SECTION 5

RESULTS AND CONCLUSIONS

5.1 SUMMARY

Titan V-1 was launched on 4 April 1963. Liftoff occurred at 16:52:37.8 Pacific Standard Time (04:52:37.8, 5 April 1963 Zulu Time). Booster engine cutoff (BECO) occurred 137.0 seconds after liftoff, and sustainer engine cutoff (SECO) occurred 295.7 seconds after liftoff.

All functions of DEM 40, which were monitored by instrumentation, occurred as planned. However, DEM 39 failed to operate properly because of a failure in its electrical system. The only events which occurred in the DEM 39 operating sequence were release of aft tie-down and cutting of fairing nose strap. Telemetry data from this flight were of excellent quality. All DEM measurements produced valid information, which will permit determination of the accomplishment of the primary objective--determination of environmental compatibility of the DEM's and missile--even though functioning of one DEM was precluded.

5.2 DEM OPERATION

a. <u>DEM 40</u>

Table IVA shows the operations of DEM 40 in chronological order, relative to missile events and programmed sequence times. The table shows that the pod operated as planned; there were no failures of instrumented functions. (The very limited telemetry channel space available prevented the measurement of many important functions, as noted in the table. See section 3-2.)

TABLE IVA

EJECTION MECHANISM OPERATION SUMMARY
(DEM PA01040)

Event	Nominal Time (Seconds)	Actual Time (Seconds)	As Programmed	Remarks
Instrumentation Power On	-150.0			
Liftoff	0	0	--	04:52:37.8 Zulu 5 April 1963
BECO (T_1)	135.74	137.0		
Pod Power On				
(a) Timer	137.0		Probable	Not measured
(b) Squibs	137.0		Probable	Not measured
Aft-Attach Separation	137.0		N.D.	Not measured
Fairing Nose Strap Separation	167.0	166.2	Yes	
Fairing Ejection	167.0	166.45	Yes	
SECO	295.0	295.7		
Timer Start	295.7	296.15	Yes	
Unlatch No. 1	296.4		Yes	
Orient No. 1	296.65	296.55/ 300.05	Yes	Reached preset angle within 1 degree
Unlatch No. 4	296.9		N.D.	Not measured
Orient No. 4	297.15		N.D.	Not measured
Unlatch No. 3	297.4		N.D.	Not measured
Orient No. 3	297.65		N.D.	Not measured
Unlatch No. 2	297.9		Yes	
Orient No. 2	298.15	298.2/ 302.25	Yes	Reached preset angle within 1 degree
Unlatch and Orient No. 7	298.65		N.D.	Not measured
Unlatch and Orient No. 6	299.4		N.D.	Not measured

TABLE IVA (Continued)

Events	Nominal Time (Seconds)	Actual Time (Seconds)	As Programmed	Remarks
Unlatch and Orient No. 8	300.15		N.D.	Not measured
Unlatch and Orient No. 5	300.9	301.1/ 301.7	Yes	Reached preset angle within 1 degree
Unlatch and Orient No. 10	303.15		N.D.	Not measured
Timer Stop	306.9	307.35	Yes	
VECO	345.7	344.7	Yes	
R/V Separation	372.7	372.3		
Timer Restart	372.3	372.55	Yes	
Eject Sure No. 5	374.05	373.9	Yes	
Eject Sure No. 7	374.30	374.3	Yes	
Eject Sure No. 10	374.55	374.5	Yes	
Eject sure No. 6	374.80	374.7	Yes	
Eject Sure No. 8	375.05	374.9	Yes	
Eject Sure No. 4	375.30	375.1	Yes	
Eject Sure No. 2	375.55	375.7	Yes	
Eject Sure No. 1	375.80	375.9	Yes	
Eject Sure No. 3	376.05	376.1	Yes	

Note: Actual Times shown thus: 332.2/336.2, indicate start and finish times of the function.

N.D. = Not determined.

b. Pod 39

Table IVB shows the functions of Pod 39, chronologically. The T_1 signal was received and initiated activation of the power supply. Section 1, which powers the timer, apparently reached full voltage and maintained sufficient output to actuate relays throughout the normal period of DEM operation, as evidenced by timer operation and switching of instrumentation circuits upon receipt of the T_2 signal. Section 2, which provides power to perform pyrotechnic and re-entry orient motor operation did not maintain the proper voltage level. Full voltage was achieved normally, but after 0.8 second the voltage dropped as shown in Figure 8. The shaped charge cut the forward fairing attach strap, but the fairing failed to eject because of the low voltage. The electrical system failure also prevented all tube orientations and decoy ejections.

TABLE IVB

MECHANISM OPERATION SUMMARY
(DEM PA01039)

Event	Nominal Time (Seconds)	Actual Time (Seconds)	As Programmed	Remarks
Instrumentation Power On	-150.0			04:52:37.8 Zulu
Liftoff	0	0		
BECO (T_1)	135.74	137.0		
Pod Power On				
(a) Timer	137.0		Probable	Not measured
(b) Squibs	137.0	137.3	Yes	Dropped to zero volt at 240.0
Aft-Attach Separation	137.0		Probable	Not measured
Fairing Nose Strap Separation	167.0	166.75	Yes	
Fairing Ejection	167.3		No	
SECO	295.0	295.7		
Timer Start	295.7	296.15	Yes	

TABLE IVB (Continued)

Event	Nominal Time (Seconds)	Actual Time (Seconds)	As Programmed	Remarks
Unlatch and orient, all tubes	296.4 through 303.15	--	No	
Timer Stop	306.9	307.5	Yes	
VECO	345.7	344.7	Yes	
R/V Separation	372.7	372.3	--	
Timer Restart	372.3	372.4	Yes	
Eject Sure, all tubes	373.90 through 375.90	--	No	

5.3 ANALYSIS OF DEM PA01039 ELECTRICAL FAILURE

DEM PA01039 failed to operate because of a failure in the electrical system. This section presents an analysis of the possible causes of this failure, as follows:

(1) Partial activation of the battery because of faulty cell construction or insufficient electrolyte added to cells at time of activation.

(2) Short circuits located:

(a) within the power supply,

(b) in the squib circuitry (beyond the current-limiting resistors R31 and R32), or,

(c) in the sequence distribution box (ahead of the current-limiting resistors).

Figure 7 shows the complete electrical system schematic.

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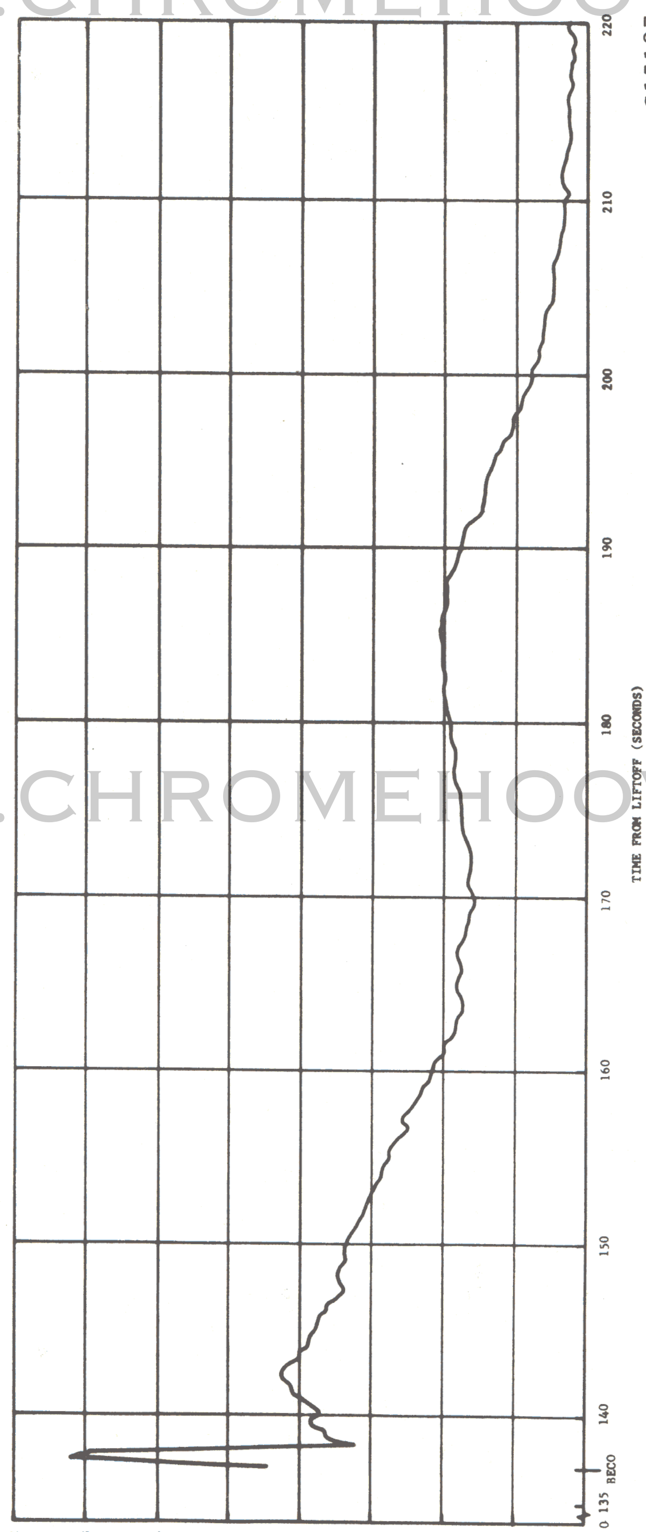

FIGURE 8. DEM 01039 POWER SUPPLY VOLTAGE VERSUS TIME (MEASUREMENT NO. A802)

5.3.1 PARTIAL ACTIVATION

The design of the battery is such that each cell must have at least some electrolyte to permit reaching any voltage level. If one cell of the series units did not activate, an open circuit would have resulted. If only a small amount of electrolyte were delivered to the cells, reduced capacity of the battery and a high internal resistance would result, which would cause a considerable voltage drop under a nominal load.

To explain the above statement, a brief description of the circuits involved at the time of activation (see Figure 9) is given, with some information on the characteristics of the power supply.

The internal resistance (R_I) of the power supply is a function of the capacity of the battery and the amount of current drawn. The R_I of this battery under full activation is about 0.4 ohm for a load condition of 2 to 22

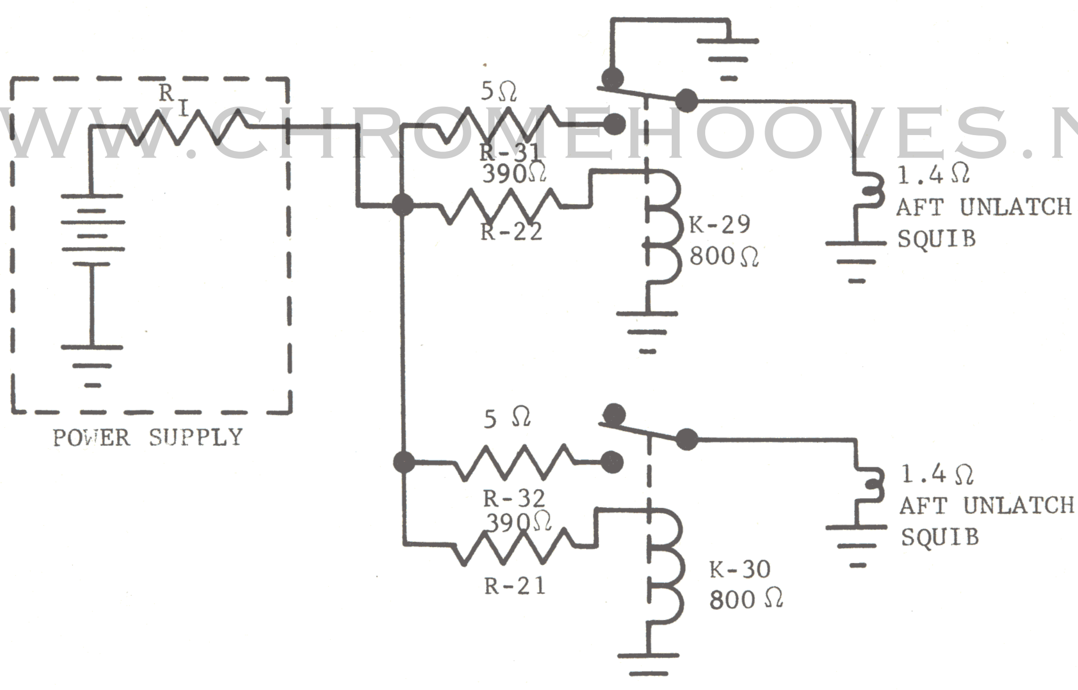

FIGURE 9. ELECTRICAL SCHEMATIC

amps (from test data). R_I will start to rise proportionally with the capacity depletion of the power supply. This R_I can be calculated by assuming a starting value and recalculating its value at some later time by monitoring the output of the battery under load. For the partial activation case, the R_I will be calculated to match the output that was obtained. The power supply can be represented by a voltage source (E) and an internal resistance (R_I). The external load (R_L) is the actual circuit used at the time of activation.

The circuit shown in Figure 9 works as follows. As the power supply is activated and the voltage starts to rise (0.2 second nominal to reach 30 volts), the aft attach squib relays close between 13.4 and 20.8 volts. The current required prior to pull-in of relays, K-29 and K-30 is

$$\frac{30 \text{ volts}}{\frac{(1190)}{2} + R_I \text{ ohms}} = 0.05 \text{ amp.}$$

(R_I is negligible under this size load.) When the relays pull in (the worst case would be 20.8 volts), the new current required depends upon R_I. The value of R_I will be calculated to match the curve obtained. (Simplified schematic. See Figure 10.)

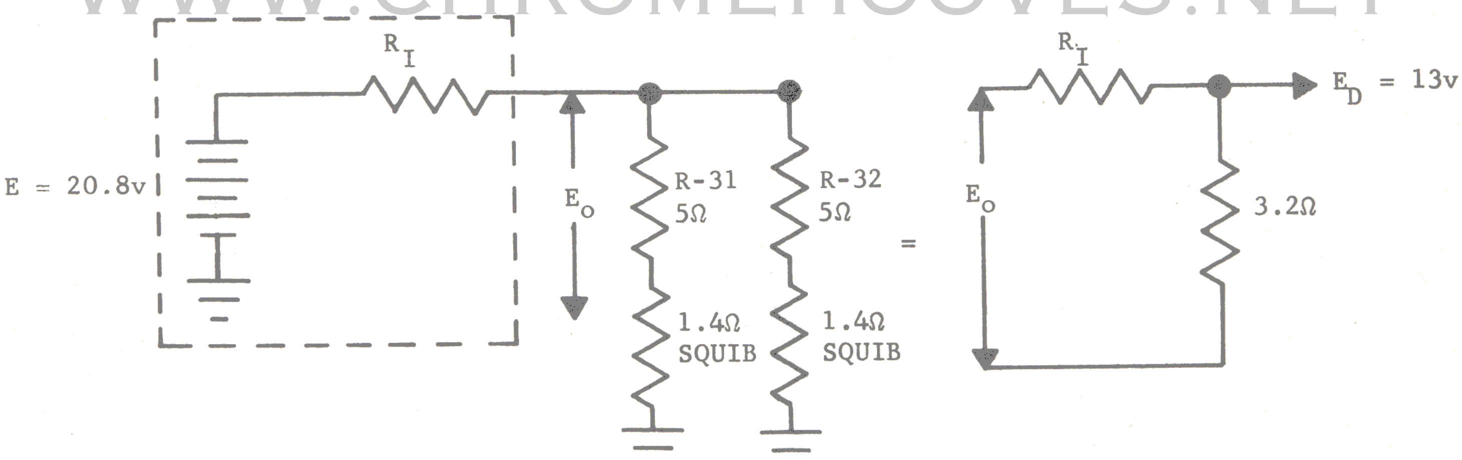

FIGURE 10. ELECTRICAL SCHEMATIC

Assuming a starting value of R_I = 4 ohms, 10 times its normal value, the squib current can be calculated:

$$I = \frac{20.8v}{7.2\Omega} = 2.89 \text{ amps} = 1.45 \text{ amps/squib}$$

Voltage across squib (and monitor circuit) = 2.89 (3.2) = 9.24 volts.

The current supplied would be enough, possibly, to fire the squibs, with a corresponding momentary drop in monitored voltage to 9.24 volts. Two possibilities would then exist:

(1) Both squibs would "open circuit" and the power supply output would rise to a 30-volt level; this possibility is satisfied by the data if the voltage drop occurred at a time and was sufficiently brief that the 5-sample-per-second commutation rate allowed it to go undetected. However, the subsequent voltage drop after 0.8 seconds would require an additional unknown change in the circuit.

(2) Either squib could have a residual current path, in which case the output of the power supply would never have reached the 30-volt level.

To develop a condition which may better match the curve, assume that the relays pulled in at the 30.5-volt level. Then, with R_L = 3.2 ohms and output voltage dropping to 13 volts,

$$\frac{R_I}{(30.5 - 13)} = \frac{R_L}{13}$$

$$R_I = \frac{17.5}{13}(3.2) = 4.31 \text{ ohms}$$

The current available for this condition is 4.06 amps, or 2.03 amps per squib, which would be sufficient to fire the squib.

After the initial voltage drop, the curve shows a rise to 17 volts (see Figure 8). Assuming that for these few seconds R_I remains constant, the new circuit parameters can be calculated and some assumptions can be made.

$$R_L = \frac{(17)(4.31)}{13.5} = 5.43 \text{ ohms}$$

This value indicates that one squib would fire and open circuit, while the other would short to 0.43 ohm. The current would then be $\frac{30.5}{9.74} = 3.13$ amps, which might not burn out the current-limiting resistor.

Now assume that the R_L remains constant and R_I increases, causing a proportional decrease in E_o. The situation at BECO + 30 can then be evaluated. At this time, $E_o = 7$ volts. Then $R_I = \frac{(23.5)(5.4)}{7} = 18.1$ ohms and the circuit is as shown in Figure 11.

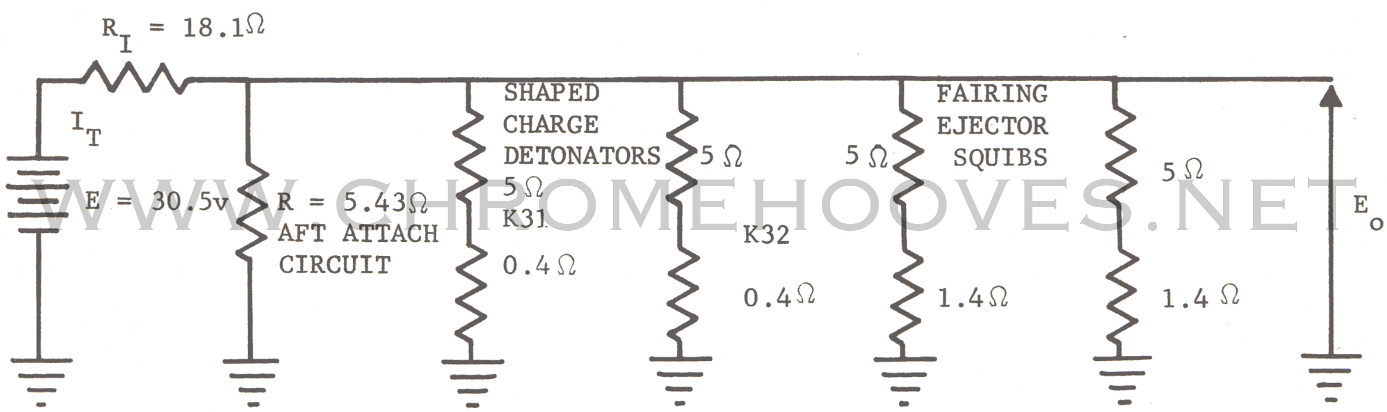

FIGURE 11. ELECTRICAL SCHEMATIC

$$\frac{1}{R_L} = \frac{1}{5.43} + \frac{2}{5.4} + \frac{2}{6.4} = 0.866$$

$$R_L = \frac{1}{0.866} = 1.2\Omega$$

Then

$$I_T = \frac{30.5}{18.1 + 1.2} = 1.55 \text{ amps}$$

and

$$E_o = 1.55 \times 1.2 = 1.87 \text{ volts}$$

As in the earlier case, a momentary drop in voltage during squib firing might not be detected on the commutated measurement, but here the voltage would remain at a partially-reduced level because the ejector squibs did not fire and would continue to draw current.

Further, the current available to the shaped-charge side detonators is

$$I_{SD} = \frac{1.87}{5.4} = 0.35 \text{ amps,}$$

which is less than the no-fire current for the detonators (Reference No. 7). Therefore, it can be concluded that the shaped charge could not have fired if partial activation of the battery had been the cause of failure. The other possible mode of failure, a short circuit, is examined in paragraph 5.3.2.

5.3.2 SHORT CIRCUIT

This portion of the analysis will show that the failure most probably occurred because of a short circuit in the system.

Assume that a low-resistance short occurred at BECO + 0.8 second, but did not stabilize in resistance until BECO + 4 seconds. As stated previously, the power supply internal resistance, R_I, is 0.4 ohm. Using the circuit of Figure 12, the load resistance, R_L, is:

$$R_L = \frac{17(0.4)}{13.5} = 0.5 \text{ ohm.}$$

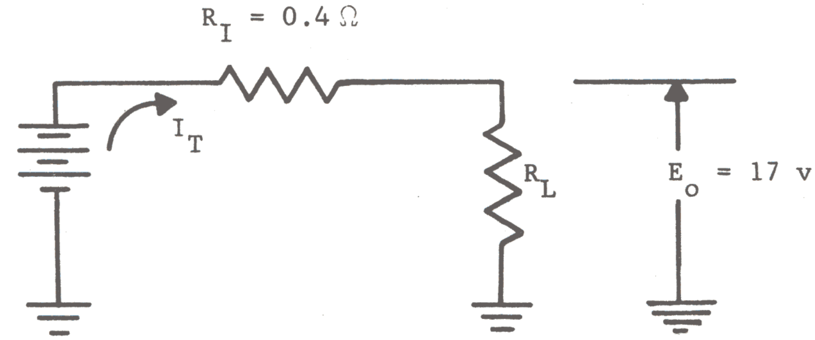

FIGURE 12. ELECTRICAL SCHEMATIC

This value, again, is assumed to stabilize at 4 seconds (because of the nature of the voltage trace (Figure 8), and is used to calculate values of R_I over the discharge period. The values are presented in Table V.

TABLE V

CALCULATED CIRCUIT PARAMETERS

Time (Sec)	E_o (volts)	I_T (amps)	R_L (ohms)	R_I (ohms)
4	17	34	0.5	0.4
10	14.5	29	0.5	0.55
20	10.0	20	0.5	1.02
30	7.0	14	0.5	1.68
35	6.5	13	0.5	1.85
40	7.0	12.7	0.55	1.85*
45	8.0	12.1	0.66	1.85*
50	7.5	11.4	0.66	2.11
60	4.0	6.1	0.66	4.37
70	1.8	2.7	0.66	10.9

* The slope of the curve changes during this time and the assumed cause is heating of the R_L, causing R_L to rise and effectively keeping R_I constant during this period.

Plotting the current calculated for these points yields a curve as shown in Figure 13, the integration of which yields a discharge capacity of 1100 ampere-seconds. The value obtained for the lot sample battery was 928 ampere-seconds, which was measured to the point where the supply voltage dropped to 25.2 volts. The 1100 ampere-second figure then compares closely with previous results, lending support to the assumption that the power supply produced its full output and must have been fully activated.

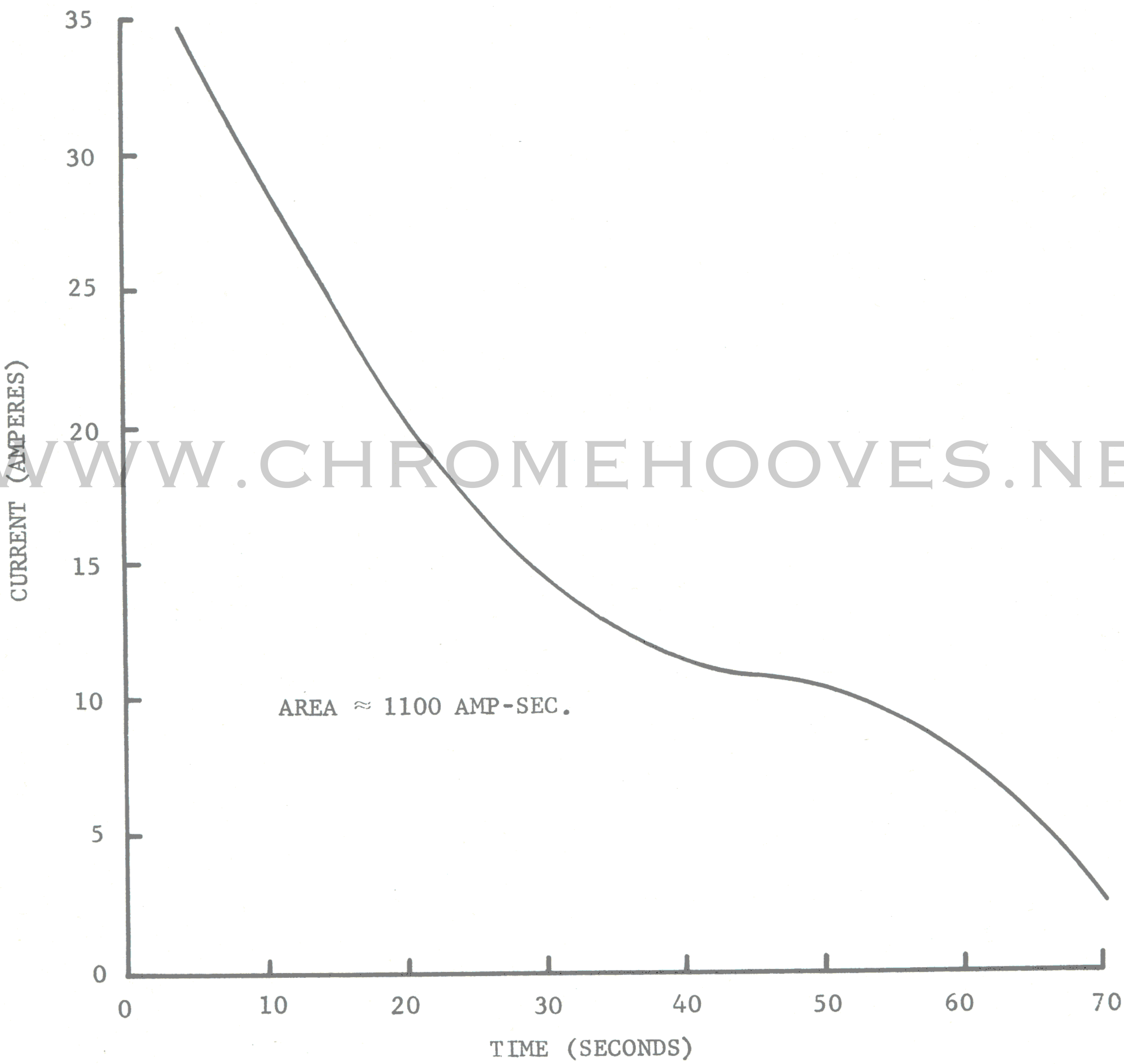

FIGURE 13. CALCULATED POWER SUPPLY OUTPUT

The situation at BECO + 30 seconds is now examined, based on the above argument. The circuit (simplified) can be represented as shown in Figure 14 and the following values can be calculated:

$$I_T = \frac{30}{2.11} = 14.2 \text{ amps}$$

$$E_o = (14.2)(0.43) = 6.1 \text{ volts}$$

$$I_{\substack{\text{Fairing}\\\text{Ejector}}} = \frac{6.1}{6.4} = 0.953 \text{ amps}$$

$$I_{\substack{\text{Shaped}\\\text{Charge}}} = \frac{6.1}{5.4} = 1.13 \text{ amps}$$

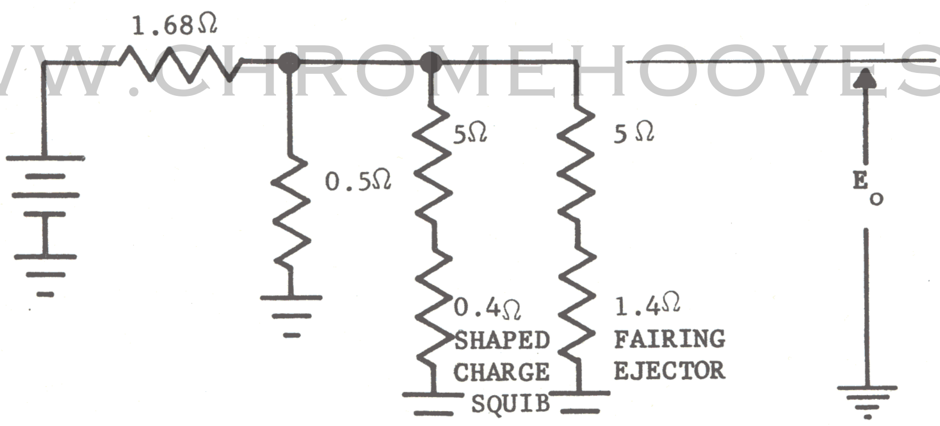

FIGURE 14. ELECTRICAL SCHEMATIC

These values indicate that, under the assumed short-circuit condition, the fairing probably could not eject but the forward attach strap could be cut by the shaped charge, since the shaped charge detonators have been fired at as

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little as 0.7 amperes in ground tests. This analysis, then, reconstructs the operation of the DEM, as it actually occurred, as shown by telemetry measurements.

Therefore, on the basis of this analysis, it is reasonable to conclude that the failure was caused by a short circuit. It should be mentioned that this type of failure can occur only between the power supply and the current-limiting resistors in series with each squib. Any shorting of the squibs will not affect the power supply because of the limiting action of the resistors and their fuse characteristics. The resistors always burn open with the application of full power supply load through them. Any current less than 3 amps will not burn open the resistor but, at the same time, the power supply output voltage will not drop lower than 28 volts.

The failure noted must have occurred after final checkout. A detailed review of the checkout procedures since the flight confirms that a condition so drastic would have been discovered during checkouts. Also, the momentary rise to full voltage tends to confirm that deduction. However, extensive study and experimentation since the flight have not disclosed any specific location at which the short circuit can reasonably be expected to occur. It is therefore considered to be a random malfunction.

5.4 AERODYNAMIC

Pressure data obtained from this flight are of good quality. A preliminary check of these data indicates that the aerodynamic loads were less than those encountered on previous Titan I flights with earlier fairing venting configurations. These preliminary results were considered a sufficient basis for the conclusion that the present vent configuration is satisfactory for use on the next and final flight planned on the Titan I missile, Titan V-4. Detailed calculations had not been completed at publication of this document. These results will be published in an addendum report at the earliest possible date.

5.5 FAIRING DEFLECTIONS

Fairing motion was measured at two locations on each DEM. These were measurements 737 and 740, located as shown in Figures 5 and 6. The results of the 737 readings are shown in Figure 15. As expected, very small deflections ($\pm$ 0.04-inch) were recorded. Reading 740 was not telemetered until BECO, when the function was switched on for the purpose of showing fairing nose motion during shape-charge operation and fairing ejections.

The 740 measurement on DEM 39 confirmed the cutting of the fairing nose strap by showing a fairing movement of approximately 0.075 inch at BECO + 29.8 seconds.

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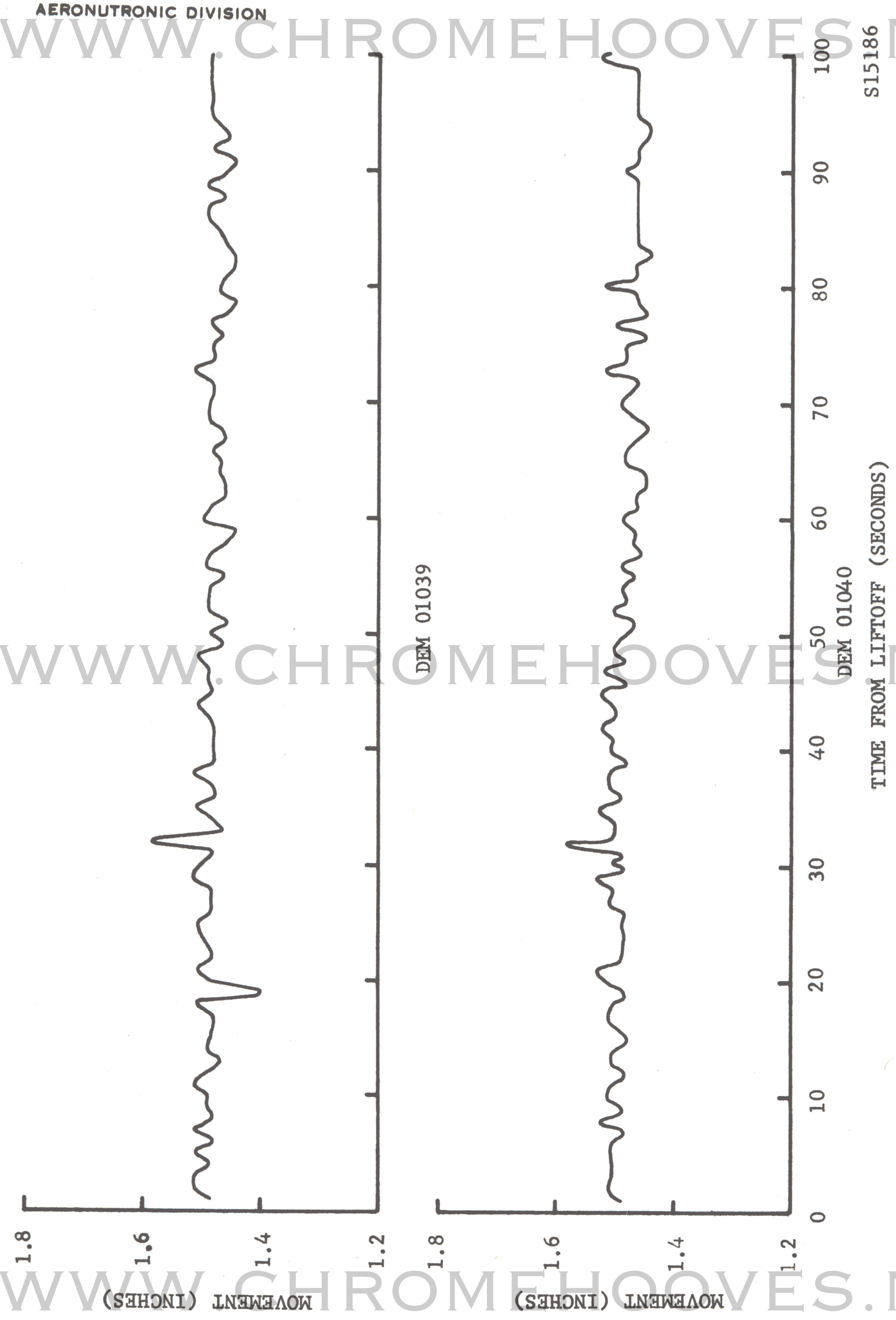

FIGURE 15. FAIRING LONGITUDINAL MOVEMENT AFTER LIFTOFF (MEASUREMENTS A737 AND B737)

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SECTION 6

CORRECTIVE ACTION

The only malfunction encountered on this flight was the electrical system power failure in DEM 01039. As noted in the analysis of that failure (Section 5.3), it is considered a random, in-flight failure, and therefore no corrective action is planned other than a continuing effort to identify specific hardware features or conditions which might cause such a short-circuit.

REFERENCES

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2. Flight Instrumentation Data Handbook Pod S/N-PA01040-Mod II, Aeronutronic Drawing No. 204072, released 27 February 1963.

3. Flight Instrumentation Data Handbook Pod S/N-PA01039-Mod II, Aeronutronic Drawing No. 204071, released 27 February 1963.

4. Evaluation Launch and Flight Test Directive for V-1 (AF-50-2252) and V-4 (AF-60-3635) Titan I, dated March 1963.

5. Tracking Support Data transmitted by Aeronutronic letter RS-4355, dated 13 March 1963 and Aeronutronic letter RS-4283, dated February 1963.

6. Metric Optical Data, Metric FPS-16 Radar Data, Metric GERTS Data, Half Moon, Pacific Missile Range Document Control No. 63-1256, dated 7 April 1963.

7. Decoy Subsystem Launch Pod Safety Report - Mod II, (Rev. D), Aeronutronic Report No. S-1238D dated 30 October 1962.

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