Ariel II Engineering Data Analysis

Phase I Report

Volume I of Two Volumes

23 June 1965

Contract No. NAS5-9104

Prepared by

Westinghouse Electric Corporation

Aerospace Division

Baltimore, Maryland

for

Goddard Space Flight Center

Greenbelt, Maryland

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ABSTRACT

This report treats of the results of Phase I of a three-phase post-launch evaluation of Ariel II satellite engineering performance. Phase I is the portion of the evaluation devoted to the reduction of telemetered data and the preparation of plots, of satellite performance in engineering units and of experiment performance in frequency units. Three major areas of interest are covered in graphical form, i.e., dynamical performance in terms of spin rate decline, power system performance, and thermal performance. Experiment performance is also displayed in the graphs, both for its own sake and because it provides the basis for assessing dynamical performance.

The graphs truly represent the tangible result of the Phase I effort which had no analytic findings as a goal. Thus, conclusions, in the normal sense, cannot be stated; however, it has been concluded that in spite of data deficiencies, the graphs provide a suitable base for Phase II and Phase III work to follow. Data deficiencies are fundamentally two. One is the incompleteness of records of telemetered data. Many passes of Ariel II over the ground stations were not recorded, and, in addition, on many orbits few ground stations were in the field of view of the communications system. The other deficiency is the absence of direct measuring sensors on the satellite to provide information about solar aspect and satellite orientation.

The next two phases begin at this point. These will be (1) Phase II which is the explicit definition of spacecraft performance with interpretation of the graphs, and (2) Phase III which is the analysis of why the performance assumed the pattern revealed by Phases I and II.

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Introduction

This report describes the effort expended and the results achieved under Phase I of the subject contract which is constituted under three phases. Reference to Appendix I "Proposal for Ariel II International Satellite Post Launch Evaluation" will serve to explain the relationship of the three phases to the total undertaking. The proposal is a useful reference inasmuch as it was recognized by the contract as the governing work statement for the programs. Briefly stated, the scope of Phase I consists largely of data reduction, that is, the conversion of the quantized frequency data into engineering units, and the plotting of the parameters versus time. Preliminary analysis of the type and quantity of data and of the anticipated scale of the variation was also required, under the scope of Phase I, to establish both the frequency of points chosen for data reduction and the format of presentation. Results of the preliminary analysis were summarized in a letter to the Technical Director. Enclosure I of that letter was adopted, with concurrence of the Technical Director, as a suitable procedure for data reduction and presentation. Enclosure I is included in this report as Appendix II. As stated in the referenced letter, the scope of Phase I implicit in the adopted plan exceeded that outlined in the proposal; consequently, downward adjustments in the scope of Phases II and III have been anticipated as a means of compensating.

The great bulk of the information conveyed by this report is contained in the section called "Reduced Data". The graphs found there fit the three categories cited in the letter of Appendix II. These categories are (1) single orbit graphs (2) 200-day graphs and (3) special purpose graphs. Single-orbit and 200-day graphs are plotted for the fourteen parameters listed in Table I in the letter and, in addition, percent sunlight and spin rate are plotted for the longer period. The plotting of solar aspect angle as a function of time is properly a result of Phase II since the rendering of this graph involves interpretation of the data. Special purpose graphs are in 3 subdivisions: (1) thermal stabilization graphs of thermistor data, (2) thermal gradient graphs constructed from various combinations of thermistor data, and (3) typical experiment responses.

At the initial commencement of Phase I effort, the state of data availability was unknown. It soon became evident that data would have to be requested from the United Kingdom. This new requirement to process data in the United Kingdom has resulted in a program stretch-out by a factor of approximately six in time. Consequently the completion of Phase I and the Phase I report has been extended by approximately 5 months beyond the original schedule.

Description of Data

The data reduced under the subject contract had four sources which were:

(1) printouts of telemetry data from the Goddard Space Flight Center having the format described as "Encoder Format" in the "Handbook for UK-2/S-52 International Satellite";

(2) printouts of telemetry data requested by the Goddard Space Flight Center from the United Kingdom, involving only channel 8 (Satellite performance parameters) of the encoder format;

(3) calibration and conversion curves provided by the Goddard Space Flight Center and in a few cases by Westinghouse;

(4) Refined and Predicted World Maps of the UK-2/S-52 orbital path which were useful for providing time, percent sunlight, orbital elements, and orbital reference points.

Item (1) of the data existed prior to the initiation of the contract and was the source of information for parameters such as spin rate, typical experiment responses and the like. It was also the basis for developing thermal stabilization curves for the first 10 orbits. Item (1) did not provide good continuity of information for any orbit but, rather, was characterized by gaps.

Contrariwise, item (2) was the source which yielded continuous orbit information. It had become obvious early in the program that incomplete real-time coverage for any given orbit would render impossible the plotting of a continuous record of any of the performance parameters. Consequently the use of "composite" orbits was introduced, wherein data from a few (usually 3 to 4) contiguous orbits are used to provide a reasonably continuous cluster of performance data. The United Kingdom people at Radio and Space Research Station were requested to select continuous orbits approximately on a weekly interval basis. The actual orbits chosen were selected to achieve groupings affording the most complete data around the orbit.

Examples of the data in the four categories are displayed in the section on Data Processing.

Data Presentation Plan

The basic rate of performance and experiment response data from the satellite to the ground stations was high. In the so-called high speed mode, which was a real time transmission of experimental and performance data from the satellite to the ground station, the data fromat was repeated every 4.654 seconds. Thus, it was neither feasible nor desirable to plot all data points.

A data plan was formulated based on the anticipated analytical requirements and upon the expected rate-of-change of parameters. Normally, points have been taken from the data at the rate of one every five minutes. This frequency of data sampling was thought sufficient for all parameters except currents, which have a modulation due to satellite spin. Since the spin modulated variation normally is faster than five minutes, the maximum and minimum values for the four-minute interval surrounding each five minute point were plotted. To show the variation, complete data for one five-minute interval are plotted for each composite orbit. As might be expected, overlapping of the data of the constituent orbits in a composite orbit presented some difficulty. Occassionally, the corresponding points in successive constituent orbits would differ. If this difference exceeded one telemetry bit, which is the ultimate resolution of the data variations, each point was plotted and identified as to the source orbit.

Typical experiment responses were requested to be plotted by Goddard Space Flight Center. In the case of the ozone spectrometer data, the graphs plotted to show spin and sun angle variations also provide a sufficient basis for showing the assumed degradation of the ozone spectrometer mirrors. In addition, selective plots have been made of spectrometer and broadband ozone data showing typical responses at sunrise, at sunset, and in a period of full sunlight. For galactic noise, data are plotted at apogee, at perigee and at an intermediate altitude. Also, one entire orbit of 100 minutes of low speed galactic noise data has been plotted. These are data which were recorded on the satellite tape recorder and played back to the ground station at a higher rate (48:1). By this means continuous orbit coverage is obtained on the recorded GN data. The term "low-speed" is derived from the fact that initial recording of the data took place at a slower speed (1/48) than the final playback.

Micrometeorite data were also plotted. These data serve as auxiliary inputs for spin rate and to some limited extent, sun angle, by virtue of the fact that the height of the calibration pulse varies with sun angle. All data are plotted on translucent sheets to permit easy combinations of graphs by means of light table. Equal time scales on the abscissa of all graphs were maintained for this reason also.

Combinations are anticipated to be made during Phase II to reveal the interdependence of parameters. The 200-day graphs and the weekly composite-orbit graphs afford means for observing both short and long term variations.

Data Processing

The basic key to data reduction was the Encoder Format, Figure 2-2 of the Handbook for UK-2/S-52 International Satellite, reproduced here as Figure 1. Both the GSFC printouts and the UK printouts were based upon this format.

At the outset, telemetry data taken at Blossom Point and other stations and both refined and predicted world map data were supplied by GSFC. An inventory of these data was compiled and is included in Table I. A record was also made from the GSFC printouts to show when ozone data were available and when broadband ozone and galactic noise data were available. Times were correlated between the world maps and the GSFC printouts to establish on what pass numbers specific kinds of data were available.

Examples of telemetry data pointouts received from GSFC are provided by Figure 2 which illustrates High Speed Mode I operation, and Figure 3 which portrays Low Speed Mode I and Mode II operation. Each three-digit data group is converted to frequency (kc) by dividing by 10 and adding 4. Thus a data group of 054 in the printout from GSFC would be equivalent to an actual frequency of 9.4 kc. Both experimental and performance parameter data are provided by the tabular printouts from GSFC.

ENCODER FORMAT

FRAME	CHANNEL 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0 5.1 0 0 196.1								PP OZ TEMP 1 0 MON CELL							
1	SYNC	M	G	M	M	M	G	M	PP OZ TEMP 2 1 OZ CELL	M	G	M	M	M	G	M
2	0 6.3 0 1 158.7	M	N	M	M	M	N	M	PP OZ TEMP 3 2 SPECT A	M	N	M	M	M	N	M
3	SYNC								PP OZ EHT 3 MON							
4	0 7.5 1 0 133.3	I	H	I	D	I	H	I	PP 4 +15 VDC	I	H	I	D	I	H	I
5	SYNC	R	S	R	R	R	S	R	PP TAPE REC 5 TEMP	R	S	R	R	R	S	R
6	0 8.7 1 1 114.9	O		O	O	O		O	PP DUMPED 6 CURRENT	O		O	O	O		O
7	SYNC	D		D	D	D		D	PP UNREG 7 BUS VOLTS	D		D	D	D		D
8	1 9.9 0 0 101.0								PP GN REEL OR 8 REG + 12 VDC							
9	SYNC	A		A	B	A		A	PP SOLAR 9 CURRENT	A		A	A	A		A
10	1 11.1 0 1 90.1	OR		OR		OR		OR	PP BATT 10 CURRENT	OR		OR		OR		OR
11	SYNC	B		B		B		B	PP BATT A 11 TEMP	B		B		B		B
12	1 12.5 1 0 81.3								PP PADDLE 4 12 TEMP							
13	SYNC								PP UPPER SHELF 13 TEMP							
14	1 13.5 1 1 74.1								PP LOWER SHELF 14 TEMP							
15	SYNC	A		B		A		B	PP GN SW 15 MON	A		B		A		B

HIGH SPEED MODE ONE

SYNC	OZONE SPECTRUM

HIGH SPEED MODE TWO

LOW SPEED MODE ONE

SYNC	GALACTIC NOISE	SYNC

LOW SPEED MODE TWO

SYNC	01	02	01	02	01	02	01	02	01	02	01	02	01	02	01

SYNC = 4.5 KC, 222.2 NS

01 = OZ PHOTOCELL

LS B/B = 15.4 KC, 64.9 NS

02 = MON PHOTOCELL

S5296A-VB-25

Figure 1

Inventory of
S-52 Telemetry Data
from Blossom Point

	U.K. Ch. 8 Data in Parentheses Pass No.		Buffer No.	Start Date/Time	Cover Date
1.	(1, stations SOL, SNP)		001	88/0808	3/30/64
2.	(2, sta. SNP, MOJ, LIM, SOL)		002	88/1139	3/30/64
3.	7, 8 (6, sta. SNT)			88/1324	3/28-29/64
4.	7, 8 (7, sta. WNK)			87/1918	
5.	9 (10, sta. MOJ, MOJ, WNK, BPO)			89/0655	4/9/64
6.	12		003	88/1517	3/30/64
7.			007	93/0808	4/14/64
8.	9, 12, 13, 23		010	88/0814	
9.			011	87/2109	4/16/64
10.			011	88/0754	4/16/64
11.	224		011	03/1124	4/16/64
12.			013	05/0513	4/20/64
13.	21, 22		017	18/2203	
14.	44 (100, sta. JOB, SOL, SNT, QUI, MOJ		018	19/1020	5/4/64
15.	(191, sta. FTM, OOM, WNK, NFL)		019	22/0543	
16.	421, 431, 432, 455 (243, sta. OOM, JOB, NFL, MOJ)			16/0805	4/28/64
17.	653, 661, 667, 681	H.S.		33/1554	5/28/64
	667, 681	L.S.			
18.	528, 533, 542, 572, 586, 600			24/1939	
19.			021	29/2114	
20.	628, 642, 656		22	31/2021	
21.	653, 654, 658		24	33/1519	5/20/64
22.	667		26	34/1455	
23.	670, 684		23	34/1910	5/18/64
24.	758, 768, 770, 772	H.S.	25	40/2352	5/21/64
	768, 770	L.S.			
25.	782, 783, 810	H.S.	26	42/1558	5/27/64
	782, 810	L.S.			
26.				54/1355	6/11/64
27.				54/1434	6/3/64
28.	979, 1007, 1008	H.S.		56/1206	6/10/64
	979	L.S.			
29.	1011, 1040, 1049	H.S.	29	58/1820	
	1011, 1049	L.S.			
30.	1109, 1137, 1147	H.S.		65/1528	6/19/64
	1109, 1137	L.S.			
31.	1179, 1207, 1218, 1235	H.S.		70/1325	6/23/64
	1179, 1207	L.S.			
32.	1249, 1274		32	75/1124	
33.	1291, 1316			70/1011	
34.	1344, 1358, 1372, 1390, 1400, 1418, 1428	H.S.		82/0310	7/7/64
	1344, 1358, 1372, 1390, 1428	L.S.			
35.	1445, 1446, 1456, 1460	H.S.		89/0532	7/10/64
	1445, 1446	L.S.			

Table I

	Pass No.		Buffer No.	Start Date/Time	Cover Date
36.	1474, 1488, 1502, 1513	H.S.		91/0626	7/13/64
	1474, 1513	L.S.			
37.	1516, 1541, 1544, 1568, 1572			94/0510	
38.	1586, 1611, 1624, 1638, 1642, 1653, 1657, 1667, 1681, 1694, 1695, 1699, 1709, 1713, 1723, 1727	H.S.		99/0304	7/28/64
	1586, 1653, 1664, 1681, 1695, 1699, 1709, 1723, 1727	L.S.			
39.	1783, 1793, 1797, 1806, 1811, 1822, 1825		40	12/2246	8/3/64
40.	1737, 1755	H.S.&L.S.		09/1700	7/31/64
41.	1853, 1866, 1880, 1881, 1892, 1895, 1905, 1907, 1916, 1919, 1923	H.S.		17/2038	8/11/64
	1866, 1880, 1881, 1916, 1892, 1895, 1923	L.S.			
42.	1935, 1936, 1948, 1952, 1966, 1977	H.S.	43	23/1418	8/14/64
	1935, 1952, 1966	L.S.			
43.	2036, 2046, 2050, 2060, 2061, 2074, 2075	H.S.	45	30/1632	8/21/64
44.	2088, 2093, 2103, 2107, 2117, 2121		46	34/0734	8/25/64
45.	2131, 2135, 2148, 2149, 2162, 2163		47	37/0806	8/28/64
46.	2177, 2186, 2188, 2202, 2206, 2215, 2217, 2219, 2233	H.S.	48	40/1345	9/4/64
	2177, 2188, 2202, 2206, 2229	L.S.			
47.	2245, 2247, 2251, 2261, 2271	H.S.	49	45/0608	9/4/64
48.	2277, 2285, 2289, 2314, 2317, 2329, 2332	H.S.	50	47/0511	9/10/64
	2272, 2317, 2329	L.S.			
49.	2342, 2344, 2356, 2360, 2370, 2371	H.S.	51	52/0253	9/11/64
	2342, 2370, 2371	L.S.			
50.	2384, 2385, 2398, 2399, 2412	H.S.	52	55/0129	9/15/64
	2384, 2385, 2398, 2399, 2412	L.S.			
51.	2426, 2430, 2444, 2455, 2458, 2469, 2472, 2473	H.S.	53	58/0007	9/21/64
	2426, 2430, 2444, 2455, 2458, 2469, 2472, 2473	L.S.			
52.	2483, 2485, 2486, 2487, 2511, 2514, 2515, 2525	H.S.	54	62/0002	9/22/64
	2483, 2485, 2486, 2487, 2511, 2514, 2515, 2525	L.S.			
53.	4 files	H.S.	55	65/0540	9/25/64
	2 files	L.S.			
54.			56	67/2113	9/28/64

Table I (Continued)

	Pass No.		Buffer No.	Start Date/Time	Cover Date
55.	2653, 2656, 2669, 2639, 2642, 2643	H.S.	57	73/2008	10/2/64
	2653, 2656, 2639, 2642, 2643	L.S.			
56.	2670, 2671, 2685, 2695, 2709, 2712, 2713, 2726, 2727	H.S.	58	75/0057	10/7/64
	2670, 2685, 2712, 2713	L.S.			
57.	3	H.S.	59	79/1719	10/12/64
58.	2783, 2798, 2822		60	82/2250	10/13/64
59.	2825, 2839, 2854, 2855, 2864, 2865, 2868	H.S.	61	85/2125	10/16/64
60.	2892, 2893, 2896, 2911	H.S.	62	90/1340	10/20/64
61.	2920, 2923, 2934, 2937, 2947, 2951, 2965, 2967	H.S.	63	92/1427	10/23/64
62.			64	96/1229	10/29/64
63.	3018, 3032, 3060	H.S.	65	99/1057	11/2/64
64.	3074, 3078, 3088, 3092, 3103	H.S.	66	03/0857	11/3/64
65.			67	05/1459	
66.			68	11/1342	11/13/64

Table I (Continued)

Inventory of World Maps
-1964-

Refined Maps

Month/Date/Time

Start	End
03/27/1733	04/01/2359
04/01/1733	04/05/1733
04/05/0005	04/10/1127
04/10/0340	04/14/1040
04/14/0208	04/21/0944
04/21/0247	04/28/0704
04/28/0104	05/05/0742
05/05/0017	05/12/0457
05/12/0041	05/20/2333
05/26/1500	05/31/2359
05/31/1218	06/06/1127
06/06/0100	06/12/0000
06/11/1800	06/19/1300
06/19/0607	06/27/0000

Pre-Launch Prediction

Month/Date/Time

Start	End
03/21/1607	03/24/1607

Predicted Maps

Month/Date/Time

Start	End
03/27/1733	04/06/2359
04/01/0000	04/08/0000
04/07/0000	04/13/0000
04/12/1800	04/20/2359
04/20/0000	04/27/2359
04/28/0000	05/04/2359
05/14/0000	05/21/2359
05/21/0000	05/28/2359
05/26/0000	06/04/2359
06/02/0000	06/09/2359
06/09/0000	06/15/2359
06/15/0000	06/22/2359
06/22/0000	06/29/2359
06/29/0000	07/06/2359
06/26/1900	07/04/2300
06/25/0000	06/29/2359
(corrections)	
07/06/0000	07/14/0300
07/13/0000	07/21/0300
07/28/0000	08/04/2200
08/04/0000	08/11/2200
08/11/0000	08/18/2200
08/18/0000	08/25/2200
08/25/0000	09/01/2200
09/01/0000	09/08/2200
09/08/0000	09/15/2200
09/15/0000	09/22/2200

Table I (Continued)

EXAMPLE OF PRINTOUT OF HIGH SPEED MODE I TELEMETRY DATA FROM GSFC

5264087/13/001

•87	1857	13.911	106	085	106	106	105	086	106	039	106	086	105	105	105	086	106	059	‡
•87	1857	14.202	105	086	105	106	105	088	106	082	106	086	106	105	106	087	106	005	‡
•87	1857	14.493	106	087	105	106	106	088	106	031	105	088	106	106	106	086	106	071	‡
•87	1857	14.784	105	088	105	106	105	088	105	055	106	090	106	106	106	090	106	005	‡
•87	1857	15.074	105	090	106	106	106	090	106	059	105	090	105	106	105	091	105	082	‡
•87	1857	15.365	105	092	106	106	105	088	106	070	105	093	105	106	105	097	105	005	‡
•87	1857	15.656	105	101	105	105	105	105	105	070	105	106	105	106	106	106	105	093	‡
•87	1857	15.947	105	106	105	105	104	106	101	071	095	106	096	106	103	106	106	005	‡
•87	1857	16.238	106	106	106	106	106	101	107	095	107	104	107	106	107	105	107	011	‡ ← FRAME I
•87	1857	16.529	107	105	107	105	107	105	106	018	106	105	106	106	105	105	093	005	‡
•87	1857	16.820	051	101	037	105	058	081	105	065	---	076	---	106	---	081	---	022	‡
•87	1857	17.110	---	101	---	105	---	104	---	053	---	097	---	106	---	104	---	005	‡
•87	1857	17.401	110	105	107	105	104	105	106	088	109	105	110	106	---	105	---	035	‡
•87	1857	17.692	110	104	108	104	104	104	105	022	109	104	---	106	---	104	---	005	‡
•87	1857	17.983	---	104	---	090	---	103	---	067	---	103	---	106	---	103	---	046	‡
•87	1857	18.274	110	091	110	090	110	101	110	044	110	101	110	106	110	101	110	005	‡
•87	1857	18.564	110	099	110	091	110	099	110	039	110	097	110	106	109	095	109	059	‡
•87	1857	18.856	119	095	109	106	109	094	109	082	108	091	108	106	109	090	109	005	‡
•87	1857	19.147	108	087	108	106	108	085	108	036	107	082	108	106	108	079	108	071	‡
•87	1857	19.438	107	068	107	106	107	075	107	055	107	072	107	106	107	072	107	005	‡
•87	1857	19.728	106	072	106	106	107	074	106	059	106	075	106	106	106	075	106	082	‡
•87	1857	20.019	106	075	106	106	106	078	106	070	106	079	106	105	106	082	106	005	‡
•87	1857	20.310	106	085	105	106	106	087	106	070	106	089	106	105	105	091	105	094	‡
•87	1857	20.601	106	093	105	106	105	093	105	071	105	079	105	105	105	---	105	005	‡
•87	1857	20.892	105	095	105	106	105	096	105	090	105	094	105	105	105	095	105	010	‡
•87	1857	21.182	105	095	105	106	105	095	105	018	105	095	105	105	105	095	105	005	‡
•87	1857	21.473	105	096	105	107	106	095	105	065	105	095	105	105	105	095	105	022	‡
•87	1857	21.764	105	094	105	106	105	094	105	053	105	094	105	105	105	095	104	005	‡
•87	1857	22.055	105	094	105	106	105	094	105	087	105	094	105	105	105	088	105	035	‡
•87	1857	22.346	105	094	105	107	105	095	104	022	104	094	105	105	105	093	105	005	‡
•87	1857	22.637	105	094	105	106	105	095	105	067	105	094	105	105	105	093	105	046	‡
•87	1857	22.928	105	093	105	107	105	094	105	049	105	093	105	105	105	093	105	005	‡
•87	1857	23.219	105	093	105	107	105	093	105	039	105	093	105	095	105	091	106	059	‡
•87	1857	23.509	106	093	105	106	106	093	105	082	105	093	105	095	105	093	105	005	‡
•87	1857	23.800	105	093	105	106	105	093	105	045	105	085	106	096	106	092	105	071	‡
•87	1857	24.091	106	093	106	106	105	092	106	055	106	091	106	106	105	092	106	005	‡
•87	1857	24.382	106	092	106	106	105	093	106	059	106	092	106	106	106	093	106	082	‡
•87	1857	24.673	106	091	106	106	106	093	105	071	105	092	105	105	106	093	106	005	‡

DAY OF YEAR; h; m; s

CHANNEL NO. 1

005 = SYNC PULSE

CHANNEL NO. 15

CHANNEL NO. 0

S5296A-VB-21

Figure 2

EXAMPLE OF PRINTOUT OF LOW SPEED MODES I & II TELEMETRY DATA FROM GSFC

Day of year	h m	s	Ch. 1														Ch. 15	Ch. 0
•97	0638	34.041	116099	116102	115099	116087	11609	116095	116097	116097	116098	116097	115098	116098	116098	116095	116005	116005
•97	0638	34.332	116094	116093	116093	116095	11609	116098	116097	116100	116102	116103	115099	116096	116092	116090	116005	---005
•97	0638	34.623	116100	116103	116099	116087	11609	116095	116097	115097	116098	116097	116098	116097	116097	116094	116005	115005
•97	0638	34.913	116094	116092	116093	116095	11609	116098	116097	116100	116103	116103	115100	116096	116091	116089	116005	116005
•97	0638	35.204	116101	116102	115098	116086	11609	116095	116097	116096	116097	117096	116097	116097	116098	116094	115005	117005
•97	0638	35.495	116093	117093	116092	116094	11609	116097	116097	116100	116103	116099	116096	116094	116091	116088	115005	117005
•97	0638	35.786	116101	116101	116098	116086	11609	116094	116097	116096	116097	117096	116097	116096	116097	116094	117005	117005
•97	0636	36.076	116093	116091	116092	116094	11609	116097	116097	116100	116102	116101	116098	116093	116089	116086	117005	116005
•97	0638	36.367	116101	117101	116097	116086	11609	116094	117097	116097	116097	116096	116096	116096	116097	116094	116005	117005
•97	0638	36.658	116092	117091	116091	116093	116093	115097	116097	116100	116102	117100	116094	116090	116085	116088	115005	117005
•97	0638	36.949	116101	117101	116097	116086	116090	116094	116096	116095	116096	116096	116097	116096	116097	116093	116005	116005
•97	0638	37.240	116093	116091	116091	116092	116092	116095	116096	116099	116101	116097	116092	116086	116081	116091	115005	115005
•97	0638	37.531	116100	116101	116097	116086	116090	116094	116096	116095	116096	116095	116096	116095	116097	116093	116005	116005
•97	0638	37.822	115091	116090	115091	116092	116092	116095	116096	116099	115101	116099	116092	116087	116086	116096	115005	116005
•97	0638	38.112	116100	116100	116096	116085	116089	115093	116095	116094	116095	116095	116095	116096	116097	115093	116005	---005
•97	0638	38.403	116092	116091	116090	116091	116092	115095	116096	116099	116100	116095	116089	116085	116093	115099	116005	116005
•97	0638	38.694	116099	116101	116097	116085	116089	115092	116095	116094	116095	116095	116095	116095	116095	116093	116005	117005
•97	0638	38.984	116091	116090	116090	116092	116093	116096	116097	116101	116099	116095	116089	116091	117098	116100	116005	117005
•97	0638	39.275	116099	116100	116095	116084	117088	116093	116095	116095	115095	116094	116095	116095	117097	116093	115005	117005
•97	0638	39.566	116092	116092	116091	116091	117093	116095	116097	116101	116099	116095	116088	116096	117100	116101	115005	117005
•97	0638	39.857	116098	117099	116095	116085	116088	116091	116094	116093	116095	117095	116095	116095	116096	116092	116005	---005
•97	0638	40.148	116092	116091	116090	116091	116091	116096	116098	116101	116097	116092	116093	116099	116101	116101	116005	---005
•97	0638	40.440	116098	116099	116095	116084	116088	116092	116095	116094	116095	115094	116094	116094	116095	116092	116005	---005
•97	0638	40.730	116092	116091	116091	116091	116094	116100	116099	116101	115097	116091	116097	116100	116101	115100	116005	115005
•97	0638	41.021	115096	116097	116094	116083	116088	116092	116094	116093	116093	116093	116094	116095	116095	116092	115005	115005
•97	0638	41.311	115091	116090	116089	116090	116095	115100	116099	116100	115094	116093	116099	116101	116101	116099	115005	116005
•97	0638	41.602	115096	116097	116095	115083	116087	115091	116093	116093	116094	116094	116094	115094	116095	116091	115005	115005
•97	0638	41.893	116090	116090	116090	116090	116097	116101	116099	116099	116094	116098	116100	115101	116100	116099	116005	117005
•97	0638	42.184	116097	116097	116093	115083	116088	116091	115094	116093	116093	116093	116094	116094	116095	116092	116005	117005
•97	0638	42.475	116092	116091	116092	116097	116101	116102	116100	116099	115094	116099	117101	116101	117100	116099	115005	116005
•97	0638	42.765	116096	116097	116094	116084	117088	116091	116093	116092	116093	116094	117095	116095	117096	116091	116005	117005
•97	0638	43.056	116094	116094	116091	116097	116101	116102	116100	116097	116096	116101	117101	116101	116099	116098	115005	117005
•97	0638	43.347	116097	116097	116094	115083	116088	116091	116094	117094	116094	116093	116094	115094	116096	116091	116005	117005
•97	0638	43.638	116092	116091	116091	116098	116101	116102	116100	117097	116097	116101	116100	116100	116099	116099	115005	116005
•97	0638	43.929	116095	116096	116094	116083	116088	116091	116093	116092	115093	116093	116035	116061	117035	116085	115035	115035
•97	0638	44.220	116035	116057	116034	116055	116035	116058	116032	116061	116033	116061	116035	116061	116035	115059	115036	116005
•97	0638	44.511	116034	116055	116035	116059	116034	116059	116032	116061	115035	116062	116035	115059	116035	115058	115034	115705
•97	0638	44.802	116034	116057	116035	115059	116032	116082	116035	116061	116035	116061	116036	115059	116035	116055	115034	---005
•97	0638	45.093	116035	116066	116032	115061	116034	116060	116035	116068	116035	116060	116035	116057	116034	116055	116035	116005
•97	0638	45.383	115032	116060	116033	116061	116035	116061	115035	116060	115036	116058	116034	116055	116035	116068	115034	115005
•97	0638	45.674	116032	116061	116035	116063	116035	116060	116036	116059	116034	116056	117034	116057	116035	116059	116032	116005
•97	0638	45.965	115034	116062	117035	116061	116036	116059	115035	116056	116034	116056	116035	116060	116032	116060	115034	115005
•97	0638	46.256	116035	116062	117035	116059	116036	116059	116034	117056	116035	116058	116033	116060	116033	116062	116035	117

DAY OF YEAR, h, m, s — DATA — CHANNEL NO. 1 — CHANNEL NO. 15 — CHANNEL NO. 0

005 = SYNC. PULSE
005 WORD IN 15 AND 0 = GN
005 WORD IN 0 ONLY = O_3 (BROADBAND)

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Figure 3

The telemetry data received from the United Kingdom, however, provides only satellite performance parameter information. The data comes in the form of three-digit groups which may be converted to actual frequency by dividing the data group by 10 and subtracting 5. Thus a data group of 144 from the UK is equivalent to a frequency of 9.4 kc. An example of the telemetry printout received from the United Kingdom is shown by Figure 4 with the accompanying descriptive sheet of Figure 5.

The two types of world maps generated by the computing facilities at GSFC provide satellite orbital information. An example of the inputs to the orbit prediction program is shown in Figure 6. The Predicted World Map includes the following information:

a. the Satellite Map which provides three-dimensional geographic position data for each minute of time as shown by Figure 7.

b. satellite orbital data relative to individual stations at roughly one-second intervals as illustrated by Figure 8.

The latter information is useful in determining when telemetry data can be expected from a particular station. The Refined World Map furnishes the following information:

a. interim definitive orbital elements at intervals of approximately one week-- illustrated by Figure 9.

b. a three-dimensional geographic position at one minute intervals similar to that provided by the Predicted World Map.

c. a weekly satellite map of special points and some orbital data as indicated by Figure 10.

The mechanics of data processing were greatly facilitated by using masks of stiff paper to read the printouts. Rectangular apertures were cut in

EXAMPLE OF PRINTOUT OF TELEMETRY DATA FROM THE UNITED KINGDOM (CHANNEL 8 ONLY)

LABEL

Telemetry Recording				D.S.I.R. R.R.S. Telemetry Data Processing Centre	
Sat.	UK2	Stn.	WNK		
Pass	106	Date	4.4.64		
Print-Out				L.H.	R.H.
Start	040142	Stop	041726	8	—
Expt.	H.K.	Encr.	HI	—	—

PRINTOUT

TIME: m	TIME: s	TIME: ms		DATA
02	02	182		172
02	02	473		201
02	02	764		181
02	03	055		180
02	03	340		179
02	03	637		187
02	03	927		170
02	04	219		178
02	04	510	*	099
02	04	800		150
02	05	091		178
02	05	382		181
02	05	673		111
02	05	964		166
02	06	255		204
02	06	545		147
02	06	836		172
02	07	127		202
02	07	418		101
02	07	709		105
02	08	000		179
02	08	291		187
02	08	582		170
02	08	872		171
02	09	163	*	099
02	09	454		150

PARAMETER NO. 0

TIME — DATA

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Figure 4

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

RADIO RESEARCH STATION

Ariel II Housekeeping Data

As from 26th June 1964 the Radio Research Station will send at regular intervals to Goddard Space Flight Center, satellite performance parameter data reduced from the most recent Winkfield tapes.

This information will be presented in long printed strips, one for each pass digitised. The following notes will be of assistance in interpreting these records.

1. The date, time of the day in hours, pass (revolution) number and recording station are entered in the rubber stamped title block on each record.

2. Sync and data tone bursts are detected in the R.R.S. equipment between one and two milliseconds before the end of the burst. The time at which each frame sync burst is detected is printed out in minutes, seconds and milliseconds in the 7 figure group which appears on the left of each line of the print out.

3. The occasional asterisk in column 8 indicates that the time on this line is that of the first sync burst in the 16 frame sequence, i.e. octal number 000.

4. Channel 8 performance parameter data are printed out in columns 9 to 11. The group of figures immediately on the right of an asterisk is therefore parameter No. 0 - ozone temperature No. 1.

5. To convert these 3 figure groups to the corresponding tone burst frequency in kc/s, subtract 50 and divide by 10. e.g. 179 becomes 12.9 kc/s.

6. 888 in columns 9 to 11 means that this burst of tone could not be digitised.

7. A cross (+) appearing in place of any digit indicates that a parity error occurred.

7th July, 1964
DNM/ESB

Figure 5

EXAMPLE OF INPUTS TO ORBIT PREDICTION PROGRAM FOR PREDICTED WORLD MAP AND REFINED WORLD MAP

```
1964 S-52

ID.NO. REF.DATE LAMBDA HMS TAU DMS SATELLITE
64151 64 03 27 12 17 48412 C06 21 3550C -52

EPOCH 64 04 21 02 47 00000

A E I P OMEGA THETA
11282708 01 73442617-01 90162798 00 20760569 01 39409470 01 19599321 01

DRAG EFFECTS T(P,Q) N(2,Q) N(3,Q)
640421 024700 74624724-07 00000000 00

EARTH CONSTANTS MU ROTATION RADIUS FLATNESS
10000000 01 58835124-01 10000000 01 33670033-02

HARMONICS
K2 K3 K4 K5
54109499-03 22849999-05 79620000-06 23199999-06

J H K L
[illegible]237999-02 00000000 00 00000000 00 00000000 00
```

35296A-VB-20

Figure 6

EXAMPLE OF PREDICTED SATELLITE MAP
—PROVIDED BY PREDICTED WORLD MAP

PREDICTED SATELLITE MAP 2

WMAP2 S-52 640705 2

PASS NO. 01530 OF SATELLITE 64151 . DATE 640713 2

041700 154.11 00.00 009201 2

DATE 640713 2

TIME HRMISE	LONG. DEG.	LAT. DEG.	O.O H. KM.	TIME HRMISE	LONG. DEG.	LAT. DEG.	OID H. KM.	
041800	155.99	02.69	008886	045600	-053.25	20.39	004354	2
041900	157.92	05.45	008562*	045700	-050.76	17.90	004598	2
042000	159.84	08.22	008237*	045800	-048.37	14.90	004857	2
042100	161.90	11.00	007910*	045900	-046.07	11.78	005129	2
042200	163.98	13.78	007584*	050000	-043.86	08.88	005414	2
042300	166.14	16.58	007260*	050100	-041.70	05.88	005710	2
042400	168.40	19.37	006937*	050200	-039.59	02.90	006015	2
042500	170.76	22.14	006619*	050300	-037.51	-00.05	006329	2
042600	173.25	24.90	006307*	050400	-035.45	-02.99	006650	2
042700	175.90	27.63	006001*	050500	-033.40	-05.90	006976	2
042800	178.71	30.31	005702*	050600	-031.35	-08.76	007306	2
042900	-178.26	32.95	005413*	050700	-029.29	-11.59	007639	2
043000	-175.03	35.51	005134*	050800	-027.20	-14.36	007973	2
043100	-171.53	37.98	004867*	050900	-025.07	-17.10	008307	2
043200	-167.75	40.34	004613*	051000	-022.90	-19.77	008639	2
043300	-163.67	42.57	004373*	051100	-020.67	-22.39	008968	2
043400	-159.23	44.64	004148*	051200	-018.37	-24.95	009294	2
043500	-154.44	46.50	003940*	051300	-015.98	-27.43	009613	2
043600	-149.27	48.14	003749*	051400	-013.50	-29.85	009927	2
043700	-143.77	49.52	003576*	051500	-010.91	-32.18	010233	2
043800	-137.91	50.60	003422*	051600	-008.20	-34.40	010530*	2
043900	-131.81	51.35	003288*	051700	-005.36	-36.59	010817*	2
044000	-125.52	51.75	003175*	051800	-002.37	-38.64	011094*	2
044100	-119.15	51.78	003083*	051900	000.78	-40.59	011359*	2
044200	-112.31	51.43	003013*	052000	004.11	-42.42	011613*	2
044300	-106.60	50.72	002966*	052100	007.52	-44.12	011853*	2
044400	-100.62	49.67	002941*	052200	011.31	-45.67	012079*	2
044500	-094.95	48.29	002938*	052300	015.20	-47.08	012290*	2
044600	-089.61	46.63	002959	052400	019.27	-48.33	012486*	2
044700	-084.64	44.71	003002	052500	023.53	-49.40	012667*	2
044800	-080.03	42.50	003068	052600	027.94	-50.28	012832*	2
044900	-075.73	40.25	003157	052700	032.49	-50.97	012980*	2
045000	-071.81	37.77	003267	052800	037.14	-51.45	013111*	2
045100	-068.18	35.16	003399	052900	041.88	-51.72	013224*	2
045200	-064.77	32.45	003552	053000	046.61	-51.79	013321*	2
045300	-061.61	29.64	003724	053100	051.33	-51.64	013399*	2
045400	-058.67	26.77	003917	053200	055.98	-51.25	013458*	2
045500	-055.88	23.55	004127	053300	060.54	-50.73	013501*	2

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EXAMPLE OF SATELLITE ORBITAL DATA RELATIVE TO A PARTICULAR STATION
—PROVIDED BY PREDICTED WORLD MAP

```
640720 215600 001996 005005-002270 03372 0304 22942 4313*       016
640720 215650 002259 005140-CC2512 04036 0000 23382 3665*   H   C16
                                                                01
       BPOINT 640720  202                                       019
Y M D  H M S  R    KM RR M/S FR CPS AZ    EL   L H A DEC        016
640720 233442 002469-005583 CC2532 31308 0000 12016 3235*   H   016
640720 233500 002367-005446 CC2470 31519 C073 12144 3431*       C16
640720 233600 002057-004125 CC2183 32343 0313 12745 4146*       016
640720 233700 001795-003838 CC1740 33430 0536 13829 4953*       016
640720 233800 C01607-002561 CC1071 34831 0701 15842 5684*       016
640720 233843 001534-001016 CC0461 35959 0747 17998 5904*   M   016
640720 233900 001521-000426 CCC193 00456 0744 15950 5869*       016
640720 233912 001519-000002 CCCCC1 00851 0733 19606 5797*    C  016
640720 234000 C01558 001119-CCC734 02210 0624 21754 5213*       C16
640720 234100 001709 003339-CC1514 03725 0389 23389 4163*       016
640720 234200 001948 004561-0C2069 04928 0099 24266 3145*       016
640720 234220 002043 004869-0C2208 05264 0000 24461 2339*   H   016
       END    BPOINT                                            016
       CCLEGE                                                   C2
       640713 000000  195                                       C2
       640720 235900  202                                       02
                                                                02
       COLEGE 640713  195                                       029
Y M D  H M S  R    KM RR M/S FR CPS AZ    EL   L H A DEC        026
640713 043431 002305-004730 CC2145 19878 0000 02058-2370*   H   026
640713 043600 C01947-003152 CC1429 19338 C261 00385-2248*       C26
640713 043615 C01899-002766 CC1254 17959 0296 35999-2217*   M   026
640713 043700 C01803-001586 CCC719 170C9 0358 34936-2116*       026
640713 043752 001762 000101-CCCCCC 15737 0352 33595-1955*    C  026
640713 043800 CC1763 000258-CCC117 15533 0351 33362-1926*       C26
640713 043900 CC1834 002070-CCC938 14083 0231 31370-1701*       026
640713 044000 CC2005 003358-CC1614 12817 0031 30555-1493*       026
640713 044008 002034 003725-CC1665 12567 0000 30398-1469*   H   026
                                                                C2
       COLEGE 640713  195                                       029
Y M D  H M S  R    KM RR M/S FR CPS AZ    EL   L H A DEC        C26
640713 061811 C02162-005283 C02396 22582 0000 04866-1721*   H   026
640713 061900 C01922-004569 CC2072 21809 0190 04033-1770*       026
640713 062000 C01684-003239 CC1469 20565 0396 02711-1862*       026
640713 062100 001544-001356 CC0613 19002 C519 01060-1954*       C26
640713 062135 001519-000083 CCC037 17958 0523 35998-1385*   M   C26
640713 062137 CC1518-000002 CCC001 17935 0527 35931-1986*    C  026
640713 062200 C01528 000846-CCC383 17269 0502 35225-1990*       026
640713 062300 CC1641 002855-CC1295 15647 0342 33499-1955*       C26
640713 062400 C01860 004337-CC1967 14330 0101 32082-1893*       026
640713 062423 0C1965 004763-CC2160 13912 0000 31629-1873*   H   026
                                                                C2
```

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Figure 8

EXAMPLE OF INTERIM DEFINITIVE ORBITAL ELEMENTS
-REFINED WORLD MAP-

```
INTERIM DEFINITIVE ELEMENTS

ORBITAL ELEMENTS FOR 64151 , -52
 FROM GODDARD SPACE FLIGHT CENTER
F  CH  64 Y 04 M 21 D AT 02 HOURS 47.00 MIN. UT
SEMI-MAJOR AXIS      007196.55  KILOMETERS  ( 004471.72 MILES)
ECCENTRICITY         0.07344
INCLINATION          051.659     DEGREES
MEAN ANOMALY         119.064     DEGREES
ARGUMENT OF PERIGEE  225.800     DEGREES,  03.0501  DEG. PER DAY
R.A. OF ASCEND.NODE  112.296     DEGREES, -04.0951  DEG. PER DAY
ANOMALISTIC PERIOD   0101.25857  MINUTES, -0.00194  MIN. PER DAY
HEIGHT OF PERIGEE    000289.63  KILOMETERS  ( 000179.97 MILES)
HEIGHT OF APOGEE     001346.69  KILOMETERS  ( 000836.80 MILES)
VELOCITY AT PERIGEE  028839      KM. PER HR. ( 017920    MI. PER HR.)
VELOCITY AT APOGEE   024893      KM. PER HR. ( 015468    MI. PER HR.)
GEOC.LAT.OF PERIGEE -34.215      DEGREES
```

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Figure 9

EXAMPLE OF SPECIAL POINTS AND SOME ORBITAL DATA

-REFINED WORLD MAP-

SATELLITE MAP OF SPECIAL POINTS AND SUMMARY OF SOME ORBITAL DATA

SPECIAL POINTS	YRMODA	HR	MI	SS.SS	PASS	LONG.DEG	LAT.DEG	1000H.KM
ASCENDING NODE	640422	14	14	19.34	000369	041.9895	00.0000	01132464
NORTH POINT	640422	14	43	03.24	000369	124.7244	51.8028	01214032
DESCENDING NODE	640422	15	08	30.60	000369	-151.7307	00.0000	00460298
SOUTH POINT	640422	15	30	36.83	000369	-067.4228	-51.8188	00412873
SUNLIGHT ENTRANCE								
SUNLIGHT EXIT	640422	14	54	41.93	000369	174.0737	37.8596	00889898
SUNLIGHT ENTRANCE	640422	14	57	59.20	000369	-176.2416	30.1448	00781118
SUNLIGHT EXIT								
SUMMARY DATA	PERCENT							
SATELLITE IN SUN	096.8							

Figure 10

the masks at location corresponding to the parameter being read. The apertures were arranged in a vertical column for reading performance parameters which appear in the vertical column in the encoder format, the number of apertures corresponding to the frequency of occurrence of a particular parameter in channel 8. The mask enabled rapid scanning to determine the maximum and minimum values of current at 5-minute intervals. The apertures were arranged in a horizontal row for experiment responses and corresponded in number to the occurrences of the particular parameter in a frame.

Inasmuch as no conversion charts were available to convert frequency entries to engineering units for the experiment responses, experiment data points were plotted directly as frequencies on the graphs. This method of plotting was consistent with the intent of the program in that experiment performance was not to be studied -- only recorded. In the case of performance data parameters, the frequency values were read from the printouts and transferred to an accounting sheet, illustrated in Figure 11, where the 14 performance parameters were placed opposite time designations. The raw data groups from the telemetry printouts were converted to frequency (kc) units as previously indicated. In the column adjacent to the frequency data on the accounting sheet, the corresponding engineering unit values for each performance parameter were subsequently entered. These latter values were derived from the 14 conversion charts supplied by GSFC and are illustrated by Figures 12 through 26. Auxiliary conversion tables were constructed from the graphs to facilitate data conversion and reduce the likelihood of graph reading errors.

Considerations of Data Utility

During the initial phases of the work on data reduction, the analytical phase requirements were considered to direct the effort toward achievement of

EXAMPLE OF INTERMEDIATE ACCOUNTING SHEET USED IN PLOTTING PERFORMANCE PARAMETERS

8/9/64 DAY 222 PASS 1926
ORBIT START TIME: 222 d / 22 h / 58 m / 00 s

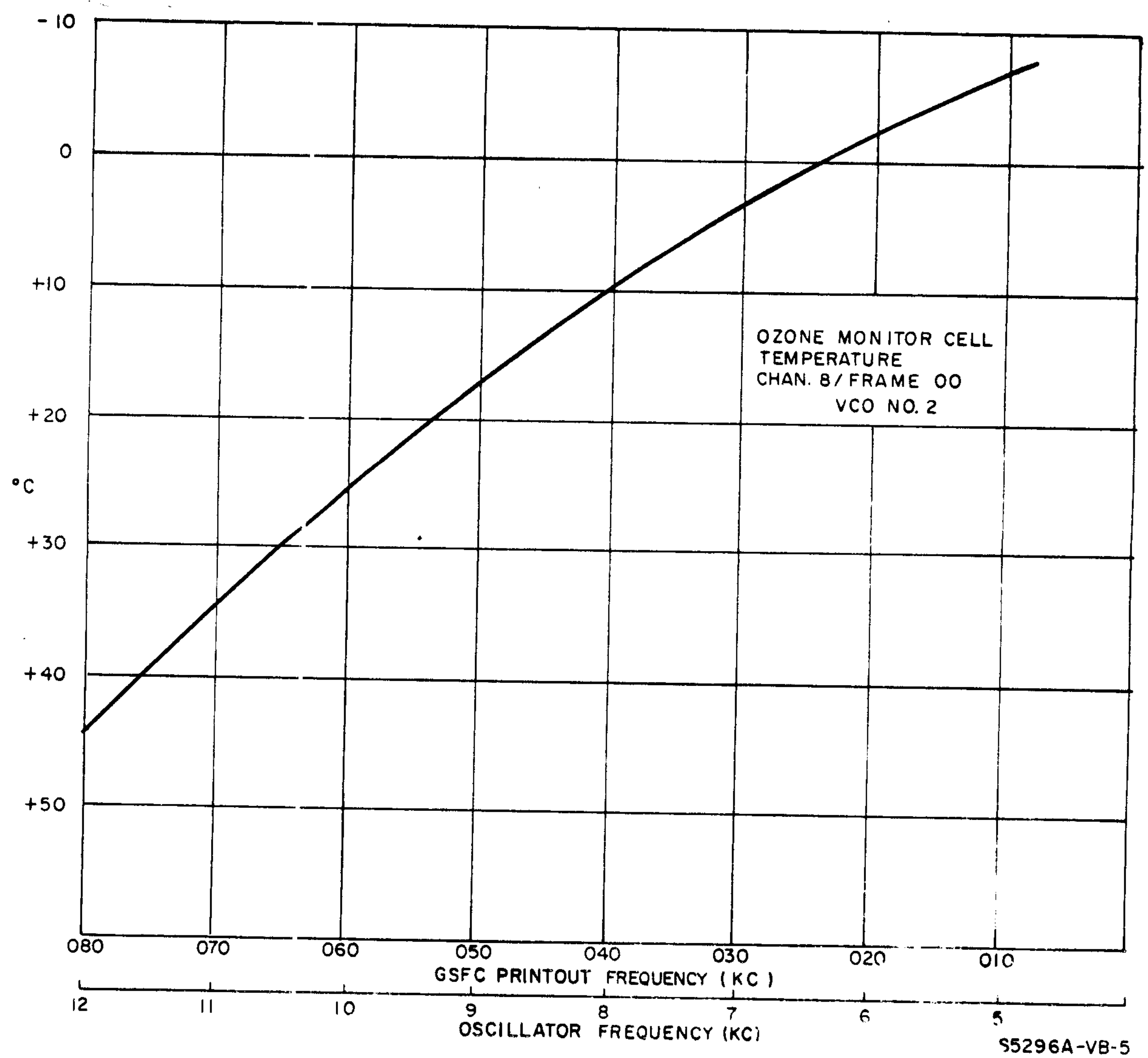
SUNLIGHT	TIME	PP00		01		02		05		11		12		13		14	
*	23/00/30	0.09	-7.2	0.53	-30.5	0.24	-7.5	0.67	15.0	0.59	24.6	0.75	-25.8	0.79	-2.2	0.69	13.4
*	05	0.09	-7.2	0.53	-30.5	0.24	-7.5	0.67	15.0	0.59	24.6	0.71	-18.6	0.79	-2.2	0.68	15.0
*	10																
*	15																
*	20																
*	25	0.09	-7.2	0.55	-24.3	0.25	-6.9	0.65	19.1	0.60	23.4	0.59	5.1	0.73	-0.8	0.66	18.2
*	30	0.09	-7.2	0.56	-21.5	0.25	-6.9	0.64	19.9	0.60	23.4	0.56	11.9	0.78	-0.8	0.65	19.9
*	35	0.09	-7.2	0.57	-19.2	0.27	-5.6	0.64	19.9	0.60	23.4	0.54	16.0	0.78	-0.8	0.64	21.5
*	40	0.09	-7.2	0.58	-16.0	0.28	-5.0	0.64	19.9	0.59	24.6	0.53	18.0	0.78	-0.8	0.64	21.5
*	45																
*	50																
*	55																
	00/00/30	0.09	-7.2	0.59	-14.0	0.31	-3.0	0.62	21.3	0.58	25.8	0.56	11.9	0.76	2.5	0.65	19.9
	5	0.09	-7.2	0.58	-16.0	0.31	-3.0	0.62	21.3	0.58	25.8	0.64	-6.0	0.76	2.5	0.67	16.7
	10	0.09	-7.2	0.57	-19.2	0.30	-3.8	0.63	20.7	0.57	26.8	0.70	-17.0	0.76	2.5	0.69	13.4
	15	0.09	-7.2	0.55	-24.3	0.29	-4.2	0.64	19.9	0.58	25.8	0.77	-29.2	0.76	2.5	0.71	10.1
	20	0.09	-7.2	0.53	-30.5	0.29	-4.2	0.65	19.1	0.58	25.8	0.82	-38.3	0.77	4.5	0.72	8.6
	25	0.99	-7.2	0.53	-30.5	0.27	-5.6	0.66	16.8	0.58	25.8	0.85	-44.1	0.78	-0.8	0.72	8.6
	30	0.99	-7.2	0.53	-30.5	0.26	-6.2	0.67	15.0	0.58	25.8	0.87	-48.0	0.78	-0.8	0.74	5.0
*	35																

TIME: h/m/s; first value of each pair: FREQ. (KC); second value: ENGINEERING UNIT VALUE

*= IN SUNLIGHT
BLANK SPACE = NO DATA AVAILABLE

S5296A-VB-23

Figure 11



OZONE MONITOR CELL TEMPERATURE
CHAN. 8/FRAME 00
VCO NO. 2
°C
-10
0
+10
+20
+30
+40
+50
080
070
060
050
040
030
020
010
GSFC PRINTOUT FREQUENCY (KC)
12
11
10
9
8
7
6
5
OSCILLATOR FREQUENCY (KC)
S5296A-VB-5

Figure 12

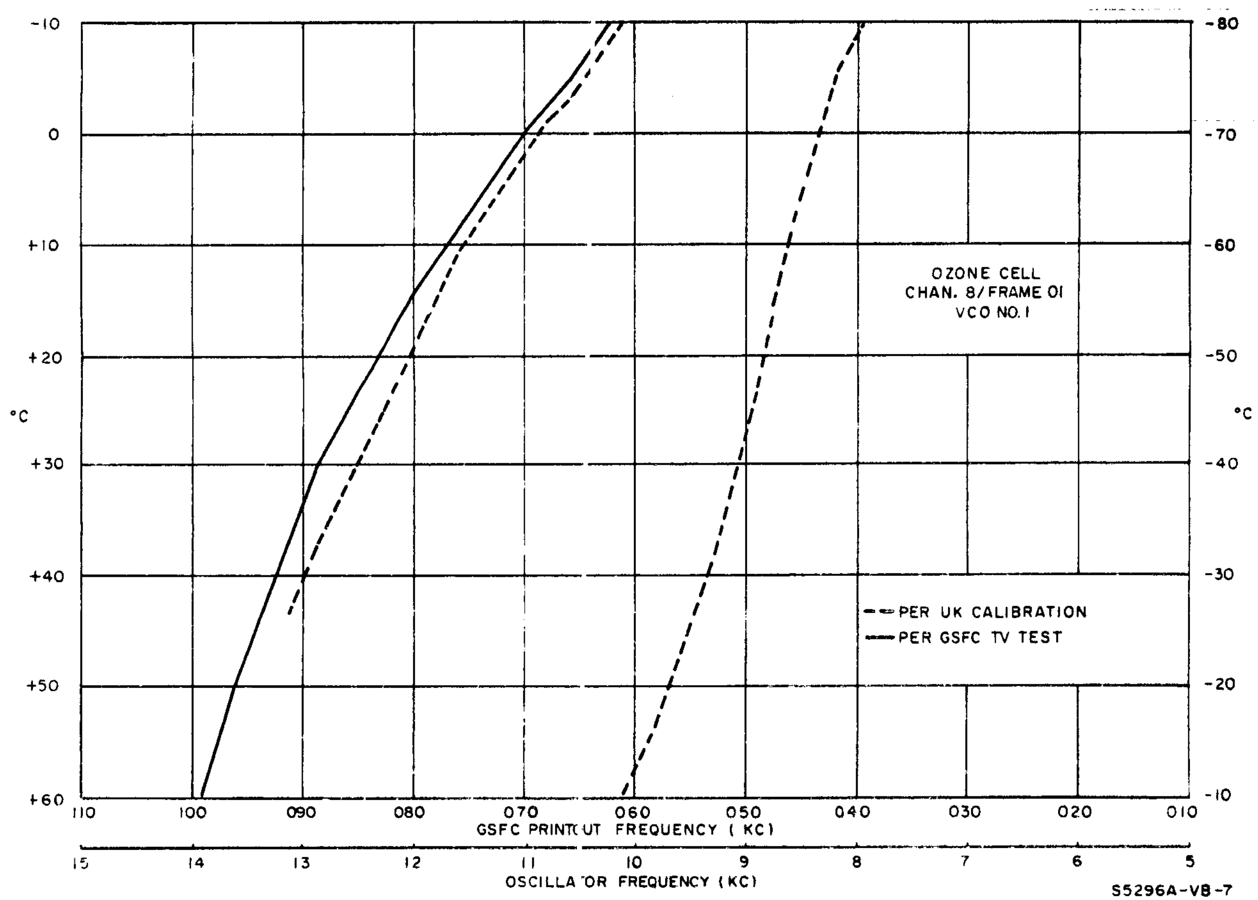

-10
0
+10
+20
+30
+40
+50
+60
°C
-80
-70
-60
-50
-40
-30
-20
-10
°C
OZONE CELL
CHAN. 8/FRAME 01
VCO NO. 1
PER UK CALIBRATION
PER GSFC TV TEST
110 100 090 080 070 060 050 040 030 020 010
GSFC PRINTOUT FREQUENCY (KC)
15 14 13 12 11 10 9 8 7 6 5
OSCILLATOR FREQUENCY (KC)
S5296A-VB-7

Figure 13

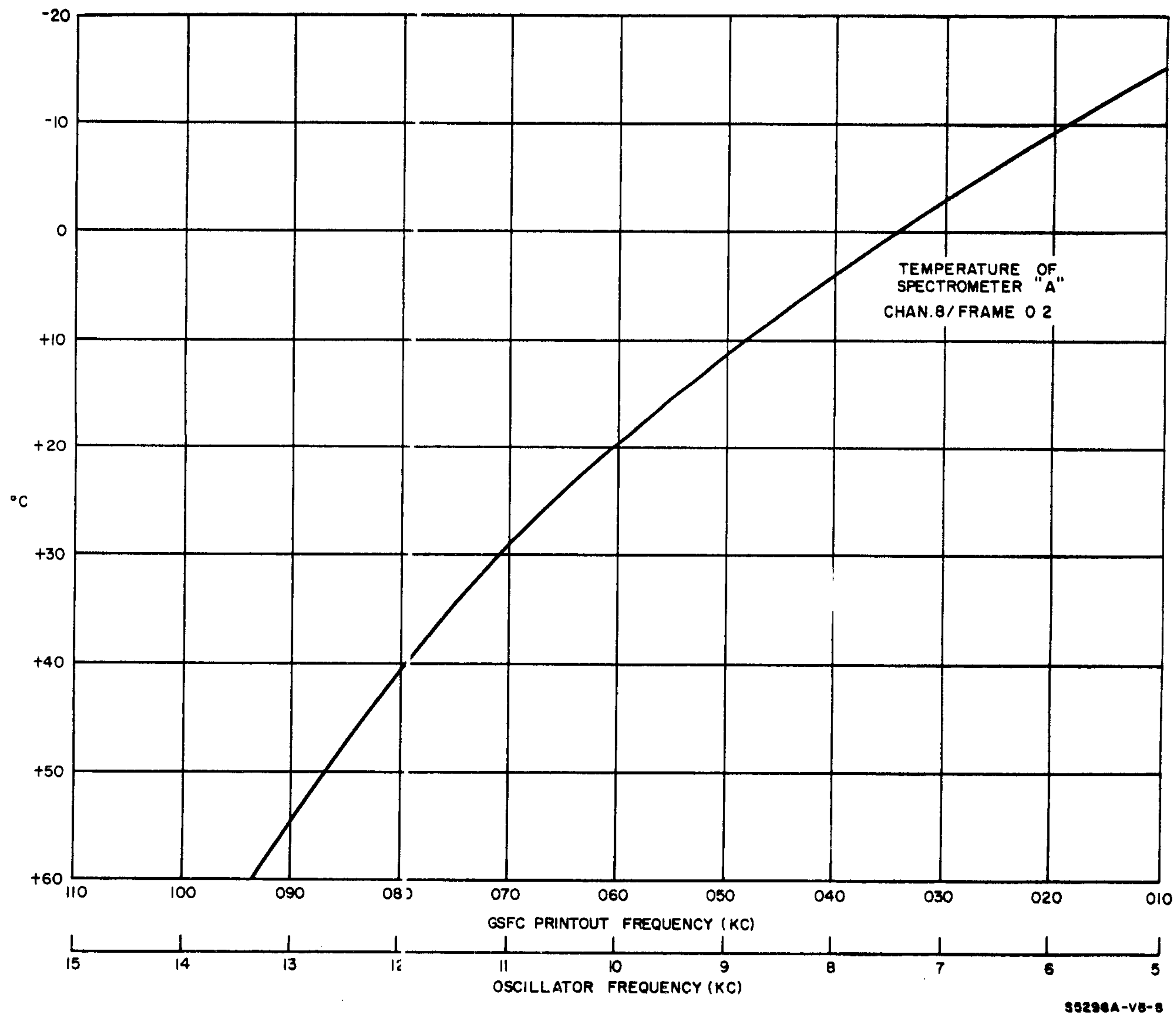

-20
-10
0
+10
+20
°C
+30
+40
+50
+60
110
100
090
080
070
060
050
040
030
020
010
GSFC PRINTOUT FREQUENCY (KC)
15
14
13
12
11
10
9
8
7
6
5
OSCILLATOR FREQUENCY (KC)
TEMPERATURE OF SPECTROMETER "A"
CHAN.8/FRAME 02
S5296A-V5-8

Figure 14

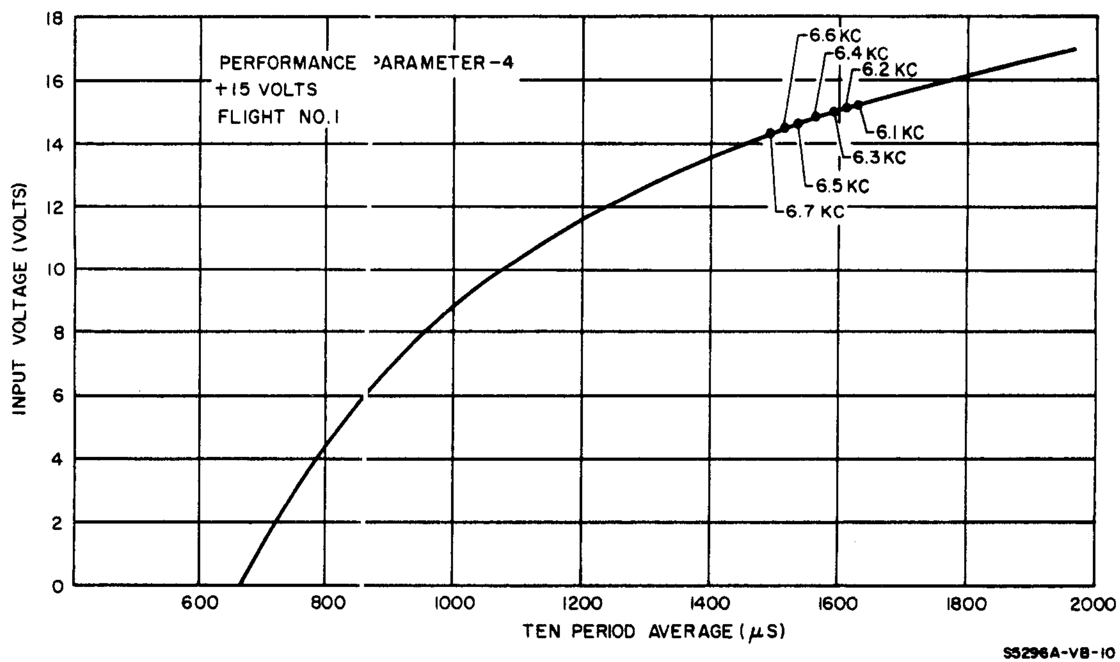

PERFORMANCE PARAMETER-4
+15 VOLTS
FLIGHT NO.1
6.6 KC
6.4 KC
6.2 KC
6.1 KC
6.3 KC
6.5 KC
6.7 KC
INPUT VOLTAGE (VOLTS)
TEN PERIOD AVERAGE (μS)
0
2
4
6
8
10
12
14
16
18
600
800
1000
1200
1400
1600
1800
2000
S5296A-VB-10

Figure 15

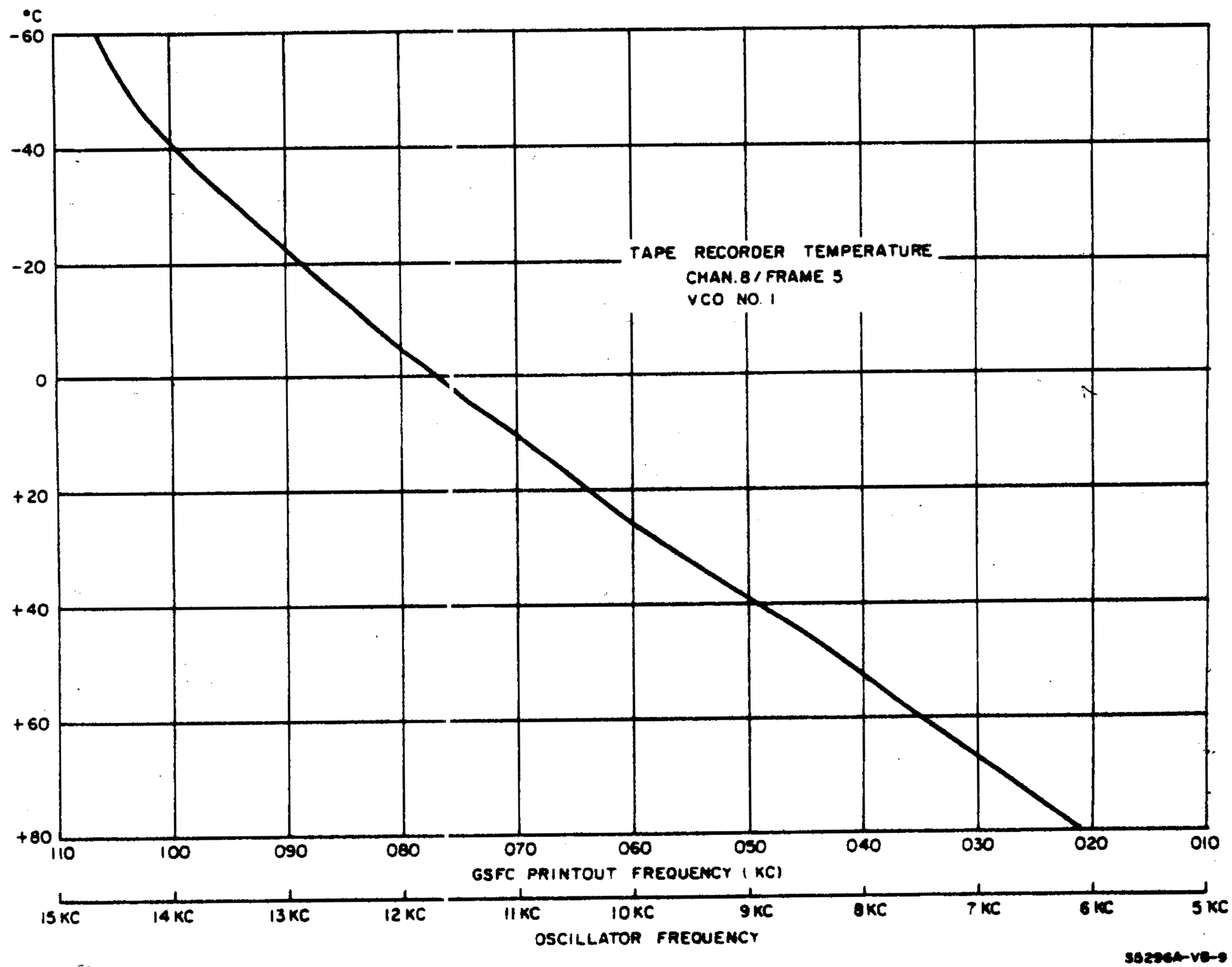
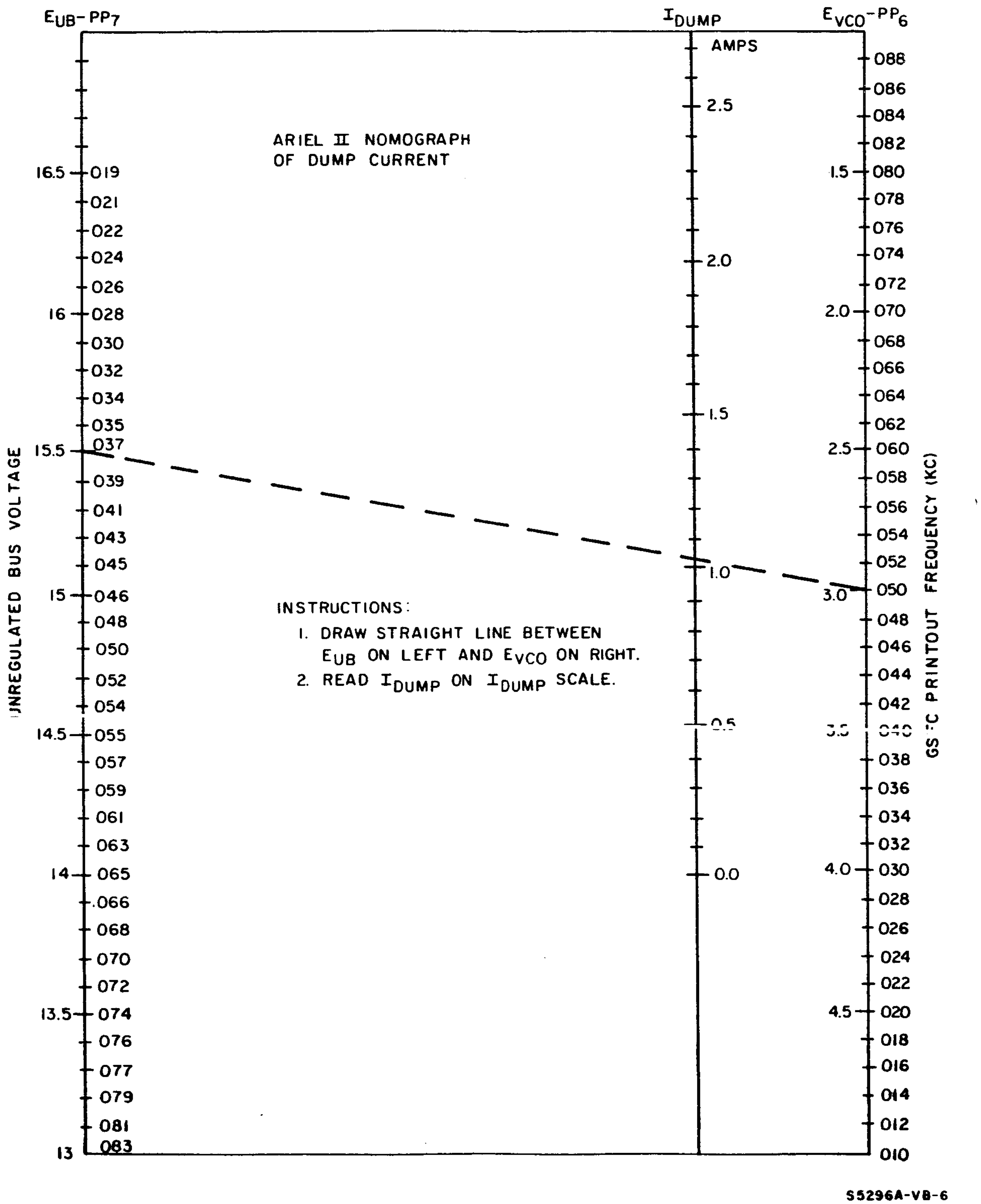
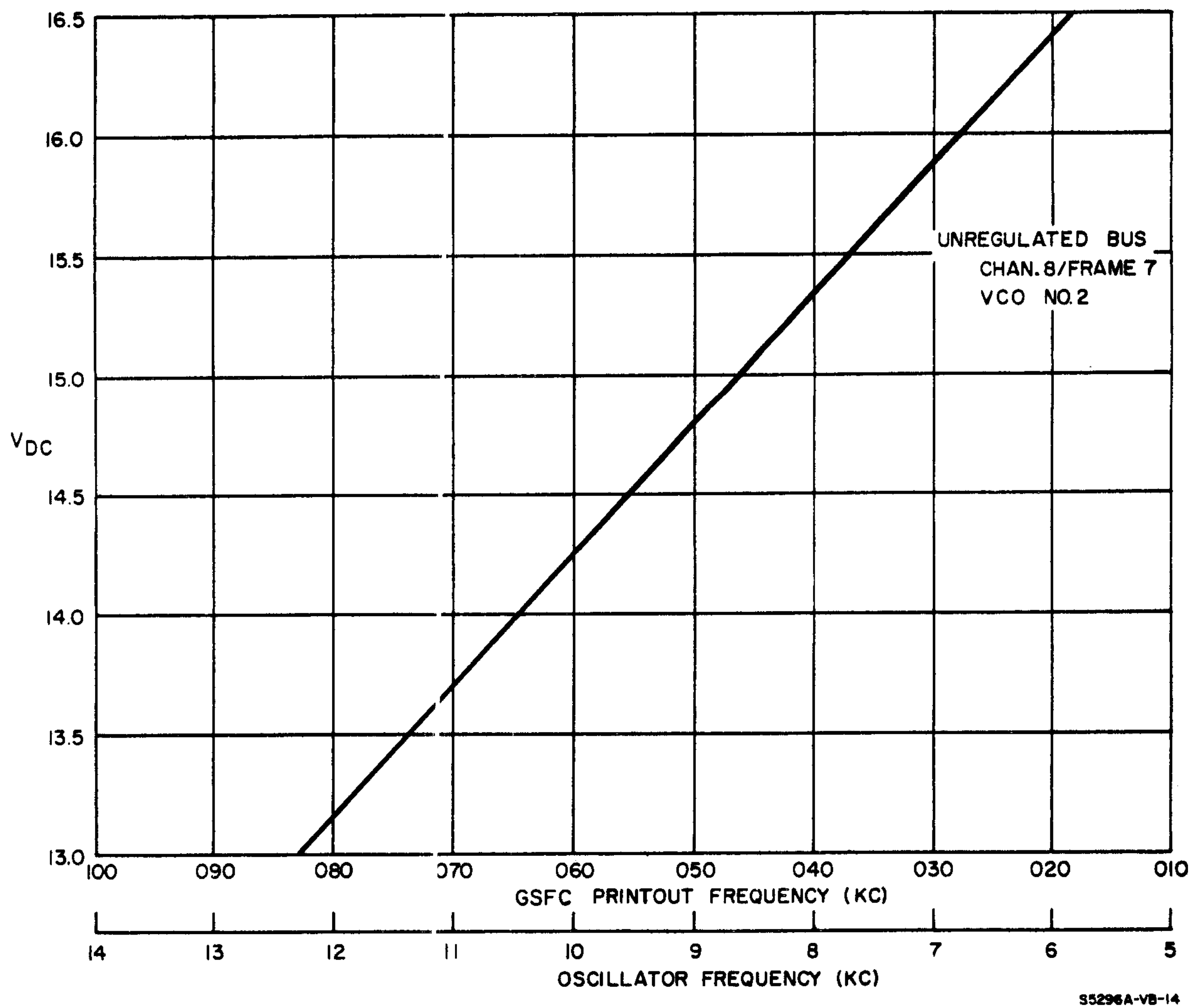

TAPE RECORDER TEMPERATURE
CHAN.8/FRAME 5
VCO NO. 1
°C
-60
-40
-20
0
+20
+40
+60
+80
110
100
090
080
070
060
050
040
030
020
010
GSFC PRINTOUT FREQUENCY (KC)
15 KC
14 KC
13 KC
12 KC
11 KC
10 KC
9 KC
8 KC
7 KC
6 KC
5 KC
OSCILLATOR FREQUENCY
55296A-VB-9

Figure 16



ARIEL II NOMOGRAPH OF DUMP CURRENT
E_{UB}-PP_7
I_{DUMP}
AMPS
E_{VCO}-PP_6
UNREGULATED BUS VOLTAGE
GSFC PRINTOUT FREQUENCY (KC)
INSTRUCTIONS:
1. DRAW STRAIGHT LINE BETWEEN E_{UB} ON LEFT AND E_{VCO} ON RIGHT.
2. READ I_{DUMP} ON I_{DUMP} SCALE.
S5296A-VB-6

Figure 17

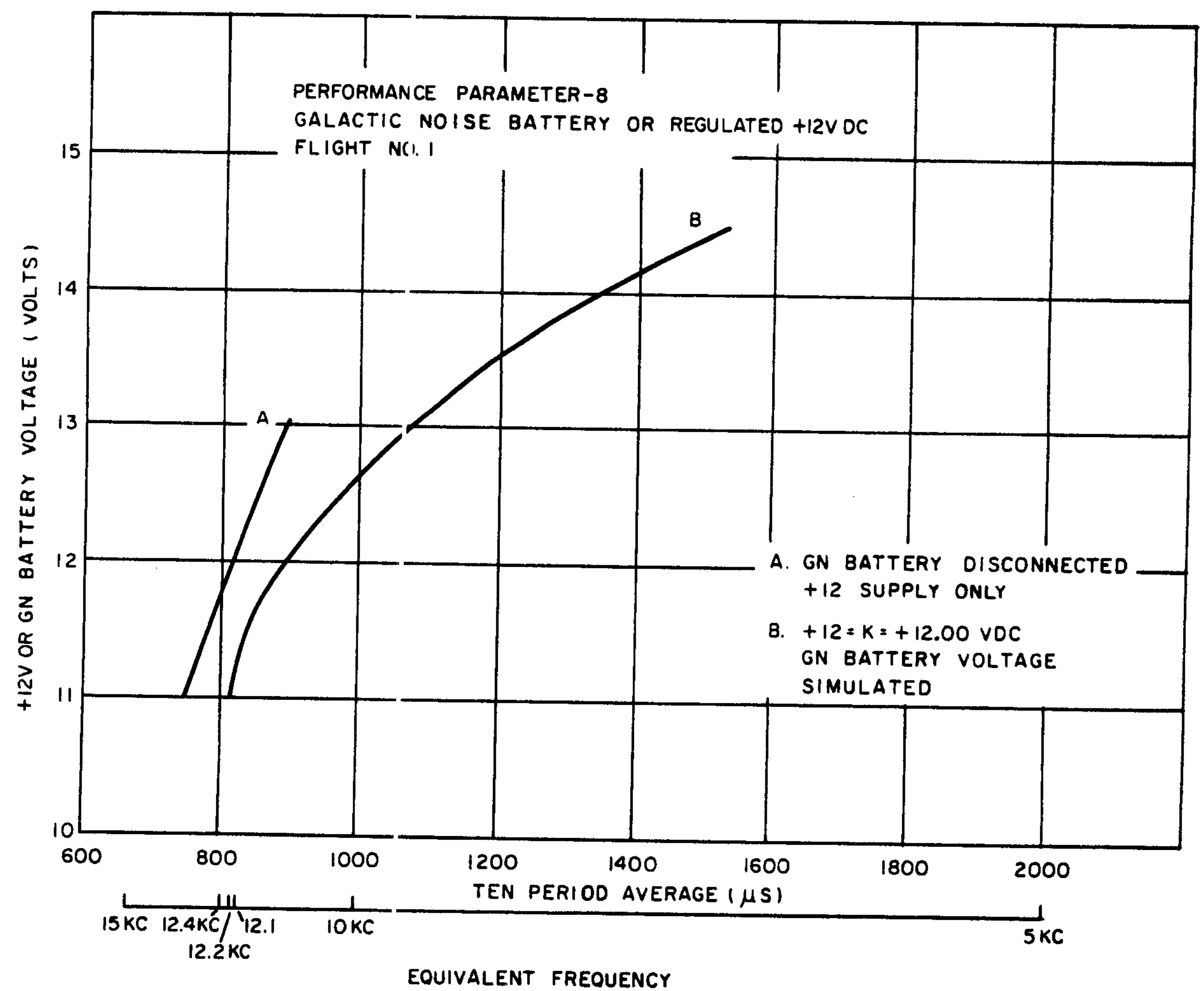


UNCLASSIFIED

Figure 18

UNCLASS

TOP
OF ILLUSTRATION

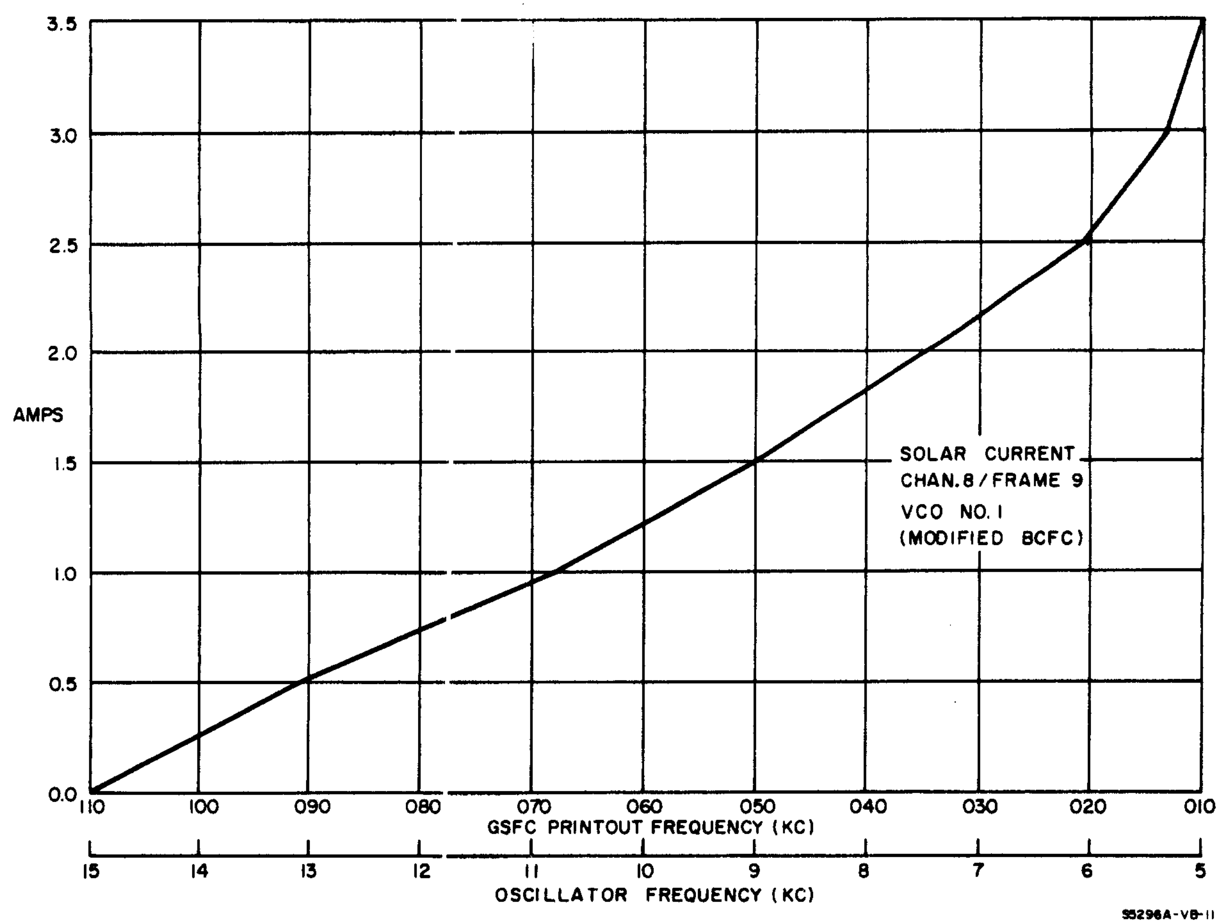


1596A-VB-12

Figure 19

UNCLASSIFIED

UNCLASSIFIED



UNCLASSIFIED
Figure 20

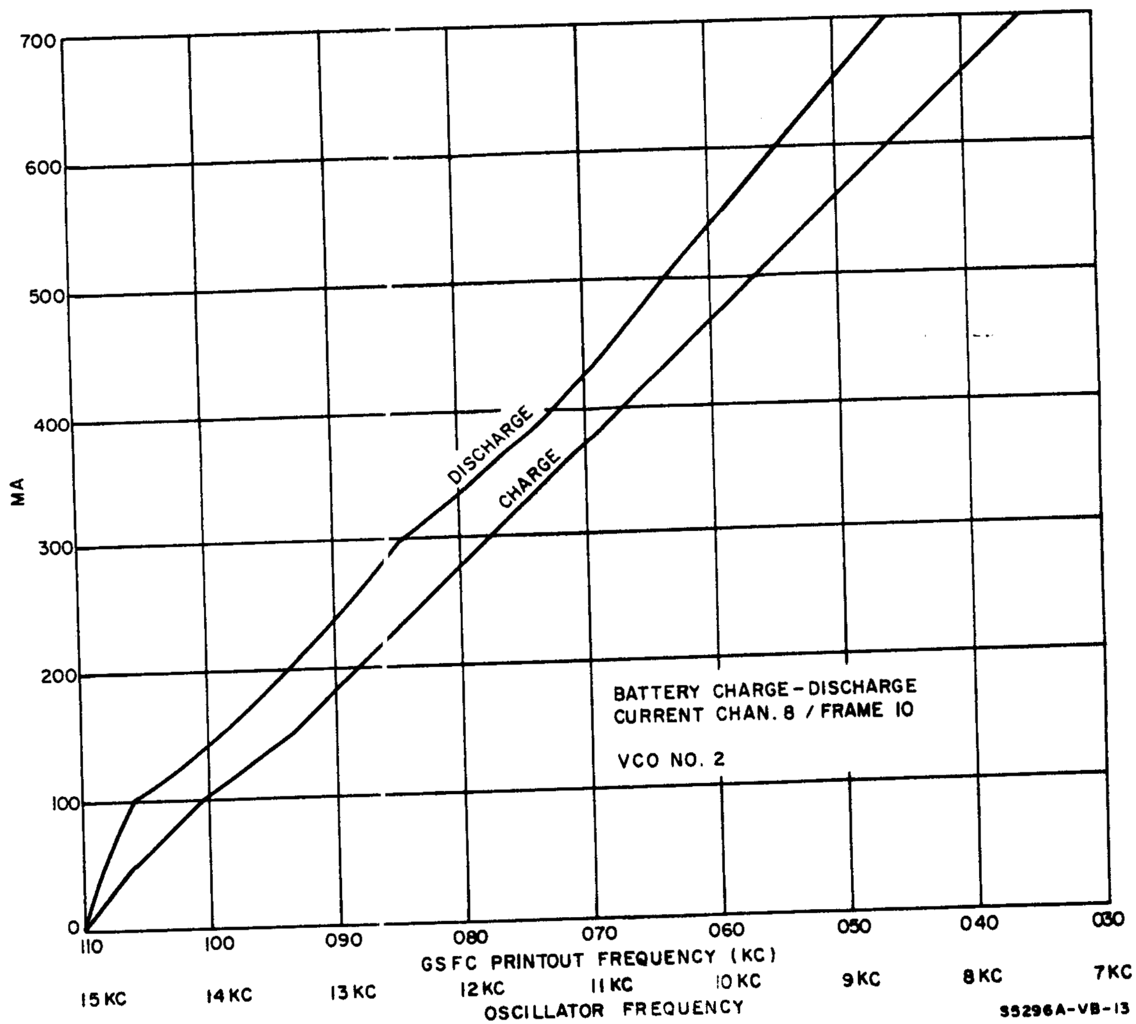

700
600
500
400
300
200
100
0
MA
DISCHARGE
CHARGE
BATTERY CHARGE-DISCHARGE
CURRENT CHAN. 8 / FRAME 10
VCO NO. 2
110
100
090
080
070
060
050
040
030
GSFC PRINTOUT FREQUENCY (KC)
15 KC
14 KC
13 KC
12 KC
11 KC
10 KC
9 KC
8 KC
7 KC
OSCILLATOR FREQUENCY
35296A-VB-13

Figure 21

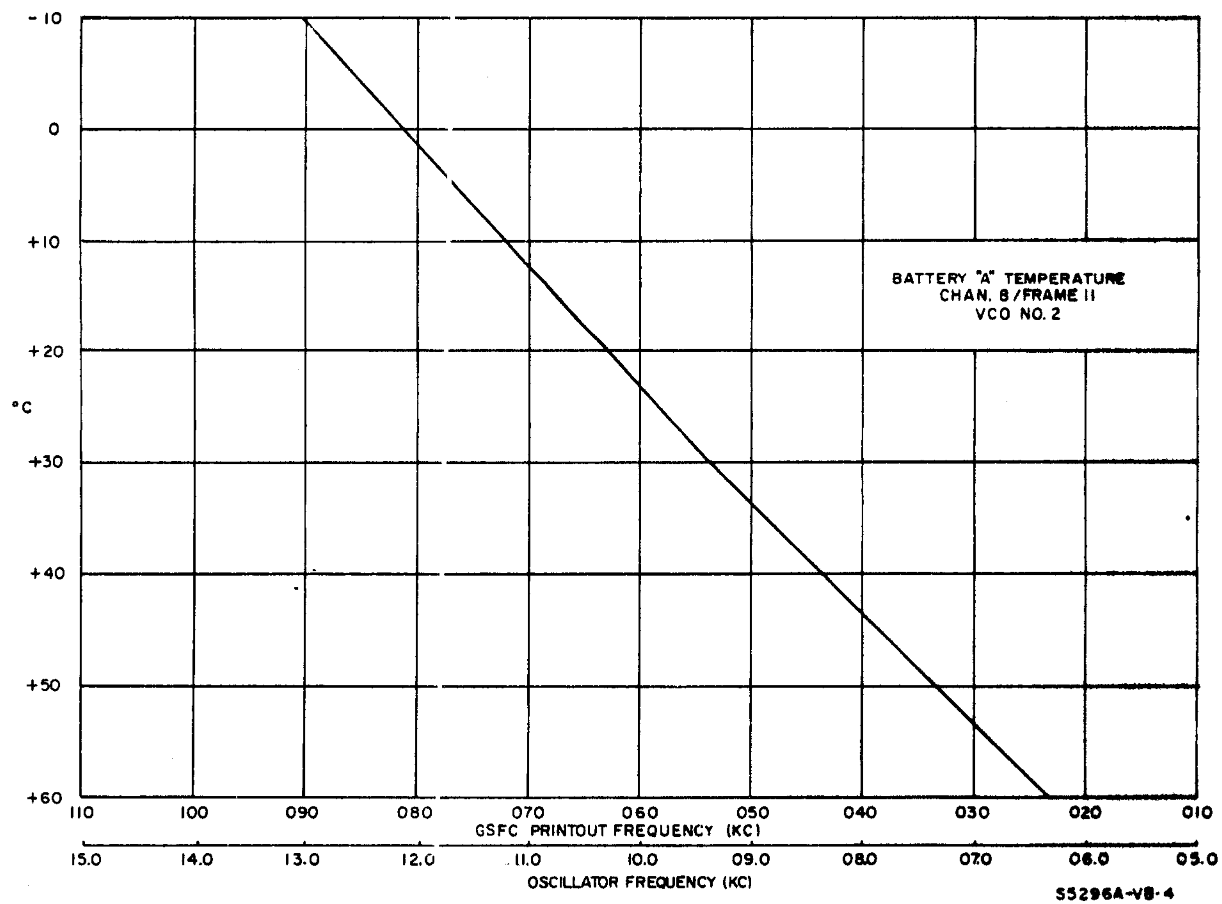

BATTERY "A" TEMPERATURE
CHAN. 8/FRAME 11
VCO NO. 2
°C
-10
0
+10
+20
+30
+40
+50
+60
110
100
090
080
070
060
050
040
030
020
010
GSFC PRINTOUT FREQUENCY (KC)
15.0
14.0
13.0
12.0
11.0
10.0
09.0
08.0
07.0
06.0
05.0
OSCILLATOR FREQUENCY (KC)
S5296A-V8-4

Figure 22

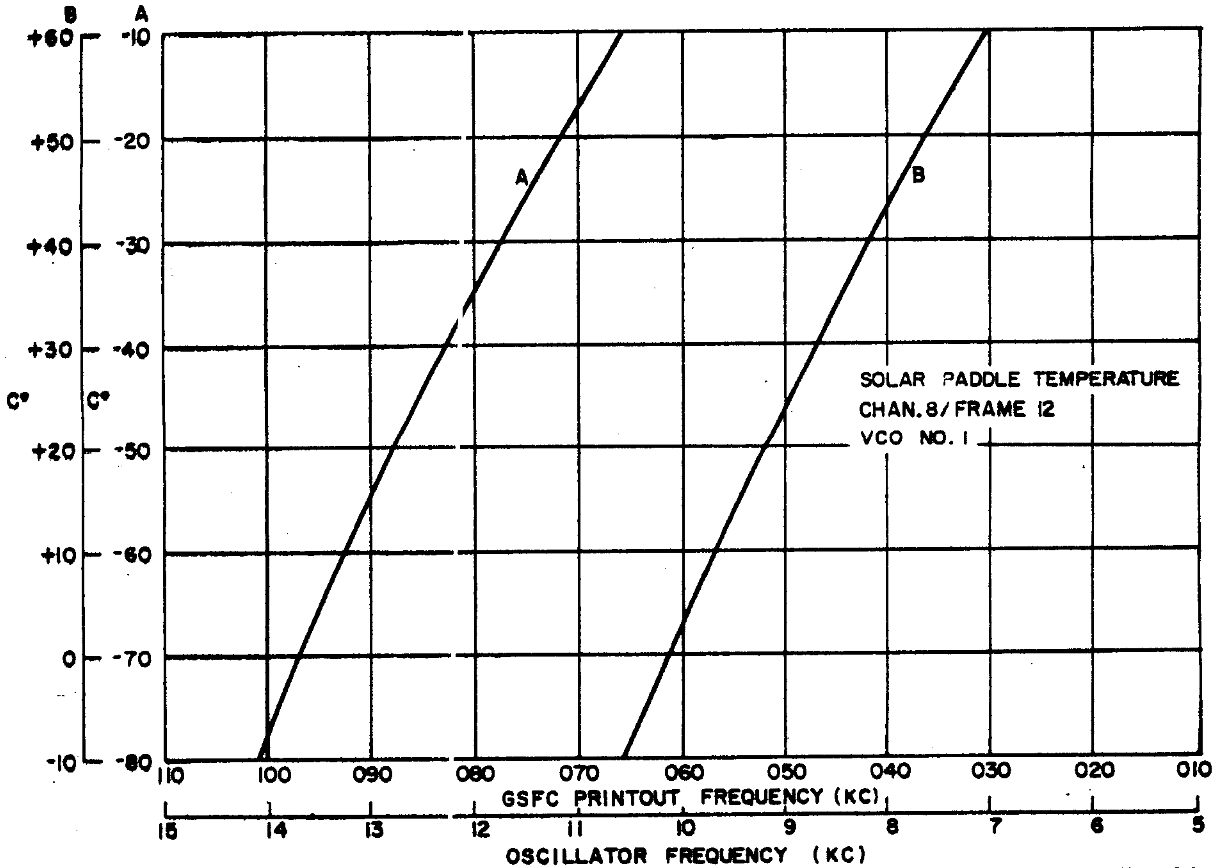

B
A
+60
+50
+40
+30
+20
+10
0
-10
-10
-20
-30
-40
-50
-60
-70
-80
C°
C°
A
B
SOLAR PADDLE TEMPERATURE
CHAN. 8/FRAME 12
VCO NO. 1
110
100
090
080
070
060
050
040
030
020
010
GSFC PRINTOUT FREQUENCY (KC)
15
14
13
12
11
10
9
8
7
6
5
OSCILLATOR FREQUENCY (KC)

Figure 23

UNCLASSIFIED

TOP
OF ILLUSTRATION

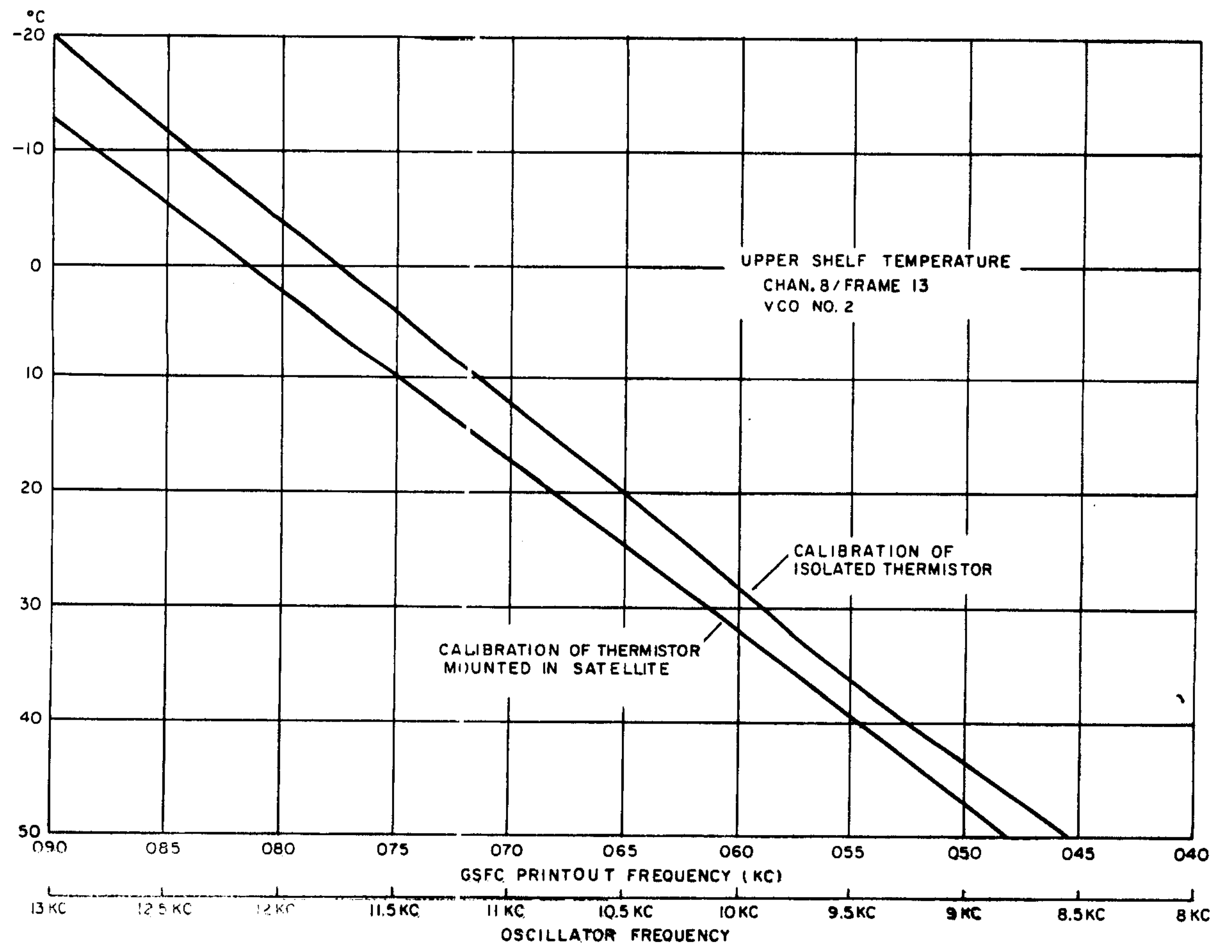


Figure 24

UNCLASSIFIED

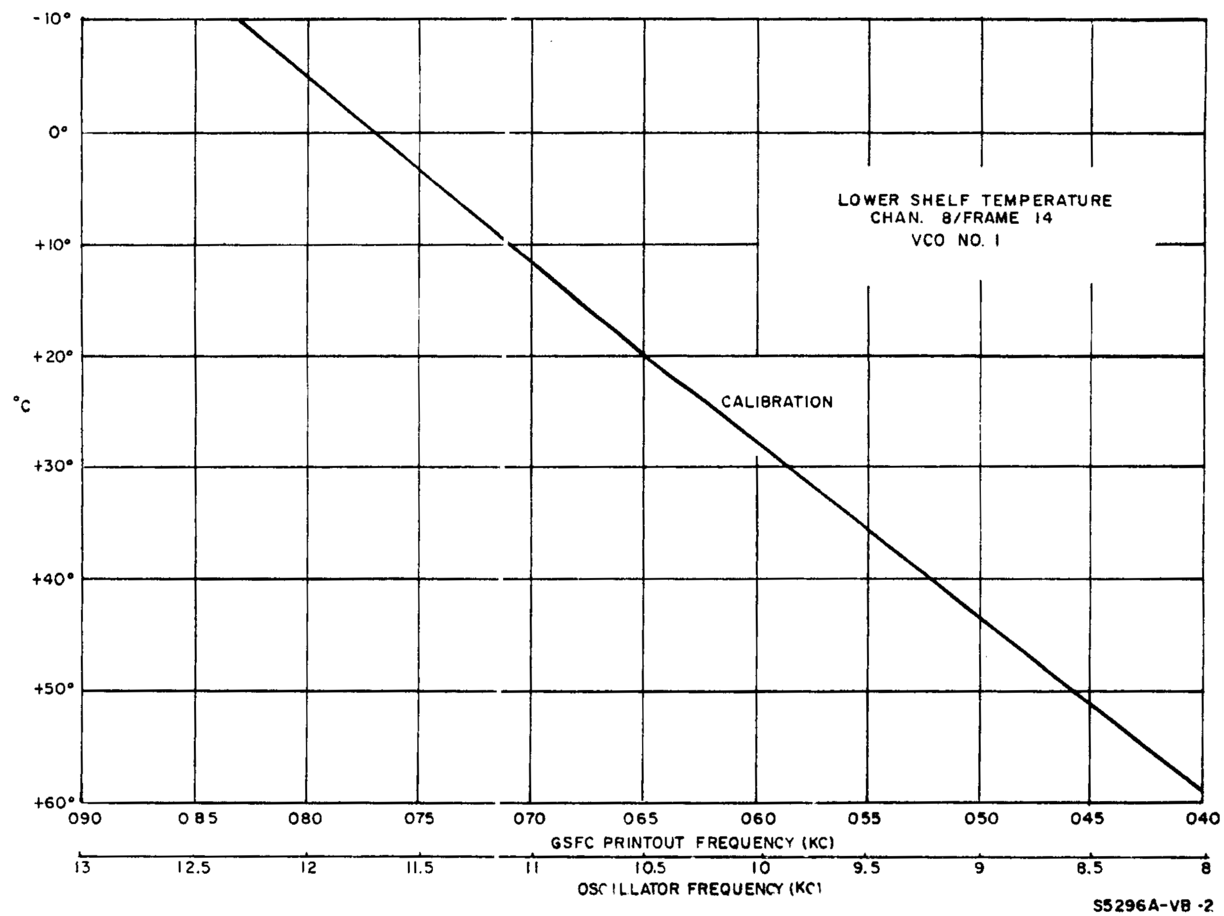
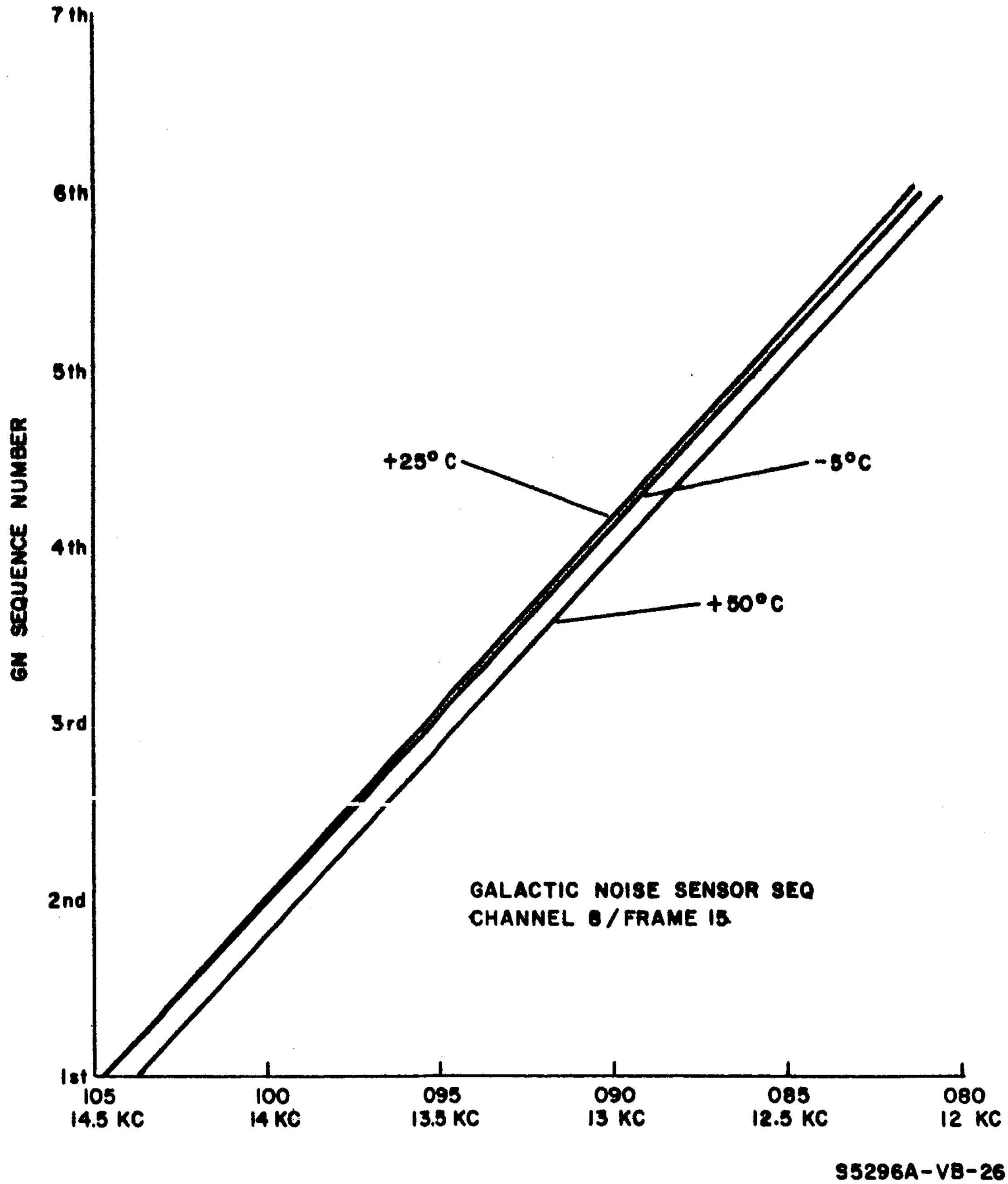

LOWER SHELF TEMPERATURE
CHAN. 8/FRAME 14
VCO NO. 1
CALIBRATION
°C
-10°
0°
+10°
+20°
+30°
+40°
+50°
+60°
090 085 080 075 070 065 060 055 050 045 040
GSFC PRINTOUT FREQUENCY (KC)
13 12.5 12 11.5 11 10.5 10 9.5 9 8.5 8
OSCILLATOR FREQUENCY (KC)
S5296A-VB-2

Figure 25


7 th
6th
5th
4th
3rd
2nd
1st
GN SEQUENCE NUMBER
+25° C
-5°C
+50°C
GALACTIC NOISE SENSOR SEQ
CHANNEL 8/FRAME 15
105
14.5 KC
100
14 KC
095
13.5 KC
090
13 KC
085
12.5 KC
080
12 KC
S5296A-VB-26

the most useful results. It is instructive to review here some of these considerations.

First in importance are the factors bearing on primary objectives 1(a) and 1(b) as described in the proposal, included here as Appendix I. These objectives are: 1(a) the unexpectedly rapid decrease in satellite spin rate, and 1(b) the satellite spin axis/sun line angle variation. It was concluded that the following data would be required from the reduction effort.

a. The curve of actual vehicle spin rate versus days from launch (0 to 200 days).

b. Time plots of raw ozone spectrometer data for one spin revolution as availability permits:

1. on nominal weekly basis

2. at selected days corresponding to maximum, minimum, and 90 degree points.

c. Time plots of raw DROD and IROD data for one spin revolution at selected times corresponding to discrete aspect angles.

d. A time plot of raw solar cell current, I_s, for one spin revolution at the point where the solar aspect angle approaches 180 degrees.

Spin rate information was derived mainly from the ozone spectrometer data wherein the cyclic pattern of the experiment response produced by satellite rotation could be correlated to time. By this means spin rate could be deduced. An auxiliary means of determining spin rate was provided by the IROD and DROD micrometeorite experiments. Observable pulses in the data were identified as the result of the scanning action produced on the IROD and DROD detectors by satellite spin.

Pulses were produced as the sunline swept past the holes in the aluminum foil strips and momentarily illuminated the detector. Sunlight passing through calibrating slits gave rise to other observable pulses.

The establishment of satellite sunline angle variations was regarded as an output of Phase II but it was felt that time plots of the raw ozone spectrometer data, of the raw IROD and DROD micrometeorite data, and of the solar cell current would provide the key to an assessment; therefore, for efficiency these data were processed in Phase I. Those plots of these data which were specifically requested by the Technical Director are included herein, but not all plots serving the sun angle determination are included.

Secondly, the Ariel II power system was studied from the standpoint of desirable data for analysis under Phases II and III. In the case of the power system, the parameters possess an interdependence which is beneficial in the assessment of anomalous behavior. Since space environmental changes are a periodic function of orbit position over the short term, the composite orbit plots were useful and satisfactory. To gauge the effects of environmental changes over the longer period, the 200-day composite graph was regarded as satisfactory. The latter graphs were expected to show aging degradation in solar cells. The power parameters plotted in Phase I are tabulated below:

(1) voltage on +15 regulated

(2) dumped current

(3) the unregulated bus voltage

(4) voltage on +12 regulated

(5) solar current

(6) battery current

(7) battery A temperature

(8) paddle #4 temperature

(9) lower shelf temperature

The +15 and +12 regulated DC voltages have been plotted to determine if they performed within design specifications in the space environment. It is anticipated that these plots will be of utility in explaining the performance anomaly in the 12-volt supply. In conjunction with the latter problem, the temperature and unregulated bus voltage plots will have value.

The solar current, battery current and dumped current are algebraically related in the sense that solar current in excess of that needed to power the load and charge the battery is dissipated or dumped. The plots displaying these data will be the foundation of a graphical analysis in later phases of the effort.

Lastly, considerations are presented which relate to thermal behavior, a secondary interest as presented in 2(a) of the proposal in Appendix I.

It has been felt that the adopted scheme of weekly composite orbit graphs plus the 200-day graphs will permit comparison of actual thermal performance with predicted performance as developed by GSFC. Plots of thermal data covering the first ten orbits were made to indicate the thermal stabilization characteristic of the satellite. Unfortunately the data is not nearly as complete during these orbits as would be desired for the purpose; however, no improvement could be effected by any alternate method of processing the data.

<u>Program for Phase II</u>

Phase II is aimed at the definition of spacecraft performance, and this will be done under the three topics previously discussed, namely, dynamical performance in terms of spin rate and surline angle; power system performance; and thermal performance.

Insofar as dynamical performance is concerned, Phase II effort will be devoted to defining the actual spacecraft performance and then comparing it with the pre-launch predictions of performance for the following parameters:

a. variation in satellite spin rate

b. variations in spin axis/sunline angle

The principal effort during this phase of the program will be to develop a plot of solar aspect angle versus days from launch. The ozone spectrometer will furnish the principal evidence for this angle since it is basically more sensitive to solar aspect than are the other sensors.

It had been assumed, prior to launch, that the angular momentum vector, $\bar{h}$, of Ariel II would be established at orbital injection and would remain substantially invariant thereafter. Thus, it had been presumed that the satellite spin axis would be initially aligned with the velocity vector at injection, and the British team assumed that this spin axis orientation would be approximately maintained in space. Also, it had been presumed that when all yo-yo weights, booms, and antennas had been deployed, that the established vehicle spin rate would not vary significantly over one year. For the case where the spin axis is presumed fixed, the angle between the direction of the assumed spin axis and the direction of the sunline--obtainable from <u>The American Ephemeris and Nautical Almanac, 1964</u> -- can be readily calculated as a function of time from launch. However, preliminary examination of spin rate plots and ozone data indicate that the assumption of a fixed spin axis orientation is invalid for Ariel II. For this reason it is felt that a necessary investigation in Phase II will deal with this orientation problem.

The time plot of solar aspect angle, when obtained by various measurements and calculations, will be compared with the comparable plot of solar aspect angle for the assumed fixed spin axis orientation. In addition, the time plot of actual vehicle spin rate obtained from the data, will be compared with predicted performance.

Phase II of the program as it pertains to power system performance is nearly accomplished when the Phase I plots are complete inasmuch as little analysis is required to infer performance from available data as is the case with dynamical performance. It may develop, however, that a graphical analysis of power system operation in terms of solar current, battery current and dumped current is instructive in providing a clearer insight into system operation.

Phase II in the thermal performance area will consist of reviewing combinations of graphs of:

(1) both ozone temperatures

(2) spectrometer and upper shelf temperatures

(3) lower shelf and battery temperatures

(4) spectrometer A and lower shelf temperatures

The purpose here is to afford some indication of thermal gradients in the satellite so that the total picture of Ariel II thermal performance will be evident.

Conclusions and Recommendations

The available data is inadequate for complete analysis of the Ariel II performance on two major counts. First, the data on the first 10 orbits has too many gaps to provide a good basis for establishing the character of thermal stabilization. Secondly, indirect methods must be employed to infer spin axis to sunline angle. The first case is the result of not recording available satellite transmission at every station pass on the first 10 orbits. Of course, the post launch evaluation and its specific goals were not anticipated or provided for in what was primarily the acquisition of experimental data. On the second count, it is seen that the lack of direct data is the result of not placing solar aspect sensors on the S-52, but here again, such instrumentation had no function in the fundamental experimental purpose of the spacecraft.

In spite of the data deficiencies it appears that useful hypotheses may be advanced and to some extent proved as a result of analytical study of Phase I plots. Phases II and III will proceed immediately and will be reported.

APPENDIX I

Proposal

for

ARIEL II INTERNATIONAL SATELLITE

Post Launch Evaluation

Negotiation J0160-2

21 September 1964

Presented to

GODDARD SPACE FLIGHT CENTER

National Aeronautics and Space Administration

Greenbelt, Maryland

by

WESTINGHOUSE ELECTRIC CORPORATION

1625 K Street, N. W.

Washington 6, D. C.

Proposal for Conducting the ARIEL II International Satellite Post Launch Evaluation

I. INTRODUCTION

This proposal describes the data reduction, data analysis, and theoretical review of the ARIEL II telemetered flight results. In accordance with the statement of work which has been prepared for this program by GSFC the objectives have been considered in two categories. They are:

1. Primary Objectives
   a. The unexpectedly rapid decrease in satellite spin rate.
   b. The satellite spin axis/sun line angle variation.
   c. Power system performance analysis.
2. Secondary Objectives
   a. Satellite thermal behavior.
   b. Analysis of other subsystem performance as derived from telemetered data.

Westinghouse, as the original prime contractor to Goddard Space Flight Center on this satellite program, is well qualified to perform this work. Key personnel assigned will be drawn from former contributors to the design and integration effort conducted on the prototype and flight satellites of the Westinghouse ARIEL II program.

II. PROGRAM DESCRIPTION

The basic data source for this investigation will be orbital data printouts supplied by the Goddard Space Flight Center Program Office. These printouts contain universal time information and location of the tracking station as well as telemetry frequencies. The Program Office will also supply required ephemeral information, and will make available such data as has already been reduced.

The program objectives will be pursued in a three phase division of effort as described in the following paragraphs.

Phase I

Using GSFC digitized data printouts, convert the performance parameter words to engineering units and plot as appropriate for the particular parameter being observed (graphs, charts, curves, etc.) as directed by the ARIEL II Project Manager.

Phase II

The second phase will be the definition of actual spacecraft performance. Using information derived from Phase I, prepare a report showing by use of curves, charts or tables the actual spacrcraft performance as compared to prelaunch predictions.

Phase III

Phase III will consist of an effort to develop theoretical bases for defining the departure of actual spacecraft performance from prelaunch predictions. An engineering report will be prepared on the information developed during Phase III and including information previously developed in Phase I, II.

Phase I

During Phase I efforts the data coordinates will be plotted for short intervals taken at an interval-to-interval spacing dictated by the indicated rate of change of the variable in question. For example, in the case of the IROD data it is suggested that one-minute intervals will be plotted with an average interval spacing of one week. These preliminary choices have been made in consideration of the anticipated utility of the data, which is the indication of spin rate. If the rate of change of spin rate for a given weekly interval seems high, or if particular orbital altitudes appear to be of major interest, additional points will be picked up. Conversely, if the rate of change is shallow, weekly points may be skipped. The attention given the problem of how much data to plot is vital to an economical performance of the program. The intervals plotted will be as widespread as possible and the data plotted per interval will be minimized.

Data checkpoints will be taken from the delayed read-out micrometeorite experiment for additional verification of the IROD data conclusions.

Ozone spectrometer data will be plotted in similar fashion to that from the micrometeorite experiments. Somewhat longer intervals may be chosen for this data inasmuch as modulation caused by coning will be sought for in addition to that caused by satellite spin. It is also hoped that under certain conditions the aspect angle of the sun line versus the satellite spin axis can be deduced from this data.

It is understood that broadband ozone scanner has some aspect sensitivity so that modulation of its output can be related to coning; therefore, it is anticipated that this data would be plotted to a schedule similar to that of the micrometeorite experiments.

The galactic noise data is not expected to be useful in connection with this evaluation program and will not be plotted.

Ground receiver AGC may prove to be of value, if it is available, from the standpoint of telemetry antenna aspect angle change. This may prove to be redundant information, however, and definite conclusions as to the advisability of using it will be deferred until actual data reduction commences.

Thermistor data will be plotted on a schedule to be developed on the basis of the observed rates of change. The thermal pattern for an orbit will be established and then redetermined after an interval of a number of orbits. Similar considerations apply to power system data, which will be useful for the secondary objective (b), and also for the primary objectives (a), (b), and perhaps even (c).

Phase II

Phase II as applied to the dynamical satellite behavior primary objectives (a) and (b) will involve surveying the reduced data from Phase I and checking for correlation between it and GSFC conclusions previously drawn about spacecraft behavior. Attempts will be made to support conclusions about spacecraft performance by means of more than one data input wherever possible but exhaustive correlation will not be carried out. Phase II will be more clear-cut in relation to the remaining objectives and will amount to a task of concise data presentation. It should be noted, however, that for performance of Phase II in the area of secondary objective (a) a review of the ARIEL II thermal analysis done by GSFC will be required before comparison can be drawn between predicted and actual performance.

Phase III

Phase III as applied to primary objectives (a) and (b) will consist of checking hypotheses which have been advanced by GSFC. For example preliminary consideration of the despin question has led to the hypothesis that the ARIEL II can be likened to an axial flow fan on which a velocity component along the spin axis will manifest itself in a torque about the spin axis. To check such a hypothesis requires correlation of the actual performance with that predicted by a computation based on the hypothesis. Comparisons are necessary in terms of magnitudes, frequencies, and phase angles of the functions where applicable. Only the most likely hypotheses will be examined.

The ARIEL II power system analysis will include comparing the actual system operating characteristics to the theoretically predicted performance. The areas which it is proposed to be specifically investigated are:

1. Anomalous behavior of the solar paddle current, the regulated +12 volt bus and the regulated +15 volt bus.

2. Battery voltage as a function of battery current and battery temperature.

3. Solar paddle current-time profile correlated with the sun line axis and spin rate.

4. Regulated bus voltages as a function of environmental conditions (temperature, load, time).

The purpose of investigating the anomalous behavior of the power system is to determine whether or not a fault did occur, and if so, what the most probable failure was.

The investigation of the battery characteristics will attempt to relate the predicted battery voltage as a function of time with the actual performance. The investigation will include determining whether or not the redundant battery charge was used, an estimate of the maximum battery discharge level, and the battery charge efficiency. These data would be compared to the calculated battery operation.

Information on the available solar cell power profile will be used to check the assumed solar cell efficiency and aspect ratio. In addition the solar cell degradation with time will be determined. Data regarding actual solar cell degradation will be quite useful in predicting future solar paddle requirements.

The purpose of determining the variation in regulated bus voltage is to compare actual regulation with that expected from the acceptance test data. An attempt will be made to explain unexpected variations in regulated bus voltage in order to improve regulator precision in future applications.

III. SCHEDULE

The proposed schedule of effort is shown in Figure III-1, in months from go-ahead. Changes in this schedule, and in specific direction of investigation taken, may be desirable from time to time. Such changes, as long as they are within the scope of the total effort and cost, may be directed at any time by the Goddard Space Flight Center Program Manager. Westinghouse will further be pleased to negotiate changes in the scope of work at the pleasure of the Program Office.

IV. REPORTS

Monthly reports describing the status of progress on the program will be prepared in accordance with Specification TD-S-100, August, 1962, Type I with the exception that point (c) of paragraph 3.1 is regarded as not applicable. This is a reference to the achievement of reliability.

A monthly financial report prepared in the format of NASA from 7-16 will be prepared and submitted at the same time as each monthly Type I, TD-S-100 report.

In addition to the monthly reports, Phase reports will be submitted upon the completion of each phase. The Phase III report will be prepared as a final report and will contain a summary of the entire program. As directed by the Work Statement rough drafts of the phase reports will be submitted to the ARIEL II Project Office for approval prior to printing.

V. PERSONNEL

The key personnel designated for the ARIEL II post launch evaluation are listed below. The special area in which each will work is given along with a statement of their applicable qualifications.

Ralph I. Hauser, Fellow Engineer, Mechanical Design and Development Engineering Section

Mr. Hauser will coordinate the program and also will participate in the dynamical analyses. His experience includes 10 years of gyro design and application. He also participated in the ARIEL II work at Westinghouse in the area of design inertia control.

Frank C. Rushing, Advisory Engineer, Equipment Engineering Project

Mr. Rushing will contribute to the dynamical analysis. His 36-year career as an engineer includes experience in dynamics of machinery. He holds 13 patents relating to vibration and balancing machinery and has been studying attitude control of satellites for the past year.

Arthur Simmons, Engineer, Analysis and Control Section

Mr. Simmons has participated in design study contracts on satellite inertial control mechanisms and on antimissiles satellite studies. He will work in the area of ARIEL II Dynamical behavior.

Henry B. Airth, Jr., Senior Engineer, Magnetic Devices Section

Mr. Airth had design responsibility in the regulated power supplies for the ARIEL II power system and will analyze power system performance.

W. Keith Stahlman, Engineer, Data Acquisition Section

Mr. Stahlman has performed mathematical analysis of data gathered from electronic systems. He has participated in the interpretation of water velocity and inertial instrument data to describe dynamical behavior of submarines. His contribution will be in the area of data reduction and correlation.

APPENDIX II

DATA PRESENTATION PLAN

DATA PRESENTATION PLAN

The final product of the Phase I effort will be three sets of graphs to be used in the Phase II and Phase III studies. Copies of the graphs will be submitted to the Ariel II program coordinator in the Phase I final report. The three sets of graphs are:

a. Single Orbit Graphs. Each graph will contain one parameter only and will be plotted over an interval from an arbitrary 0 to 100 minutes. Table I lists the parameters for which graphs will be made. Figures 1 through 14 are sample graphs of actual data. Each graph will be plotted on tracing paper, with like time scales, so that several may be overlaid on a light table for analytical purposes. These graphs will be constructed with data principally from orbits 1, 2, 6, 7, 10 and the weekly orbits (b from paragraph 1). The performance parameters will be read at 5 minute intervals, except for the currents modulated by the satellite spin. In these cases, maximum and minimum values will be read every 5 minutes from approximately 30 second intervals about the 5 minute point. Also, on these graphs, several cycles of the signal will be plotted to illustrate the modulation of the signal.

b. 200-Day Graphs. The principal inputs of these graphs will be average values read from the graphs from paragraph (a) above. Where necessary, points may be filled in using Blossom Point data. These graphs will be used to show large scale trends. For this reason, the time scale will be no finer than a day. Graphs will be made for the same parameters as above (Table I). Ordinates will agree for like parameters. Figure 15 is a sample plot of assumed data.

c. Special Purpose Graphs. A number of special purpose graphs will be made:

(1) A graph of the first ten orbits illustrating the thermal stabilization of the satellite. It will include the eight temperatures monitored, aspect angle, and periods of sunlight and darkness.

(2) Graphs showing combinations of thermistor data. The following combinations will be studied:

(a) both ozone temperatures

(b) spectrometer A and upper deck temperatures

(c) lower deck and battery temperatures

(d) spectrometer A and lower deck temperatures

Graphs will be plotted for the day of maximum sunlight, the day of minimum sunlight, the hottest day, and the coldest day.

(3) Graphs necessary to show typical experiment responses to changing conditions. These will include:

(a) Ozone Plots. Ozone spectrometer graphs showing a sunset and a sunrise from the first week of flight. Additional ozone spectrometer graphs over the 200-day graphs showing a sunset, a sunrise, and a full sunlight period.

(b) Micrometeorite Plots. Micrometeorite graphs over the 200-day period.

(c) Galactic Noise Plots. Galactic noise graphs over the 200-day period from times when the satellite was at apogee and perigee and at interesting points shown with respect to apogee and perigee. One galactic noise graph from an entire 100 minute orbit.

TABLE I

PARAMETERS FOR SINGLE ORBIT AND 190-DAY GRAPHS

P.P. No.	Parameter	Uses 1 - Spin rate 2 - Spin axis/Sun 3 - Power supply 4 - Thermal Behavior	Remarks
0	OZ Temp. 1, Mon. Cell	4	
1	OZ Temp. 2, OZ Cell	4	
2	OZ Temp. 3, Spect. A	4	
4	+15 v	3	
5	Tape Rec. Temp.	4	
6	Dumped Current	3	
7	Unreg. Bus	3	
8	12 v	3	
9	Solar Current	3	
10	Batt. Current	3	
11	Batt. A Temp.	3, 4	
12	Paddle 4 Temp.	3, 4	
13	Upper Shelf Temp.	4	
14	Lower Shelf Temp.	3, 4	
	% Sunlight/Time in and out of sunlight	3, 4	Obtained from world maps. Straight lines for single orbit graphs.
	Spin rate	1, 2, 3, 4	Obtained from ozone and/or micrometeorite experiments.
	Sun Angle	2, 3, 4	(Obtained from ozone and/or micrometeorite experiments.)