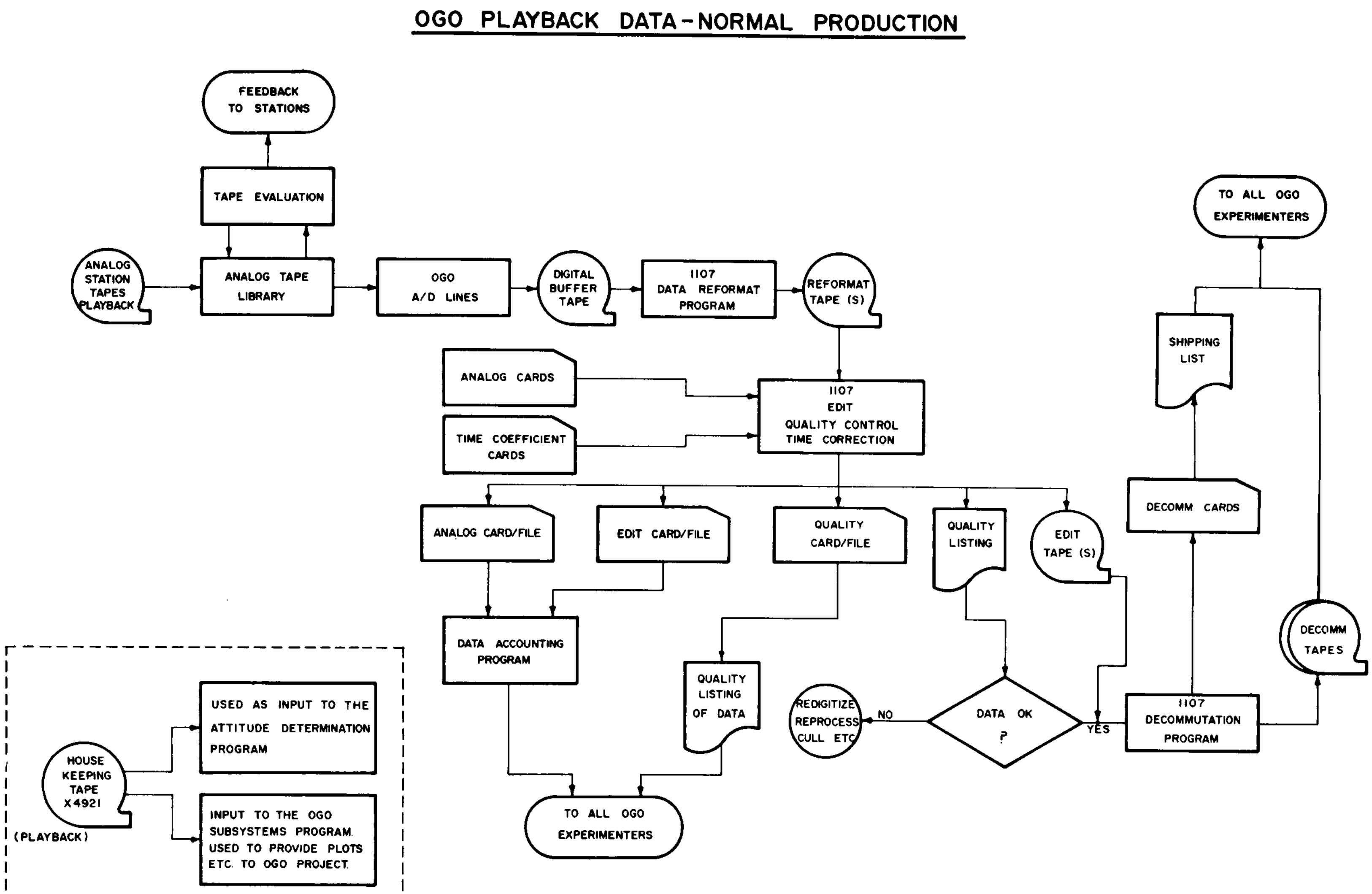


Figure 6 - OGO-2 Playback Data - Normal Production by Telemetry Computation Branch
(Caughey and Quann, 1965)

1. Data within a file is all from the same (Greenwich) day.

2. Data within a file is all of the same format (as regards bit rate, etc.).

3. Data within a file is all from a particular ground station.

Each file begins with a label record describing that file (including the date).

C. Each data record contains the data from one spacecraft sequence including:

1. The time of the first bit of the sequence.

2. The time of some high resolution point (to be defined later) occurring within that sequence (if determinable).

3. The clock readouts from the spacecraft.

4. The experiment data itself.

This means that one record contains 36.864 sec. of data at 4 KBS, 9.216 sec. at 16 KBS, and 2.304 sec. at 64 KBS.

5. OUTLINE OF EXPERIMENTER DATA REDUCTION PROCEDURES

Up to this point we have described only steps through which the data passes before coming to the experimenter. The data is essentially still "raw." This raw data is then run through a series of computer programs (on an IBM 7094-7040 direct couple system) to:

1) Weed out suspect data

2) Provide a tape of good data suitable for analysis.

A detailed description of the procedures will follow in subsequent sections. A brief description is as follows:

A. The bulk of the processing, including the weeding out of the suspect data is done in the "MAIN PROCESSOR." (See Figure 7) The data is divided

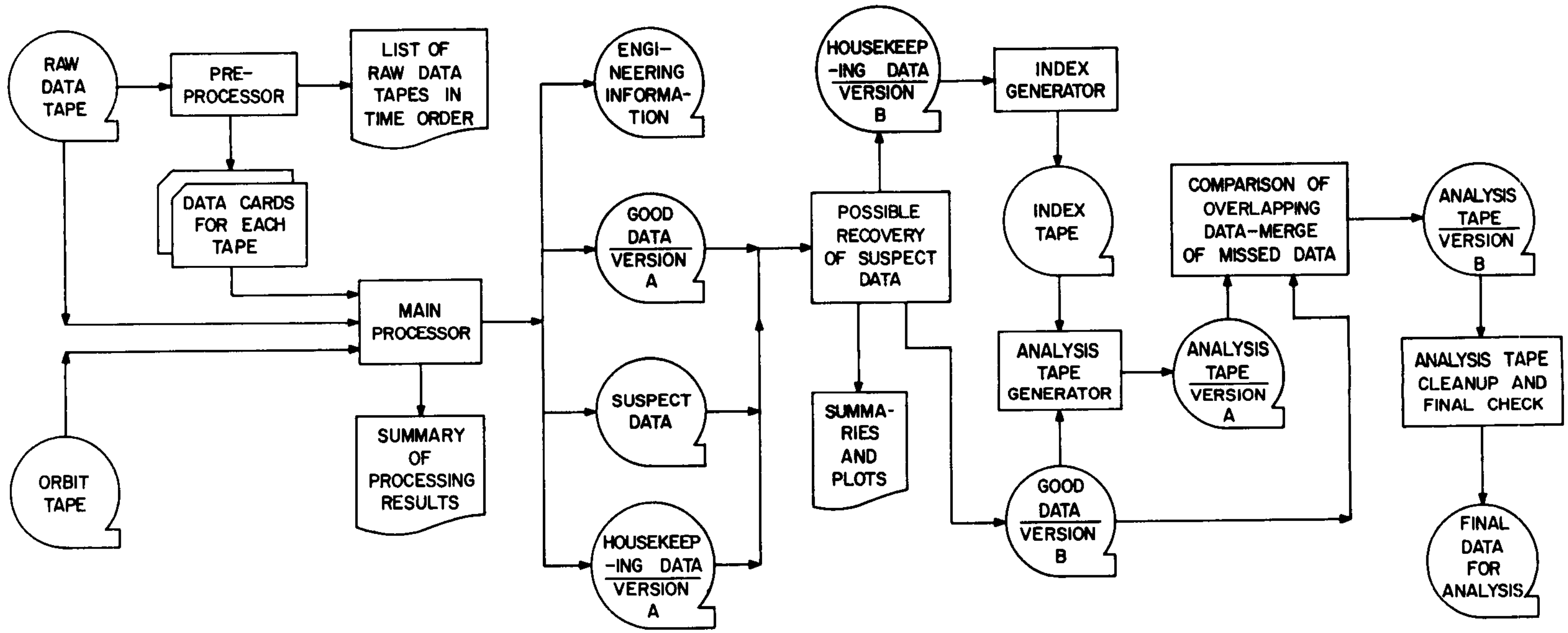


Figure 7 - Data Processing Flow. Applicable to Both R.T. and C.S.P. Data

into three categories and output onto three data tapes (Engineering Information, Good Data, and Suspect Data); a fourth tape contains housekeeping describing the input, what was accomplished and what kinds of data output occurred. Data is processed in the order specified by a set of data cards fed to the program and may be out of time order. No attempt is made to eliminate or flag redundant data.

B. Before being fed to the main processor, the data is preprocessed. This results in a printed description of each tape, the tapes being described in order of their start times. The preprocessor also punches the data cards necessary for the main processor.

C. The data considered suspect in the main processor is examined (by plotting, etc.) and where possible is reprocessed.

D. After recoving as much suspect data as is worthwhile the data needs to be time ordered with redundant data removed. This is done by creating an index to the data such that each entry in the index contains a contiguous span of data (i.e. no significant time gaps). These entries are then time ordered and compared with one another to check for redundant data so that the final index contains entries in time order with redundant data flagged. The non-redundant entries are then used to create, from the Good Data tapes, a preliminary version of an analysis tape which will be in time order and will not contain redundancies.

If a significant amount of overlap occurs in the data, the data from the various sources is compared and at the same time any non-redundant data missed in the first generation of the analysis tape is retrieved and a new analysis tape is generated.

Finally, the analysis tape is run through a program designed to detect and remove any remaining erroneous data before the analysis tapes are released to the data center for general distribution.

6. CULLING OF SUSPECT DATA

In the main processor (Figure 7) a series of tests are performed on all data with the object of separating out any data which is in any way suspect. These tests, aside from tape format checks, fall into four main categories: i) Engineering Tests, ii) Status Field Tests, iii) Tests on the Data Itself, and iv) Time Tests.

i) Engineering Tests

a) Power. Four separate sub units of instrumentation are contained in the experiment; two sensors and two scalers. In normal operation these are all turned on, but occasionally power has been turned off to one or more units. As long as at least one sensor and one scaler is on, some data will be retrievable. The program checks the power conditions and ignores all "data" from power off conditions.

b) Temperature. The sensors of the Rb^{85} magnetometer are critically temperature sensitive and may give spurious data if the temperature is not properly controlled (Farthing and Folz, 1966). The temperatures at the critical points are monitored and the program checks this information and classes data as suspect if the temperature goes beyond certain limits. In operation, the instrument has not departed from its design temperature sufficiently to affect the data.

c) Comb Filter. An electronic comb filter is inserted in the spacecraft electronics previous to scaling to enhance the signal-to-noise ratio (Farthing and Folz, 1966). The status of this filter is contained in subcommutator words 6 and 70 and is checked for validity by the program. If the filter malfunctions, the data will be considered suspect. This test has, as yet, rejected no data.

d) Amplitude. The magnetometer sensors occasionally become oriented relative to the field vector such that their output voltage becomes excessively low, a condition known as a null zone (Farthing and Folz, 1966). When operating in main frame format (not flexible format), the amplitude from each sensor is sampled once each frame. As long as the sum of the sensor amplitudes is sufficiently high, the data will be scaled correctly; however, if this amplitude becomes too low the scalers may count noise or the comb filter may track the third harmonic of the magnetometer frequency. The critical voltage level varies with the magnitude of the field being measured. This was carefully determined before launch and the program considers any data suspect when the voltage reaches a level slightly greater than the highest possible voltage at which spurious scaling can occur.

In the flexible format mode, telemetry words are not available on which to transmit the amplitude data. In these cases we must rely on the other tests to remove any data which is erroneous. We believe this is being done satisfactorily, although it is impossible to be certain.

ii) Status Field Tests

During the Edit and Decom phase of their data processing, Telemetry Computation Branch assigns a 36 bit status field to each frame. This status field indicates the following:

a) Whether or not time is corrected. (The definition of corrected time will be discussed under Time Tests.)

b) The number of bit errors in the frame sync words.

c) The type of data in the frame.

d) A flag to indicate if the frame is so poor as to be totally ignored by their program. When a frame of this nature occurs, Telemetry Computation Branch substitutes a word with a characteristic bit pattern in place of our data word. This insures proper record sizes. These frames are called "fill" frames. If an entire record is "fill" it will not appear on the decom tape.

e) The subcom count, a number from 0-127

f) Miscellaneous flags which are meaningless after the decom phase.

The following checks are made on these items:

a) The subcom count is verified.

b) Fill data is checked for and these frames are ignored but counted.

c) The data type is verified.

d) The time flag is verified.

e) The bit errors in the frame sync word are checked for excessive telemetry noise.

Any verification failures, fill frames or excessively noisy frame sync words result in the data being suspect.

iii) Data Tests

These tests are applied to the data themselves and, considered as a whole, have proven very successful in weeding out bad data.

a) Redundant readouts. It has been previously mentioned that frequently the data counted during one half second may be read out in telemetry frames more than once during the next half second. The program knows the time relationships between the timing pulses and the readout times and can predict when multiple readouts will occur and how many to expect (from 2 to 25 depending upon format). If a certain number (always greater than 80%) of these are not equal the data point is considered suspect.

b) Reference check. Since the theoretical descriptions of the earth's field in the range of altitudes traversed by POGO is already known to within a few percent, a good method of detecting severe error is to compare measured and theoretic field. The theoretic field currently used is the GSFC(4/64) field (Cain, et al., October 1964). If the measured field differs by more than 500 gammas for this theoretic field, the data point is considered suspect.

   In order to minimize the computation necessary in this check, an approximation to the theoretic field is used. This is determined by choosing three field points spaced no more than 37 seconds (of time) apart on the orbital path of the satellite. A parabola passing through the three points is computed and, for times lying within the two end times, the result is used for the theoretical field.

Extensive tests were made which indicate this approximation to be within one gamma of the original theoretic field.

All previously discussed tests result in individual data points being considered suspect. It is felt, however, that when the amount of data points considered suspect reaches a certain percentage of the total data input that it would be wise to reject entire records of data (A record, you will recall, is one spacecraft sequence, 36.864 seconds of 4 KB data.) and this procedure is followed for both of the above described tests. Some checks apply only to entire records being rejected; these include the next two to be discussed.

c) Zero check. When the ddha interrogates a scaler during the half second when the scaler is counting, the readout will be zero. If these readouts are non-zero when we receive the data, then the spurious value has been substituted for the original zero sometime between the interrogation by the ddha and the output by the decom program of the Telemetry Computation Branch. Presumably these non-zero values result during the A/D conversion whenever the S/N ratio is poor. For 4 KBS main frame data, a count is kept of the number of these readouts which are non-zero. This is believed to be a measure of the quality of the telemetry process. If the count exceeds a certain limit (currently set at six for each scaler, i.e. if the count for one scaler reaches six), the entire record is considered suspect.

d) Differencing check. The difference test is a limit test of the second differences of the data. Whenever three successive data points are available (i.e. not rejected by a previous check) the second difference is computed, and if it is too large a counter is advanced. The current limit used for the second difference is 20 gammas. If the counter becomes too large the entire record is considered suspect. The current limits on the counter are 15 at 4 KB, 5 at 16 KB, and 3 at 64 KB. Due to the fact that this test does not reject individual data points it has proved useful only under circumstances where the data has a significant amount of scatter but is not erroneous enough to fail the reference check.

iv) Time Tests

It is extremely important that the correct time be associated with each data point. OGO-2 may encounter field gradients of up to 40γ/sec (see Section 11, Data Quality) which gives a possibility of an equivalent error of 1γ if the time is incorrect by 25 msec.

There are essentially two different timing rates associated with the spacecraft: 1) the timing pulses, from which the counting periods for the scaling of the magnetic field data are determined and 2) the data readout times which determine the format of the data received by the experimenter. (Both of these timing pulses are derived from the same master oscillator.) In order to process the data, we must know the relationship between these timing rates and, in order to assign correct time to the data, we must have an accurate estimate of the Universal Time of each timing pulse. The main difficulty in accurately determining time stems from the fact that the telemetry contains no direct indication of when the timing pulses are occurring.

If the data format is carefully examined, it is soon apparent that the relationship of the two timing systems forms a predictable pattern. For example, at 4 KBS it takes .288 sec. to read out one frame, i.e. the clock register is interrogated every .288 seconds. If we examine Figure 8 we see clearly the type of pattern which emerges. In the first, third, and fourth seconds three readouts occur (in .576 seconds) and in the second and fifth seconds four readouts occur (in .864 seconds). The normal pattern is an alternating 3-4; three identical readouts, then four, then three, then four, etc. This is occasionally interrupted by two successive threes, as seen in the third and fourth seconds of Figure 8. When this occurs the clock readout immediately preceding (or following) the 3-3 combination is called a high resolution point (H.R.P.) because the 1st readout <u>after</u> or <u>before</u> the 3-3 is within 16 milliseconds of a clock update. At 4 KBS this 3-3 occurs twice each 125 frames and then the entire pattern repeats. If both 3-3 combinations are found, the relationship between the two time systems can be determined to ±4 MS because the two 3-3 combinations occur 19.008 seconds apart whereas the associated timing pulses will be 19.000 seconds apart. Similar patterns occur at 16 and 64 KBS which allow resolution of the two time systems to at least ±4 MS. The relationship between the two time systems is always determined by finding high resolution points, resulting in a possible error of ±4 MS.

Turning our attention to real-time data only, recall that, as the data from the spacecraft is recorded on analog tape at the ground station, various time signals are also recorded. These time signals

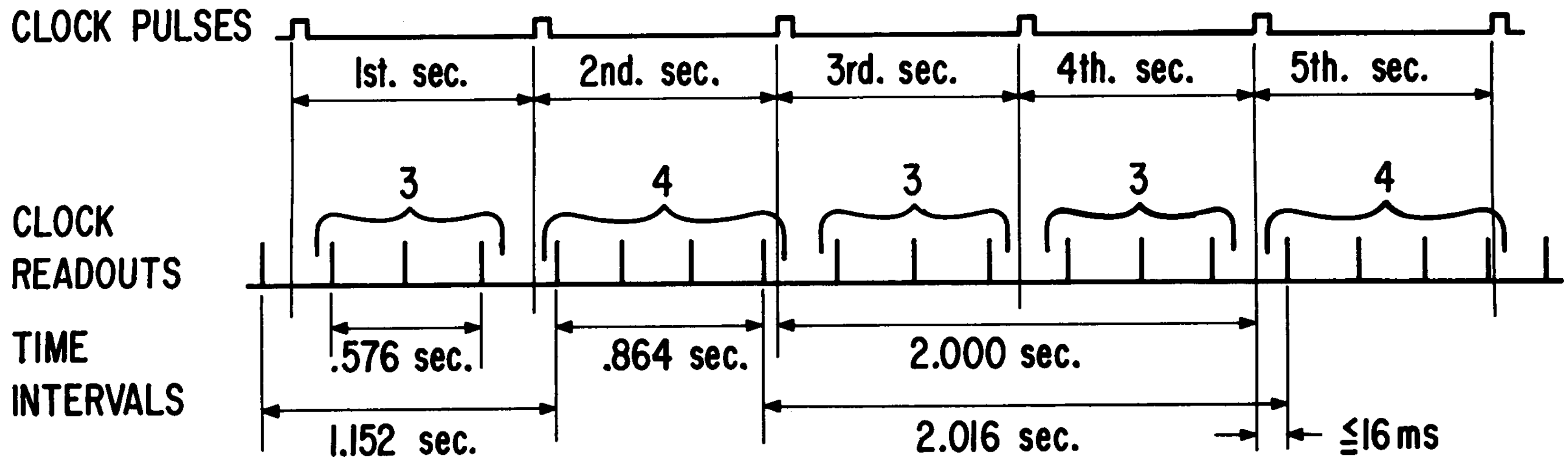


Figure 8 - Clock Readout Patterns

are decoded in the STARS-1 time decoder (Demmerle, et al., 1964) as part of the A/D conversion, assigning U.T. to each frame as it is digitized. These Universal Times are subsequently corrected (Caughey and Quann, August 1965) for transmission time delays from 1) WWV to the ground station, and 2) satellite to ground station. At this juncture what is known as "time fitting" (Caughey and Quann, August 1965) occurs. For a particular time interval a series of high resolution points are determined from a selected sample of edited real time data. This results in a series of clock counts and associated universal times which are fed as data to a program which uses the least squares technique to determine a linear relationship between clock count and universal time. Maximum residuals to these fits are usually less than 20 milliseconds, often considerably less; typical root-mean-square residuals are on the order of 3-9 milliseconds. The residuals are due to a combination of several factors; the most obvious are: 1) short term drift of the spacecraft clock, and 2) inaccuracies (and variability) of the transmission time from WWV to the ground station. No further fitting has been attempted, the results of the time fit being "fed back" into the edit program so that all times on the data received by the experimenter are derived from the fit.

Playback data entails a different procedure since the U.T. on the analog tape is meaningless. Time is assigned to the playback data by finding a high resolution point and then determining the U.T. from the fit derived from real time data during the same time period.

All of the above time correction is performed by the Telemetry Computation Branch of GSFC before their Decom run, and only the results are seen by the experimenter. When we receive the data the time should be fully corrected in that all transmission times have been accounted for and the relationship between readout time and the data counting gates should be established to ±4 ms. As a cross check, however, we enter as parameters into the main processor 1) the slope of the applicable time fit and 2) the time of some clock count during the day for each day. These parameters are sufficient so that given a U.T. we can easily determine if it lies on the curve computed in the applicable fit. At the start of each data file the program searches for a high resolution point (H.R.P.) and, if one is found, compares it to the correct fit. If it differs by more than 26 milliseconds the entire file is considered suspect. If the data is so bad that we are unable to determine a H.R.P. but we are furnished with one on the tape, the one furnished is compared with the fit, using the same (or more stringent) criteria for passing the test. If a H.R.P. is found and we are furnished with one on the tape, both are compared to the fit. The 26 milliseconds was arrived at empirically. Ideally this limit should be 12 milliseconds since their error is supposed to be ±4 milliseconds and our H.R.P. determination is accurate to ±8 milliseconds. When comparing their input H.R.P. to the time fit the limit should ideally be 4 milliseconds. In practice, for C.S.P. data, the H.R.P. furnished on the source data tapes are rarely over 1 ms. from the time fit and our computed H.R.P. are usually within the 12 ms. although a few cases of differences up to 20 ms. have been found. For real time data the high resolution points usually fall between 1 and 20 ms. from the time fit. We have recently discovered that the 16 KB time checks are usually within 8 ms. while the 64 KB time checks are usually between 12 ms. and 22 ms. We conclude that the 64 KB times are in error by the time necessary to read out one frame, i.e. 18 ms. The source of this error is not yet known except that it is present on the tapes which we receive from Telemetry Computation Branch.

A time test is also performed for each record within the file before it is processed except that if a H.R.P. is furnished on the tape no search is made for one in the data.

Another type of time check is made at the start of each record. One of the input times in our data is the time of the first bit of the sequence making up the current data record. Since each data record covers a fixed period of time, the input time can be compared to a previous input time. The difference between those times is required to be equal to the time required for an integral number of records to occur. The accuracy required in this test is ten milliseconds.

These tests have proved very successful. For example, several programming errors were discovered in the Edit program of the Telemetry Computation Branch which resulted in a high (about 25%) percentage of real time files with bad time. These were rejected immediately by the program. Inaccurate time has not been a major problem with playback data except in a few instances. In the early phases of data reduction we were receiving data which contained a time error which slowly accumulated within a file at a rate of about ten milliseconds per hour of data. This error was detected on those files whose time span exceeded 1.5 hours, the nature of the error was determined, and our programs fixed to eliminate the error.

In summary, the tests are performed in the following sequence:

A. Once each file

1) A basic tape format check

2) An extensive time check

B. Once each record

1) A basic tape format check

2) A limited time check

3) Engineering parameter check

C. Each data point

1) Status field check

2) Reference check

3) Zero check

4) Difference check

7. OUTPUT FROM MAIN PROCESSOR

While performing tests upon the raw input data the main processor also routes it onto three output data tapes and creates a housekeeping tape containing the pertinent processing parameters. These four tapes have a standardized format as follows:

A. The first file on each tape is a tape label (containing one ten-word record) identifying the tape number and the type of data on the tape. The tape label is further described in Appendix A.

B. Each successive file is a data file. The first record on each data file, for all four tape types, is a (15 word) record, called a File Housekeeping, describing the file.

C. All records following the File Housekeeping are data records. These are peculiar to the type of tape involved.

Each input file is processed as an entity and, if it results in output of a particular type, all of that output will be contained in the same file on each output tape. Thus each input file results in one File Housekeeping record which is always output onto the Housekeeping tape. If the entire file is suspect (e.g. erroneous time or erroneous tape format) the only other output will be to the tape containing suspect data (called the Garbage tape). If, on the other hand, some good data results, the File Housekeeping will also be written on the tape containing engineering information (called the Subcom-Amplitude tape, or SATAPE), and the tape containing good data (called the Good Data tape). Since the File Housekeeping applies to only one input file, all information describing that input file is placed in the file housekeeping including the date and data type. For a complete description of the contents of the File Housekeeping see Appendix A.

Just as each file, so each input record is processed as an entity, unless the entire file is suspect. This always results in a record on the housekeeping tape but only results in outputs on the other tapes in the following circumstances:

Conditions	Good Output	Suspect Output	Engineering Output
Record rejected for bad power, temperature, or filter	No	Whole record	Yes

Conditions	Good Output	Suspect Output	Engineering Output
Record rejected for null zone	No	Whole record	Yes
Record rejected for bad time	No	Whole record	No
Record rejected for excess bad data	No	Whole record	Yes
Record has all good data	Whole record	No	Yes
Record has some suspect data, some good data	Yes	Yes	Yes

Modified Julian Time is used on all output tapes. This representation of time consists of a day number (e.g. January 1, 1900 is day 15020) and a fraction of that day (UTC), measured from midnight (e.g. noon, U.T., = .5). The day number is contained only in the file housekeeping records and the fraction of day appears in other records as needed.

The simplest data output format is that of the good data tape where all records after the File Housekeeping contain two words (floating point) for each data point, 1) the fraction of day at the center of the counting interval for this data point (precision approximately one millisecond) and 2) the measured magnetic field. Detailed data formats for the other tapes will be found in Appendix A.

Since the order in which the data appear on the output tapes from the main processor is the same as the order in which the source data were processed, it is worth noting that on our source data tapes all data within a file is in time order, although large time gaps may occur. The start time of all files on an input tape are also usually in time order, although the files from different tapes may interleave. It is also possible to have the same data recorded more than once, both real time and recorder playback, since on occasion the satellite is visible to two (and, rarely three) ground stations simultaneously. This results in output tapes which are not completely in time order and which contain redundant data.

8. RECOVERY OF SUSPECT DATA

The checks performed on the data in the main processor may consider data suspect, and consequently reject it, on one of three levels. If only a few data points in a record are suspect they may be output to the suspect data tape as individual points without rejecting the entire source record. If, however, some data check is failed by too many points or the record fails an engineering or time test, the entire record will be output to the suspect data tape. The worst case is when an entire file is of such a nature as to be unprocessable and is consequently rejected in its entirety. When designing the Main Processor (see Section 13) it was decided not to mix good and suspect data on the same output tape. At that time little was known of the types of suspect data which would arise in practice or of what recovery techniques might be possible. As of this writing a recovery program has been written and successfully applied to the command storage playback data from the period 10/14/65 to 10/24/65. The program was then revised in the light of our experience with the October data and applied to the data from 10/29/65 to 11/15/65. It is these results which are reported here.

In considering the recovery problem, the real time data is in a different class from the playback data because the number of real time data points is less than 1/5 that obtained from playback data. Since the effort necessary for the recovery of real time data is about twenty times more per data point than for playback (due to the multiplicity of readouts for each data point resulting from the higher bit rates), making a recovery effort very costly for the small amount of data which might be retrieved, we decided to make no effort to recover suspect real time data.

Two criteria determined whether or not we attempted to recover suspect playback data: 1) is it in a chunk large enough to be significant for the analysis of the data, and 2) is there a reasonable chance of recovering a significant amount of the chunk.

As discussed in Section 6, suspect data falls into four broad categories:

1. Format or tape read errors rendering the data unprocessable
2. Entire files rejected when the time differs from the time fit
3. Entire records rejected because
   a) power was turned off
   b) a null zone has occurred
   c) time is inaccurate
   d) the data itself fails a test
4. Individual data points rejected because the data itself fails a test.

Approximately 1.2% of the total data set falls into category four. This data is widely scattered throughout the total data set and no recovery was attempted. We are unable to cope adequately with data in Category 1; this data is reprocessed by the Telemetry Computation Branch after which it goes back through the main processor.

Some file level time rejections (Category 2) were found to be caused by the input times being placed in the record preceding the correct record. These were easily corrected and most of the data successfully recovered. Inaccurate time on individual records caused only one large block of data to be rejected (as of this writing). This large block was found to be due to a slowly accumulating time error (see Section 6, Time Tests) whose rate of accumulation was found, the times corrected, and most of the data recovered.

It was found for records being rejected because too many data point failed the reference or zero tests, that, in most cases, more individual data points could be rejected before considering the entire record suspect. This procedure does not unduly increase the number of bad points escaping detection, and it is these types of suspect data which form the bulk of the data recovered.

The process of recovery proceeds as follows:

A. Data processing summaries are examined to find where chunks of rejected data over 5-10 minutes long have occurred.

B. If the underlying cause of rejection is not understood (as with most suspect time) printouts of the original data records are carefully examined (by hand) to gain an understanding of the problem.

C. If there is any doubt as to the recoverability of the data or as to the quality of the data being recovered, plots of both measured field and ΔF (measured field minus theoretical field) are made and examined carefully.

D. Only after the reason for the data being suspect is thoroughly understood and the recoverability is established does the actual recovery take place. At this time the original housekeeping record (or file) is flagged, indicating that the data has been reprocessed, and a new housekeeping file is added to the housekeeping tape summarizing the results of the recovery attempt. The recovered good data is organized into new data files and added to the end of the good data tape applicable to the period of time into which the data falls.

Reprocessing consists of passing the data through the same tests as are in the main processor with the rejection levels reset so that most of the data will no longer be rejected. In addition, the reprocessed data is selectively plotted to be sure the resulting data is of acceptable quality. For data from times subsequent to 10/24/65 an additional data check has been added during reprocessing of suspect data. After all other tests have been performed on a record (since this is always playback data, one record is 36.864 seconds of data), an array of measured minus theoretical field, called ΔF, (theoretic field computed as described in Section 6, iii, b) is formed. A least-squares, linear, fit is made to the ΔF array and the average absolute deviation from the fit is computed. Any points deviating by more than five times the resulting average are then rejected. If the resulting average is above .4 gammas the fit is repeated, up to five times, unless two successive fits result in the same average. If after all iterations have been completed the average is still above 2 gammas, none of the data is accepted.

9. A TIME ORDERED INDEX

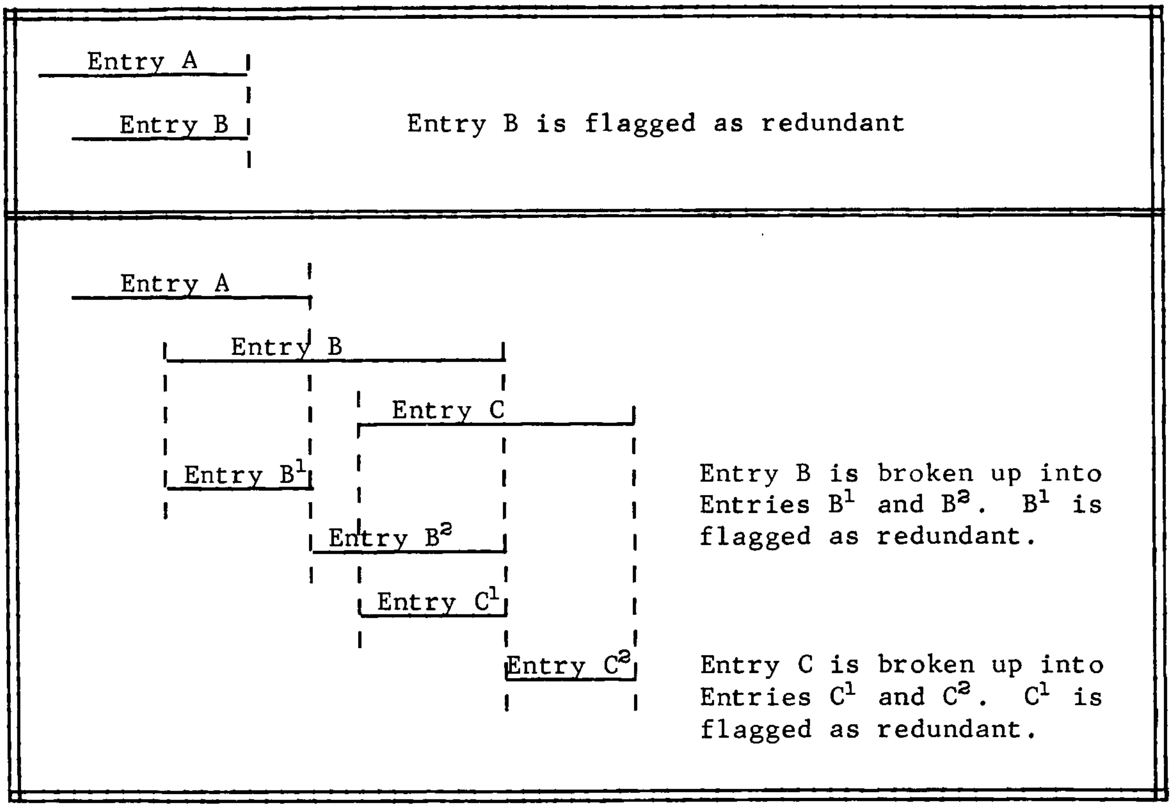
When planning and coding the main processor we naively assumed that we would receive the data in time order and with redundant records removed by the Telemetry Computation Branch choosing the best of those that overlap. In practice none of these criteria are completely met. The data is processed in time order insofar as is possible but there remain a significant number of overlapping and out-of-order files. In fact, some files have time gaps of 2-3 hours where the data from the gap is contained in a different file. The housekeeping tape was originally intended to serve not only as a summary of the data processing procedure but also as a handy index, time ordered, to the data. It was soon apparent that time-ordering the housekeeping tapes and flagging redundant data during the data reduction process would entail a large programming effort and use large amounts of computer time. At this juncture the concept of an index tape was invented.

The generation of an index tape occurs in three steps. First, the housekeeping tape is scanned and, as long as there are no time gaps over five minutes, one entry is made in the index tape for each file. This includes the following information:

1) Housekeeping tape and file number
2) Good data tape and file number
3) The date
4) The start and stop fraction of day
5) The number of records on the housekeeping file
6) The number of records on the good file
7) The start and stop record numbers on the housekeeping tape
8) The start and stop record number on the good data tape

If a time gap (or gaps) of over five minutes occurs, more than one entry per file will result; thus the data described by an entry will contain no time gaps of over five minutes. The second step in the process is to order the index entries by time.

In the third step, redundant data is flagged. This is done by considering successive entries on the index; we know that the earlier entry begins before (or at the same time as) the following one. If the times of some entry are completely contained within the times of a previous entry, the (later) entry is flagged as redundant. If part of some entry is contained within the times of an earlier entry, the later entry is broken up into two (more if necessary) entries so that each either completely overlaps the earlier entry (and is flagged as redundant) or does not over overlap at all. The following figure illustrates the process:



The resulting final index tape contains entries which are in time order with redundant data flagged. It is to be noted that when two entries overlap (i.e., one is flagged as redundant), they may not contain completely overlapping good data because data from one may have been suspect when data from the other was not. (This may arise, for instance, if two ground stations receive a tape playback simultaneously but with a large difference in the quality of the telemetry.)

10. DATA FOR ANALYSIS

The end product of any data reduction procedure must be a data set in a form both suitable and convenient for analysis of that data. We have used the following criteria for our final data tapes, called Analysis Tapes:

1. The data should be easily accessible to the FORTRAN programmer.
2. The data should be in time order, each data point appearing only once on the tape (i.e., no redundant data).
3. Only good (non-suspect) data should appear on the tape.

The resulting format is a binary tape generated by IBM 7094 FORTRAN IOCS and therefore readable by same. It contains no tape label. All records are two hundred (200) words in length and each file contains all the (available, good) data from a particular day. End-of-tape is indicated by two successive tape marks. Within each file the first record is a label such that the first word contains the modified Julian Day number of the data in that file and the second word contains the day number (MJD) on which the file was generated from the good data tapes. Both of these words are fixed point and the rest of the words in the record are unused.

Each data record contains 100 data points, each in two floating point words, the first being the fraction of day of the data point and the second, the value of the magnetic field in gammas. The time system is that described in Section 7.

The final version of the analysis tape is derived in several steps. (See Figure 7) First, the non-redundant entries on the index tape are used to retrieve data from the good data tape in time order with no overlap. This results in a preliminary version of the analysis tape. Next, the redundant entries on the index tape are used to retrieve the data from the good tape which should overlap data already put on the preliminary analysis tape. During this process the redundant data from the good tape is compared, both in time and in magnetic field value, with its counterpart on the good tape. A summary of the comparison results is contained in the section on data quality. If any points are found on the good data tape which are not already on the analysis tape they are set aside in a scratch tape and then merged with the data on the preliminary tape to form an intermediate analysis tape.

Formation of these analysis tapes utilizes only command storage playback data. At this stage in the processing we have a C.S.P. analysis tape (the intermediate analysis tape) and an R.T. index and good data tape. (See Figure 9) The same type of data comparison is then done between the R.T. data and C.S.P. data as was done between the overlapping C.S.P. data, resulting in a point by point comparison of equivalent data points and a merging of unique data points into another intermediate analysis tape.

The final step in the data reduction process is a general clean-up and double checking of the analysis tape to be released to the data center. A final data test is performed, called the ΔF fit test, to attempt to eliminate any remaining spurious data and the tape is checked to be sure that the data is indeed in time order and has no redundant data.

The ΔF fit test consists of fitting a linear curve to one record of analysis data, unless a time gap of over 30 seconds occurs, in which case multiple fits occur as long as a fit interval contains six or more points. In order to achieve a more sensitive test, the fit is not made to the data itself but rather to the value of ΔF (difference between the measured field and a theoretical field) computed using the GSFC (9/65) coefficients. The rms of the residuals to the fit is then

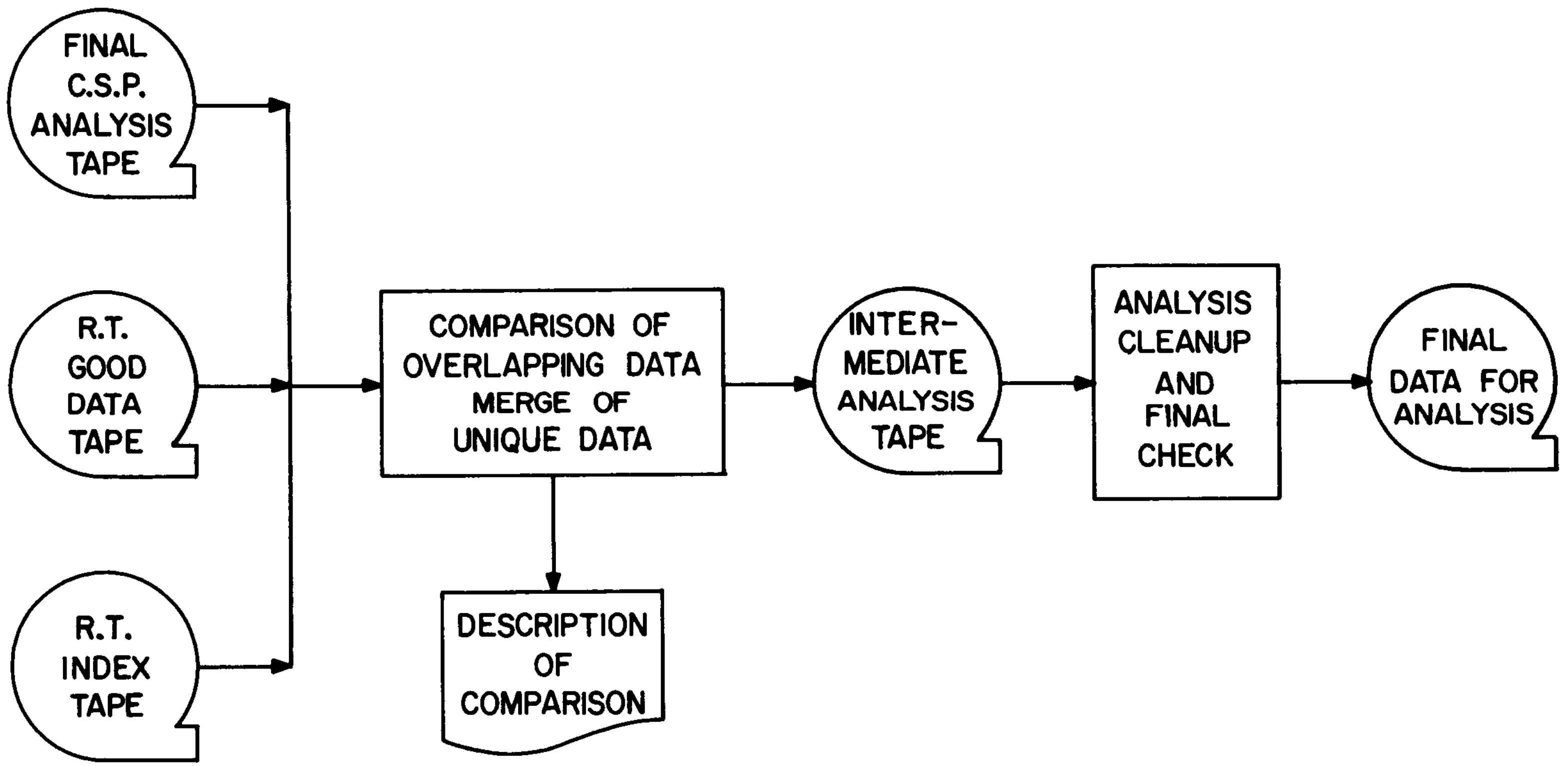


Figure 9 - Integration of Real Time and Playback Data and Formation of Final Analysis Tape

computed and any point deviating from the fit by more than three times the rms is rejected. Whenever any points involved in a fit are rejected, both the ΔF array and the residuals to the fit are plotted for visual display. In addition, whenever the rms of the residuals exceeds 2γ a plot is made, even if no points are rejected, so that we may be sure that spurious data is not being overlooked by the test.

11. DATA QUALITY

An assessment of the quality of this data must be made in two areas. Each data point consists of a time and of its associated magnetic field value. Inaccuracy in either of these quantities reflects on the accuracy of the data point.

The magnetic field values are computed from the equation

$$\text{field} = \frac{\text{Larmor frequency}}{g_{Rb85}}$$

where the Larmor frequency is the self-oscillating frequency of the sensor combination and g_{Rb85} is computed from the Breit-Rabi formula. The value used for g is 4.66737 gammas/second $\pm 3.5 \times 10^{-5}$ (Sarles, 1966). The accuracy of the field computed in this way has been measured at the sensor output by comparison with a proton precessional magnetometer (Farthing and Folz, 1966). The measured accuracy varies from $\pm 0.5\gamma$ at 15,000 gammas to $\pm 1.5\gamma$ at 64,000 gammas. These figures already take into account any inaccuracy in g_{Rb85}. The digitization process results in a ± one count (or ± .43 gamma) resolution of the digitized field.

The output from the spacecraft is a fixed point count accumulated for a fixed interval of time (say ΔT) which is .49984375 seconds for scaler A and .500015625 seconds for scaler B, when the spacecraft clock is running at its nominal rate.

The interval ΔT is known to $\pm 10^{-6}$ seconds and the clock rate (CR, clock rate is here defined as the number of seconds between "one second" timing pulses) to one part in 10^5 (see subsequent discussion of clock accuracy). The Larmor frequency is computed by:

$$\text{Larmor frequency} = \frac{\text{count}}{(\Delta T)(CR)}$$

The accuracies given above result in a computed Larmor frequency accurate to better than 1.2 parts in 10^5. Since the accuracy of g_{Rb85} is already accounted for in the figures for instrumentation accuracy, and machine round off error is less than one part in 10^8, the inaccuracy in computing the field from the count is less than 1.2 parts in 10^5 (.18γ at 15,000γ, .768γ at 64,000γ).

The actual OGO-2 orbit is considerably higher, in both apogee and perigee, than originally planned. This required the magnetometer to operate in magnetic fields lower than its design range (15,000 to 64,000 gammas). The magnetometer design (particularly the amplifier phase characteristics) is such that the instrument accuracy should be maintained at the previously described levels throughout the actual operating range encountered.

When the S/N into the comb filter becomes less than about 2/1 the count becomes spurious. This is very obvious on data plots. The data tests successfully eliminated all but a very small percentage of the resulting spurious data and we believe that the ΔF fit test on the analysis tape has eliminated the remainder.

The only additional source of error in the magnetic field value is telemetry error. We include in this 1) bit errors in the scaler count arising in A/D conversion due to a low signal-to-noise ratio in the spacecraft to ground telemetry link (or in the recording process at the ground station) and 2) any bit errors introduced in our data when being edited and decommed by the Telemetry Computation Branch at GSFC (see Section 4). No evidence of the latter has been found.

Bit errors can be difficult to detect since an error in the least significant bit is equivalent to an error of only .42 gammas. We believe that our data checks are eliminating the vast majority of data containing this type error. All of the data points at 16 KB and 64 KB have duplicate readouts and over 50% of the data points at 4 KB have duplicate readouts. It is unlikely that telemetry noise would effect these duplicate readouts in the same way which means that the redundant readout test (Section 6, iii, a) should eliminate this problem for over one-half of the data. For the rest of the data the reference, difference, and zero checks will eliminate the worst cases and the ΔF fit test on the analysis tape should catch the rest.

The best indicators of the quality of the telemetry signal are the amounts of data rejected by the main processor when it is performing the various data checks, and the percent of fill and noise frames which occur. Table 2 (the Quality Summary) contains a summary of these indicators for the period 10/14 thru 10/24, 1965. Twelve percent of the C.S.P. data from this period of time was rejected in the main processor. (This figure does not include a few files not processed when a preceding file on the source tape had a sufficient number of tape redundancies to cause processing to cease altogether on that tape.) Over one-quarter of the data rejected is accounted for by tape redundancies and another quarter of the rejected data is accounted for by inaccurate time. However, 471 of the 526 records rejected by the time tests were later reprocessed and 466 of them recovered. The quality summary shows how many records were

Table 2

Quality Summary Data Period
10/14/65-10/24/65

A. Magnetic Field Value Parameters

Source Records Processed C.S.P. 16712

RECORDS REJECTED BY MAIN PROCESSOR			
Total	Failed	2006
	Reprocessed	1476
Percent Failed		12.0
Reference Test	Failed	298
	Reprocessed	78
Difference Test	Failed	52
	Reprocessed	4
Zero Test	Failed	300
	Reprocessed	255
Redundant Readout Test		Less Than 54
Time Test	Failed	526
	Reprocessed	471
Tape Redundancies	Failed	534
	Reprocessed	534

Total Resulting Good Points 994,473

POINTS REJECTED FROM REMAINING RECORDS	
Total	10,424
Percent	1.04
Reference Test	3617
Redundant Readout Test	3898

Percent frames which are fill

Percent frames which are noisy

Reprocessed Suspect Data (C.S.P.)

Source Records Processed		2029
RECORDS REJECTED WHILE REPROCESSING	Total	116
	Percent	5.72
	Reference Test	73
	Difference Test	7
	Zero Test	6
	Redundant Readout Test	Less Than 21

Total Resulting Good Points		129,779
Total Good C.S.P. Points 10/14/65 to 10/24/65		1,124,252
POINTS REJECTED FROM REMAINING RECORDS	Total	6948
	Percent	5.08
	Reference Tests	2304
	Redundant Readout Test	2873

Redundant Playback Points Compared	98,333
Percent of Total Data Sample	8.7%
Number of Points Agreeing Within 1 Gamma	98,329
Number of Points Agreeing Between 1-2 Gammas	1
Number of Points Disagreeing More Than 5 Gammas	3
Number of Points Considered to Have Wrong Measured Field Value	4
Percent	.0041%
Source Records Processed R.T.	37,245

RECORDS REJECTED BY MAIN PROCESSOR	Total	13,369
	Percent	35.89
	Time Test	9,244
	Tape Redundancies	755
	Reference Test	1495
	Difference Test	390
	Records Rejected Not Including Time Tests	4,125
	Percent of Total Records	11.%

Total Resulting Good Points		135,977
POINTS REJECTED FROM REMAINING RECORDS	Total	1321
	Percent	.96%
	Reference Tests	484
	Redundant Readout Test	313

Percent frames which are fill

Percent frames which are noisy

Redundant R.T. vs. C.S.P. Points Compared	87,722
Percent of Total Data Sample	7.8%
Number of Points Agreeing Within 1 Gamma	87,657
Number of Points Agreeing Between 1-2 Gammas	13
Number of Points Agreeing Between 2-3 Gammas	1
Number of Points Agreeing Between 3-4 Gammas	4
Number of Points Disagreeing More Than 5 Gammas	47
Number of Points Considered To Have Wrong Measured Field Value	65
Percent	.074%

B. Time Accuracy Parameters

Redundant Playback Points Compared	98,333
Percent of Total Data Sample	8.7%
Number of Points With Times Within 2 ms.	97,418
Number of Points With Times Within 2-10 ms.	858
Number of Points With Times Within 10-20 ms.	57
Number of Points With Times Disagreeing More Than 20 ms.	0

Redundant R.T. vs. C.S.P. Points Compared	87,722
Percent of Total Data Sample	7.8%
Number of Points With Times Within 2 ms.	36,847
Number of Points With Times Within 2-10 ms.	2,759
Number of Points With Times Within 10-20 ms.	41,199
Number of Points With Times Within 20-30 ms.	6,570
Number of Points With Times Within 30-40 ms.	0
Number of Points With Times Within 40-65 ms.	347

reprocessed from each type of rejection. The records which are not completely rejected still contain a certain percentage of suspect data. For this time period this percentage was 1.04. The table shows this figure along with the number of points in each of several main rejection categories. Comparable indications are available for the reprocessed data. While the statistics for entire records rejected during reprocessing are included in the Quality Summary, the numbers are not comparable to those from the main processor since the rejection criteria have been relaxed. The percentage of suspect data from those records not completely rejected is still a good indicator. For the period 10/14-10/24, 1965, it was 5.08%, five times the figure from the main processor. The reprocessed data is, indeed, of substantially lower quality than the good data resulting from the main processor. This means that a higher percentage of data are likely to be accepted as good when they are really spurious. A visual inspection of plots produced by the suspect data reprocessor for the data from 10/14-10/24, 1965, bears this out. We would estimate from .5 to 1% of the recovered data is spurious to some degree. These errors are usually less than 10γ but may occasionally be 100γ or more. These points should be eliminated by the ΔF fit test on the analysis tape.

Because of the high percentage of spurious data placed on the good data tape during reprocessing of suspect data, the new test described in Section 8 has been added to the suspect data reprocessor. This test reduced the spurious points, detected by visual inspection of the plots from the reprocessor, to less than 1/20 of one percent when the data from 10/29/65 to 11/15/65 were reprocessed. We intend adding this test to the main processor in the near future.

The statistics from the real time data reveal a startling percentage of entire records rejected. This is almost exclusively the result of inaccurate time. Indeed when the rejections from the time tests are not taken into account the percentage rejection is within one percent of the similar figure for C.S.P. data. The "time problem" will be discussed later in this section. The percentage suspect data resulting from those records not completely rejected is also very nearly the same as for C.S.P. We conclude that, aside from the time problem, the C.S.P. and R.T. data are of comparable quality.

A good indicator of the amount of spurious data finding its way into the good data tapes is obtained by comparing overlapping data. C.S.P. data overlaps occur under two circumstances. Occasionally two telemetry stations are able to simultaneously receive the same telemetry from the spacecraft. Secondly, each station usually records the telemetry on two recorders simultaneously. In either case, if the Telemetry Computation Branch processes both sources we will have overlapping data. Another source of data overlap is when RT data and CSP data are taken simultaneously. Obviously there is a greater degree of independence in sources when RT is compared to CSP than when CSP is compared to CSP.

The statistics from the overlap comparison are given in two parts in the Quality Summary. First the CSP-CSP overlap and secondly the RT-CSP overlap. Both comparisons are over a statistically significant percentage of the data and both indicate less than .1% spurious magnetic field values.

As of this writing, complete analysis cleanup figures are not available. Preliminary statistics from test runs of the analysis cleanup program indicate that about .4% of the data is being removed from the analysis tape. This is not unduly higher than the amount of spurious data found while comparing overlapping data, and indicates that most of the spurious data are being removed. A visual inspection of data plots confirms this conclusion.

Because the times associated with the data are derived from the time fit, the accuracy of these times depends both upon the accuracy of the fit itself and on the accuracy to which the data time matches the time fit.

The time checks in the main processor are all oriented toward assuring that the data times match the time fit. These tests assure that i) at the start of the file the data time matches the time fit to 26 milliseconds, and ii) the time for each record matches the time at the start of the file to 44 milliseconds. We are confident that almost all of the times on the data (over 95%) agree with the time fit to within 30 milliseconds. The possibility exists, however, that isolated chunks of data will be up to 70 milliseconds different from the time expected on the basis of the time fit.

For C.S.P. data after January 25, 1966 and R.T. data after November 19, 1965, the time for each record is compared to the time fit itself. An accuracy of 26 milliseconds is required. This means that the maximum deviation of data times from the time fit will be 26 ms.

When comparing overlapping data the times are compared as well as the field values. The results of these time comparisons are shown in Part B of the Quality Summary. For C.S.P. overlap with C.S.P. data all times were within 20 milliseconds and most were within 2 milliseconds. For R.T. overlapping with C.S.P. there is a large group agreeing within 2 milliseconds and another large group differing between 10 and 20 milliseconds. This unexpected time difference is due to a constant bias of 18 milliseconds on the 64 KB real time data, present on the source tapes received from the Telemetry Computation Branch. Unfortunately the error was detected too late to correct the problem on any data before August of 1966.

In spite of this bias all of the comparisons, except one small batch, agreed to within 30 milliseconds. The small amount of data whose time error is about 66 ms, resulted from a small time error in a 64 KB file which went undetected by our time check and amounts to .4% of the data compared.

We conclude that the bulk of the data in the analysis tapes (that which derives from the C.S.P. data) has times agreeing to within 20 ms. of the time fit. The remainder of the data agrees to within 30 ms. of the time fit with the exception of some small amounts which may be off up to 70 ms. Between 4-8% of the data has a constant bias of 18 ms.

The accuracy of the time fit is difficult to assess. The Control Equipment Branch at GSFC (Laios, 1967), who are responsible for the equipment at the various ground stations, inform us that the station clocks can be synchronized to within one millisecond of the received signal from WWV and that the master oscillators at the stations are stable to better than one part in 10^{10} per day. This stability implies that once synchronization with WWV was attained many days would have to pass before the station clock would differ more than a millisecond or two from WWV.

The time codes placed on the analog tape (See Section 4) should, therefore, be accurate to ±2 ms. These time codes are decoded by the STARS-I time decoder (Demmerle, 1964) with a resolution of 1 ms. and a precision of one ms. Thus the claimed accuracy of the time into the time fit program is better than 3 ms. Since the resolution of the clock update is ±4 ms. (See discussion of high resolution points, Section 6, iv), the accuracy of the time fit data should be better than $\sqrt{3^2 + 4^2}$, or better than 5 ms.

The only other inaccuracy in the data into the time fit should be that of the short term drift of the satellite clock. This is specified to be one part in 10^6. The long term drift of the clock should be accounted for by the time fit.

Table 3 gives a summary of the results of the first seven time fits. The maximum residual and the RMS of the residuals are both given. These are consistent with the accuracies claimed.

Table 3

Time Fit Accuracy*

Time Fit	Dates Included	Maximum Residual	RMS of Residual
1	10/14-10/15/65	4 ms.	1.69 ms.
2	10/16-10/24/65	11 ms.	4.08 ms.
3	10/29-11/ 1/65	15 ms.	7.37 ms.
4	11/ 1-11/ 2/65	8 ms.	3.27
5	11/ 3-11/ 4/65	5 ms.	1.67
6	11/ 3-11/13/65	17 ms.	5.426
7	11/14-11/23/65	18 ms.	4.86 ms.

*Supplied in personal communication from Mr. Ed Szajna of Telemetry Computation Branch.

On the basis of the information at hand we believe that the time fits are generally accurate to better than ten milliseconds.

A computer check was made of the field gradient utilizing the actual OGO-2 orbit and the GSFC(9/65) magnetic field model. The gradient $\Delta F/\Delta T$ was computed at one minute intervals (ΔT was a constant 5 seconds) for a 50 day period beginning November 1, 1965. The largest gradient found was 39.92 γ/sec. If 40 γ/sec is taken as a practical upper bound for field errors due to time errors, then the maximum field error for 80 ms. of time error is 3.2γ and for 10 ms. of time error it is .4γ.

The following table summarizes the sources and amounts of the inaccuracies present in the data:

	Peak Error		RMS* Error	
	At 15,000γ	At 64,000γ	At 15,000γ	At 64,000γ
Digitization inaccuracy	±.43γ	±.43γ	±.25γ	±.25γ
Sensor inaccuracy	±.5γ	±1.5γ	±.29γ	±.87γ
Accuracy of digitization interval	±.18γ	±.768γ	±.1γ	±.44γ
Accuracy of time fit	±.4γ	±.4γ	±.23γ	±.23γ
Accuracy of match of data time to time fit				
70 ms.	±2.8γ	±2.8γ	±1.62γ	±1.62γ
30 ms.	±1.2γ	±1.2γ	±.69γ	±.69γ
Totals				
If time-time fit match is 30ms	±2.26	±4.30		
If time-time fit match is 70ms	±3.86	±5.90		
Square root of sum of squares of RMS errors				
If time-time fit match is 30ms			±.83γ	±1.25γ
If time-time fit match is 70ms			±1.69γ	±1.93γ

*RMS error $= \left[\frac{1}{\text{peak error}} \int_0^{\text{peak error}} x^2\,dx\right]^{1/2} = \frac{\text{peak error}}{\sqrt{3}}$

Taking all of the above error sources into account, both in the field value and time value, we would (confidently) estimate the data on the final analysis tape (with the possible exception of a few scattered points) to be better than 2.0γ, with the probable accuracy better than .83γ at 15,000γ and 1.25γ at 64,000γ.

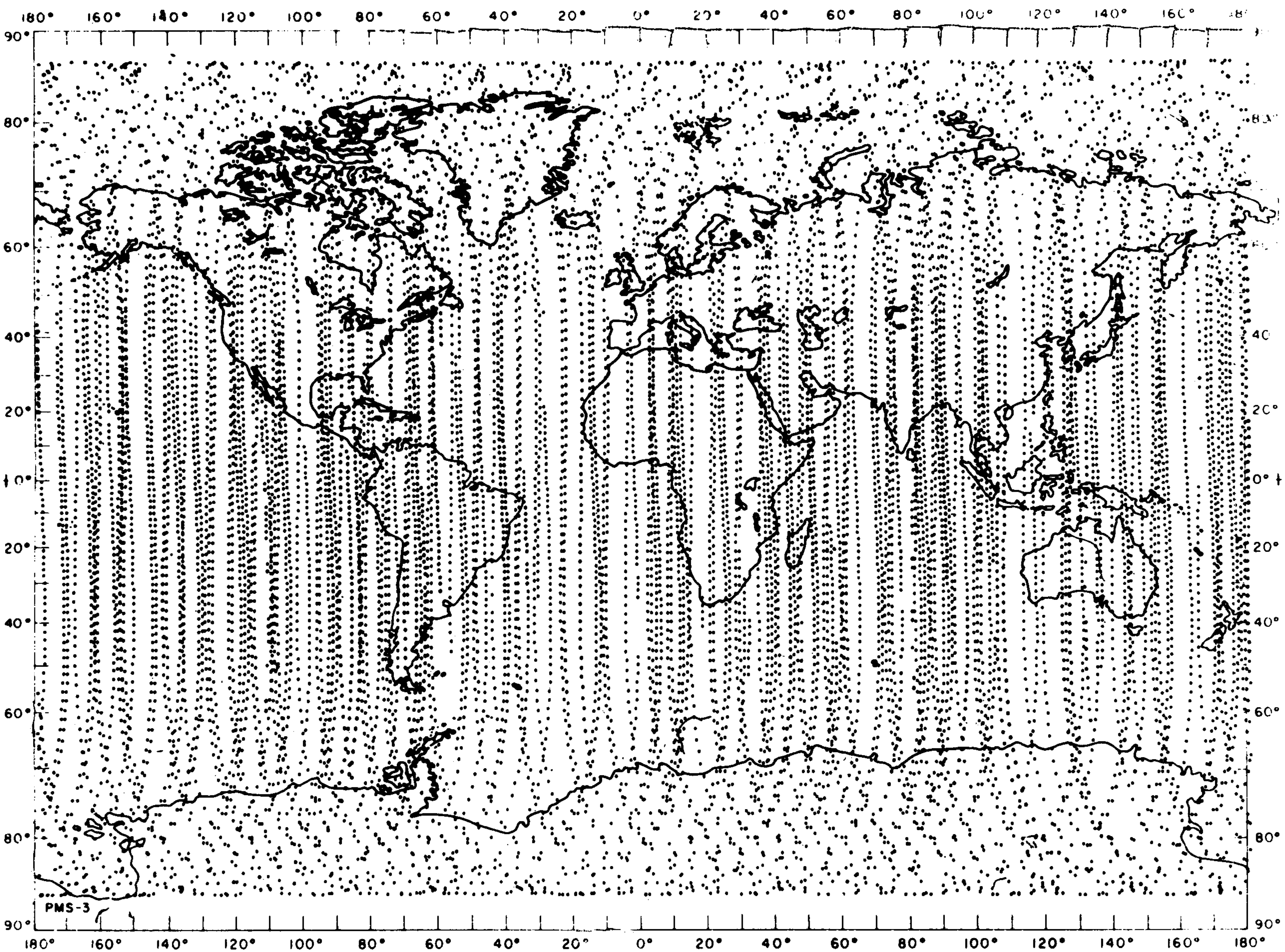
12. DATA EXTENT

Figures 10 and 11 show the data coverage from OGO-2. Figure 10 is a plot giving the geographical distribution of all playback data (both good and suspect) for the time period 14-24 October, 1965. Altitude is not indicated but limited altitude inferences may be drawn from the knowledge that perigee is in the northern hemisphere (perigee varied from approximately 0° latitude to 30° latitude during this period) and occurs at a local time of approximately 5 a.m. (Langel, 1967).

The distribution of the data as a function of Universal Time is given in Figure 11. This figure includes both C.S.P. and R.T. data (again both good and suspect). The date is indicated on the ordinate, one horizontal line applying to each day, and the Universal Time along the abscissa. Gaps occur where there is no magnetic field data.

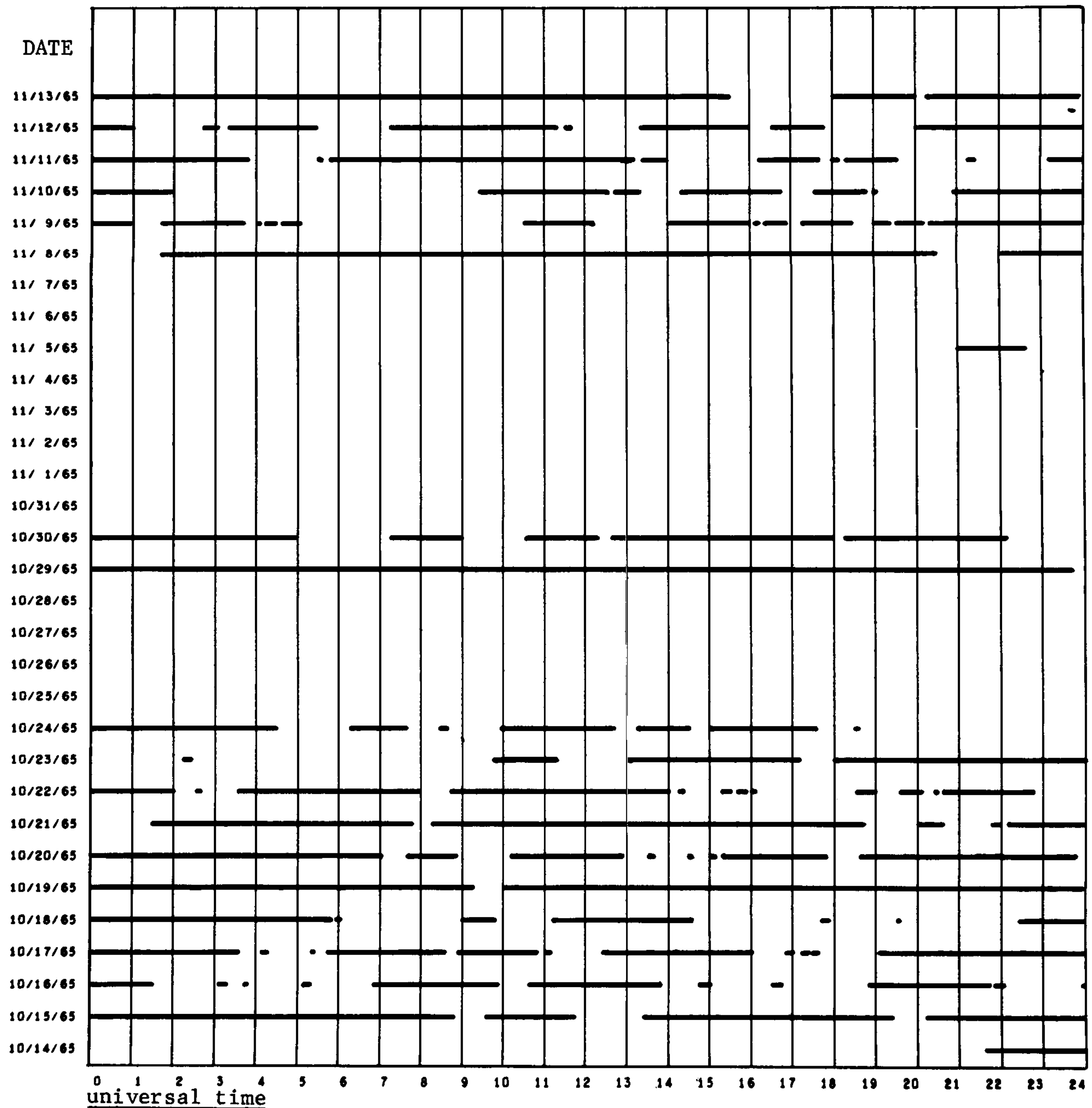
13. PROCEDURES IN DATA PROCESSING

From the very beginning of this effort our goal has been to supply the analyst with data tapes containing all of the good data but no spurious data. This, of course, is a highly idealistic goal. The preceding sections of this report (particularly Section 11 on Data Quality) should give the reader a fair idea of our success in meeting our goal.



Geographical Distribution of C.S.P. Data, 10/14/65 - 10/24/65

Figure 10



Combined C.S.P. and R.T. Data Coverage

Figure 11

In this section we briefly describe part of the rationale behind our methods and some thoughts about how our procedures could be improved, both with existing computer hardware and with some of the new hardware currently being made available.

One alternate approach to data processing would be to reformat the original data into a format convenient to the analyst (including coordinate transformations, transformations into engineering units, etc.) and then construct an index to the data for access purposes. This means that the analyst is left to determine which data is suspect, to time order the data, and to eliminate redundant data. Another extreme would be for the data processor to eliminate all data which he (even remotely) suspects may be erroneous and make no attempt at recovery, thus insuring only good data for analysis. Both of these approaches require a minimum of programming, but neither approach satisfies our goals.

Because we wish to eliminate all spurious data, we have built extensive "tests" into our processing programs so as to detect any data with a significant probability of being erroneous. We had no inkling whatsoever, before launch, of what forms the erroneous data would assume but hoped that the tests would prove adequate without rejecting data needlessly. Not knowing how successful the tests were going to be, we decided not to reject any data irretrievably but, rather, to set it aside together with enough descriptive information to tell us why it was considered suspect. This led to the "Suspect Data Tape."

We have tried to organize our data in its most useable form, that is, so that a particular type of data appears in that format from which it may be most easily accessed when being used in its most important application. The data usages considered are described in the following table:

Data Usage

Data Type	Primary Use	Secondary Uses
Suspect	Reprocessing and merge with good data	Evaluation of experiment instrumentation and of telemetry digitization and processing procedures.
Engineering	1. Indicate when data may be suspect	Correlation with unexplained phenomena during data analysis
	2. Evaluation of instrumentation performed	
Good	Analysis of earth's magnetic field	Examination to assure accurate measurements.

With the primary usage of the final good data in mind we arrived at the following criteria for our good data tapes:

1. They should be kept separate from the suspect and engineering data.
2. They should be as free as possible from suspect data.
3. The data should be grouped into time intervals such that all data from a particular interval is contained on one and only one good data tape.

The source data comes to us in files, each of which has certain unifying characteristics, such as data format and ground station at which recorded. Within each file are sub-units called records, each containing data from one spacecraft sequence. To maintain quick and ready reference to any portion of the data, throughout most of the data reduction process, these units of data organization have been maintained up until the time the analysis tapes are formed. Thus there is a one to one correspondence between input files and records and output file and records, except on the analysis tapes. This organization enables us to examine data from particular stations, of particular formats or from particular tapes and/or runs from the Telemetry Computation Branch.

An alternate approach would have been to simply keep track of the source tapes, files, and records on which suspect data occurs and go back to these tapes for reprocessing. The arguments advanced for this are that it would involve fewer overall tapes and that special programs to read the suspect tapes would not be necessary. However, a typical time period (say 10/14-10/24/65) to be processed (either for the first time or for reprocessing) will include from 40-80 source tapes. Some suspect data results from each of these tapes, always including some entire records and sometimes some sizeable chunks. Reprocessing would rarely include less than 20 of these tapes, with bits and pieces needed from each tape. In contrast, all of the suspect data from such a time period can be contained on one suspect data tape.

Reprocessing with the main processor would require that the main processor be able to access individual records on each input tape. On the other hand subroutines to access output data tapes (e.g. good data, engineering and housekeeping) normally have very flexible access capabilities. We have concluded that by making our data access routine slightly more flexible (i.e. able to handle additional formats) and limiting our main processor routines so that they can only pick-and-choose among files (instead of records also) does not really cost us any programming effort and gives us far more flexibility in reprocessing suspect data than we would have if we re-ran it through the main processor and, at the same time, actually reduces the number of tapes necessary to handle during reprocessing.

Another consideration in the problem of reprocessing suspect data is that if reprocessing is done from the source tapes, all information regarding the original rejection must be kept on the housekeeping tape, whereas if a new tape is written flags may be mixed with the data to indicate why the data was considered suspect. These flags may then be used in reprocessing to help control program decisions.

The programming effort to reprocess the data for the first ten days after launch has been less than four man-months above what would have been required if the suspect data had simply been ignored. The effort to extend reprocessing to other periods of time will now simply consist of the time to make any program changes necessary to cope with new situations not encountered with the initial ten days data. The resulting program has a large amount of flexibility in selecting data to be reprocessed; it can process entire files, groups of records, or individual records. It is capable of plotting all or part of the data reprocessed during a run and may easily be modified to change data rejection criteria from file to file. In operation the major portion of time probably is consumed in remaking the housekeeping tape (to be discussed shortly) to indicate what has been reprocessed with what results. This arrangement seems to give highly satisfactory results.

We expect that the amount of data reprocessed from the suspect data tape will drastically decrease in the near future. Reprocessing consists of putting the data to the same tests as in the main processor, with different rejection criteria, and of developing new tests as needed, under more closely controlled (and monitored) conditions than is possible in the main processor. The obvious next step is to modify the main processor in accordance with the new procedures. This is being carried out successfully at the present time.

The housekeeping tape has proved invaluable as a detailed record of both the main processing and suspect data reprocessing. We have often used it when seeking to determine, in detail, the quality of data at a particular time or on a particular file and record. It has been used to produce various types of data summaries including the index tape, plots of data coverage (both spatial and temporal) and summaries of data quality for given periods of time. While we feel that this tape has proved very useful, hindsight tells us that it can be vastly improved. Its initial generation costs very little either in programming effort or in machine time. However, when reprocessing suspect data the entire housekeeping tape must be rewritten to indicate that the initially rejected data has been reprocessed and to describe the results of the reprocessing. This is a bit expensive in machine time.

The format of the housekeeping tape has proved more cumbersome and less useful than originally intended. Substantial amounts of data render it too long to be used as a rapid index to the other tapes and it contains too much information for the quick, short, summaries which we have occasionally wanted. For future efforts we feel that the file housekeeping should be expanded to where a set of file housekeeping records will serve in place of our index tape. Such a set of file housekeeping records should also provide a quick summary not only of what files have been processed but also of the general quality of the results. At the same time the record housekeeping should be contracted to the point where sorting the housekeeping tape into time order is no longer a major undertaking.

Among the peripheral hardware being made available for the next generation of computers are the removable "disk pack" and the data cell. Because these devices are of the "direct access" type they have the potential to make data access an order of magnitude simpler than tape systems, such as the one described in this document. For example, the disk pack should be ideally suited for containing housekeeping information. The data could still be grouped into logical "files," one to one with input files. Two advantages are immediately obvious:

1. Since records can be updated in place (without disturbing their neighbors; unlike tape), when suspect data is reprocessed it will not be necessary to re-create the entire housekeeping data set.
2. Time ordering may be achieved without costly sort techniques by using proper indexing and chaining techniques for the file level housekeeping.

If the cost/data bit of the data cell can be made reasonable (say no more than twice that of storing the same data on tape), then the data cell would offer similar advantages for data storage as the disk pack for housekeeping storage.

14. DISCUSSION AND CONCLUSIONS

To those who have faced the data herein described since long before OGO-2 was launched, the characteristics of the data, even to the most minute detail, seem very obvious. We hope that a good measure of this knowledge and experience is contained in the preceding sections. Our confidence in the quality of the data being released to the NASA Space Science Data Center is very high.

While we feel that others should be able to profit from our efforts in data processing, one should be aware of some of the unique features of this experiment and this satellite before generalizing from our results to those from other satellites and even from our experiment to others in the OGO satellites. This experiment was probably the simplest in concept on OGO-2. It sampled the main scalar field at roughly equal intervals of one-half second regardless of the bit rate and format (main comm. or flexible format) and with little concern for the spacecraft attitude. The most serious problem encountered was that of identifying the data with the appropriate Universal Time to an accuracy consistent with the instrumentation accuracy.

We should note in retrospect that the OGO series is probably the most complex and flexible satellite observatory ever to achieve any degree of success. This complexity is multiplied in the low altitude, polar, half of the OGO series by the complex scheduling problems caused by short (10-15 min) station passes, and by the power problems caused by rapid cycling through eclipses when the satellite leaves the twilight meridian. The satellite flexibility and complexity (particularly the usage of flexible format) is more of a hindrance than a help for this particular experiment and indeed makes the effort of data reduction many times greater than for data recorded on a less complex system. This inherent complexity, coupled with the intermittent operation of the spacecraft and with the program problems in Telemetry Computation Branch's time correction, has in fact raised the problems of processing and evaluating the data a good order of magnitude over that which might have been achieved with a less ambitious project.

As has been seen some of the system redundancy is helpful in gaining greater confidence in the recorded results; most is not. The recording in real-time at the receiving stations of data that are also recorded on board appears to be a useful aid for cross comparison and for filling gaps in the recorded data. The usefulness of the special purpose system, placed in operation partly as back up to the main data recording system, has yet to be realized in providing additional data information. Of course if the main recording system had failed, this document would be discussing only the results from the special purpose telemetry.

ACKNOWLEDGMENTS

An effort of this magnitude necessarily involves many individuals. The overall project is under the direction of Dr. J. C. Cain who has given a great deal of help in establishing our basic philosophy as well as guiding us in the selection of data test criteria. Significant direct participation in the programming was taken by Mr. Dean Wood (then with Aero Geo Astro Corp.), Mr. W. Jungemeyer and Mr. L. Karleson (then with Computer Sciences Corp.). I must also acknowledge the valuable advice of Miss S. Hendricks (of GSFC), Mr. L. McCarter (of New Mexico State University) and Mr. J. Premeaux (of Vitro Services, Inc.).

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APPENDIX A: Tape Formats

The following pages contain a detailed description of the formats of our more important tapes. These include the analysis tape, housekeeping tape, subcom-amplitude tape (engineering information), and the good data tape. All of these, except the analysis tape, begin with a one file, one record, tape label which is also described. Section 7 of this document should be consulted for further explanation.

WORLD MAGNETIC SURVEY ANALYSIS TAPES

These tapes consist of the current best data set from the OGO-2 satellite. The data is in time order and each point appears only once on the tape. The tapes are binary, FORTRAN generated with a standard record length of two hundred (200) words. One full day's data appears in each file, with the number of files on each tape determined at generation time. The tape will end with a double end of file.

FILE FORMAT

The first record of each file is a label record:

Word 1: The Modified Julian Day number of the data in this file (Fixed Point)

Word 2: The Modified Julian Day number on which the file was generated (Fixed Point)

Word 3: The Good Data tape number from which the data came (Fixed Point)

Word 4-200: All zero

Each data record contains 100 data points, each in two floating point words, the first being the fraction of the day of the data point,* and the second being the value of the magnetic field in gammas. This might be viewed as an array Data (I,J) where I varies between 1 and 2 and J runs from 1 to 100. Then, Data (1,J) would be the time associated with the field in Data (2,J). The final data record in each file is packed with zeros to make it 200 words in length.

*All data times are in UTC and refer to the middle of the approximately half second over which the field is averaged.

TAPE LABELS, WORLD MAGNETIC SURVEY TAPES

WORD		CONTENTS
1	(BCD)	Flag indicating type of tape 1 = good data 2 = garbage data 3 = housekeeping 4 = subcom-amplitude 5 = spare 6 = real time output 7 = housekeeping } special purpose data 8 = data } special purpose data 9 = composite minute-vector tape
2	(BCD)	Tape Number
3	(BCD)	Start Day
4	(BCD)	Stop Day
5		Spare
6-10	Same as	1-5 except Binary

FILE HOUSEKEEPING RECORDS

Word	Bits	Contents
1	S-17	File number from original data tape
	18-35	Number of records on the original file
2	floating point	Modified Julian Day Number on which the data in this file occurred
3		Data type
	S-7	Spare
	8	Time flag indicating corrected or uncorrected time
	9-11	Equipment group
	12-20	Receiving station
	21-29	Bit rate
	30-35	Flexible Format number if any
4	S-11	File number on original analog tape
	12-35	Analog tape number
5	S-11	File number on buffer tape
	12-35	Buffer tape number
6	S-6	Limit to the number of data points with too many disagreeing readouts allowed to accumulate in one record
	7-11	Number of bit errors allowed in frame sync word before considering noisy
	12-18	(4kB main comm. only) Number of non-zero words, which are supposed to be zero, allowed to accumulate in one record
	19-35	Flag indicating when and why the entire file is on the garbage tape

Words	Bits	Contents
		Bit 19 indicates if the data has been subsequently reprocessed 0 means no 1 means yes
7	S-17	DECOM reel number } combination is the tape number
	18-35	DECOM run number }
8		Spare
9	S-3	Value of switch used to tell program how to treat filter data
	4-7	Switch for temperature data
	8-11	Switch for power data
	12-13	Switch for reference check
	14-20	Limit to number of difference check failures allowed to accumulate in one record
	21-27	Limit to number of reference check failures allowed to accumulate in one record
	28-35	Limit to total number of bad points allowed to accumulate in one record
10	floating point	Number of gammas used as limit in the differencing check
11	S-23	Good data tape number
	24-35	File number
12	S-23	Garbage data tape number
	24-35	File number
13		Spare
14	S-23	Subcom-amplitude data tape number
	24-35	File number

Word	Bits	Contents
15	S-17	Switch indicating how much time correction our program should do
	18-35	Switch indicating what to do with uncorrected time

Record Housekeeping Records

WORD	BITS	CONTENTS
1	floating point	Fraction of day of first bit of the spacecraft sequence making up this record.
2-4	floating point	Geocentric position at time indicated in word 1 2 - latitude 3 - longitude 4 - radius
5	S-11	Record number from original data tape
	12-23	Record number on good data tape, if any (0 if none)
	24-35	Record number on garbage tape, if any (0 if none)
6	S-11	Number of words in record on good data tape or number of words of good data found before whole record went on garbage tape.
	12-23	Number of words in record on garbage tape.
	24-35	Flag to indicate why entire record went on garbage tape. bit 24 indicates if the data has been subsequently reprocessed 0 means yes 1 means no
7	S	Flag to indicate if a time gap exists between this record and the next one.
	1-35	Time Flag
8	S-7	Count of data points with too many disagreeing readouts
	8-15	Count of readouts which failed the reference check

WORD	BITS	CONTENTS
	16-23	Count of difference check failures
	24-35	Flag indicating status of the magnetometer signal amplitude
9	S-8	Number of frames of fill data occurring this record
	9-17	Number of noisy frames this record
	18-23	Spare
	24-35	Record number on tape containing subcom and amplitude information
10	S	Flag indicating whether or not we are connected to the special purpose transmitter
	1-11	Flag indicating status of the comb filters.
	12-23	Flag indicating status of power to the experiment
	24-25	Flag indicating status of temperatures monitored in the experiment
11-13		Reserved for keeping track of spacecraft commands
14		Used only if this record contains data overlapping other data received
	S-11	Last garbage tape on which overlapping data was put (all overlapping data, after the first occurrence, goes to the garbage tape)
	12-23	Corresponding garbage tape file number
	24-35	Total number of times overlap has occurred.
15	floating point	Number of gammas to which measured data must agree with theoretical field in order not to reject the data point.

SUBCOM-AMPLITUDE TAPE DATA RECORDS

WORD	BITS	CONTENTS
1	floating point	Fraction of day of first bit of the spacecraft sequence making up this record (floating point).
2	S-11	Subcom word 50
	12-23	Subcom word 51
	24-35	Subcom word 52
3	S-11	Subcom word 114
	12-23	Subcom word 115
	24-35	Subcom word 116
4	S-11	Subcom word 6
	12-23	Subcom word 70
	24-35	Analogue calibration
5-6		Analogue calibration
7		Amplitude flag
8-103		(Main commutator only) Up to 32 groups of three words each giving the sensor amplitudes from every 4th frame (out of 128) in the record. Fill frames will be missing. The three words contain: 1) Voltage of Sensor A (floating point) 2) Voltage of Sensor B (floating point) 3) Frame number (fixed point)

Good Data Tape Data Records

These tapes have variable length records, not exceeding 148 words and always containing an even number of words.

Two floating point words are present for each data point, 1) the time, in fraction of day, at the center of the counting interval for the data point and 2) the field value derived from the count.