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PRODUCT ASSURANCE PROGRAM TECHNICAL REPORT
FOR THE
RADAR CROSS-SECTION REDUCTION
OF
RE-ENTRY VEHICLES (U)

31 March 1963

CONTRACT AF 04(694)-25

PA-TR-3

CHRYSLER CORPORATION MISSILE DIVISION

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Prepared by the
Reliability Organization

CHRYSLER CORPORATION MISSILE DIVISION

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RCS REDUCTION RE-ENTRY VEHICLE CCS-1FT
SEPARATION AND ATTITUDE CONTROL SUBSYSTEM
RELIABILITY ANALYSIS AND PREDICTION

I. INTRODUCTION

This report presents the preliminary reliability analysis and prediction summary for the Radar Cross Section Reduction Re-Entry Vehicle CCS-1FT (REX-3). The reliability analysis and prediction was performed on the Separation and Attitude Control Subsystem as presently defined. It is anticipated that some changes will be made prior to the official release of the drawings for fabrication.

The reliability analysis for the structure of the re-entry vehicle has not started because of the lack of placement error information and delays in structures design definition. This analysis will be contained in a subsequent report which will be prepared for the quarterly period ending June, 1963.

The major difference between this second generation vehicle and CS-1FT (REX-1) is that the CCS-1FT (REX-3) vehicle does not incorporate an Instrumentation Subsystem. Also, the Separation and Attitude Control Subsystem in CCS-1FT is somewhat simplified and uses a re-chargeable battery.

II. OBJECTIVE

The objective of the Product Assurance Program is to provide a reliability analysis of the CCS-1FT re-entry vehicle in order to determine its capability in performing the required flight mission. The desired reliability goal for the Separation and Attitude Control Subsystem, as stated in the program plan, is as follows:

Separation and Attitude Control Subsystem $R_{SA} = 0.905$

III. CONCLUSION

It is concluded from the results of this analysis and evaluation that the following numerical reliability prediction for the subsystem can be stated:

Separation and Attitude Control Subsystem $R_{SA} = 0.9712$

IV. DISCUSSION

A. General Assumptions

The predicted reliability of the control subsystem for the CCS-1FT vehicle is based on the following general assumptions:

1. That a complete functional checkout and appropriate inspection is made prior to installation on the booster and that all re-entry vehicle subsystems are in a "go" condition prior to lift-off.

2. That Aerospace Ground Equipment (AGE) reliability is 100% and will cause no secondary failures within the re-entry vehicle.

3. That the booster is 100% reliable in providing the necessary signals, initial trajectory orientation, and telemetry where these are required.

B. General Plan

The plan that was followed to establish the stated numerical reliability prediction is contained in Section V and the Appendices of this report. In general, this plan has the following format:

1. Define control subsystem function.

2. Prepare the system Reliability Functional Diagram - A worded diagram which illustrates component function and component critical mode of failure.

3. Prepare Component Application Sheets - Determining if the application of the component is within its electrical and environmental design specifications.

4. Establish the Reliability Block Diagram.

5. Contact manufacturers of control subsystem components for reliability and qualification test data.

6. Establish component reliability using manufacturer's test data or the RADC Reliability Notebook.

7. Establish Reliability Evaluation Sheets.

8. Compute the estimated reliability.

V. RELIABILITY ANALYSIS AND PREDICTION

A. Analysis

In order to predict reliability, it is first necessary to perform a reliability analysis. The procedure used in the reliability analysis for the Separation and Attitude Control Subsystem is detailed as follows:

- Define the system or equipment in terms of function.

- Define system components in terms of required function and modes of failure which can cause system failure.

- Determine if the application of the component is within its electrical and environmental design specifications.

- Determine the operating period during which system components are expected to function successfully.

1. Functional Description

During the flight of the CCS-1FT vehicle, the state of the Separation and Attitude Control Subsystem can be separated into three modes. These modes are as follows:

Mode 1 - Lift-off to Separation Signal (The control subsystem is under battery power; however, it performs no function.)

Mode 2 - Separation Signal through Vehicle Spin (The control subsystem performs the separation function of firing the explosive nuts and the attitude orientation function of pitch, de-pitch, and spin.)

Mode 3 - Vehicle Spin to Impact (The control subsystem is inactive and performs no function.)

Prior to lift-off, the vehicle is enabled by a signal originating from Aerospace Ground Equipment (AGE). This signal, which consists of a negative pulse, actuates two latching type relays located in the vehicle. These two relays start the following series of events:

- Battery is connected to system bus.
- Regulated voltage is applied to timer oscillator.
- Timer is zeroed.

When the timer is zeroed, a signal is fed back to AGE where it indicates that the vehicle is in a ready state.

During this period of enabling the vehicle, a constant monitoring of the control subsystem is maintained by AGE. The monitor checks the following portions of the control subsystem:

- Battery Voltage
- Voltage Regulator Output
- Separation Squib Circuits
- Pitch Squib Circuits
- De-Pitch Squib Circuits

- Spin Squib Circuits
- Timer Clamped Output

The monitor is of the "go, no-go" type which only indicates that failure has occured and gives no indication of what has failed. If the monitor indicates a failure, the AGE will automatically disable the vehicle.

Since lift-off will not occur if the monitor indicates a failure, the reliability of the control subsystem is considered only from lift-off through vehicle spin. However, any portion of the monitor circuit that could cause a failure to the control subsystem during flight is included in the reliability prediction.

If the monitor indicates a "go" condition and if the vehicle indicates it is enabled, then the control subsystem is ready for lift-off. After lift-off, the control subsystem does not perform any function until it receives a separation signal from the booster. Upon receiving this signal, a relay is activated which starts the series of events which fires the explosive nuts to separate the vehicle from the spacer. The control subsystem timer starts when the electrical connector between spacer and vehicle has physically separated.

To obtain the correct attitude orientation for re-entry, the timer delivers output signals at a prescribed time to fire the pitch, depitch and spin rockets. After the timer has completed its attitude control cycle, it delivers a fourth signal which de-activates the control subsystem by disconnecting the battery from the subsystem bus. De-activating the control subsystem after attitude orientation is complete is not a factor of control subsystem success, but it is a possible factor of control system failure if it occurs prematurely; therefore, this function is included in the reliability of the control subsystem.

2. Component Function and Modes of Failure

A review of system schematics established the function a component is required to perform for mission success, and a failure mode was established by non-performance of the required function. The types of failure modes for components used in the control subsystem are defined as follows:

- Resistors, diodes, and transistors - open, short, and drift
- Relays - Coil open or shorted, failure of contact sets to open and stay open or close and stay closed.
- Battery, timer, rockets, and explosive nuts - Failure to deliver their required outputs when supplied their required inputs.

The results of this functional and failure mode evaluation for the Separation and Attitude Control Subsystem are shown as Figure 1 and Figure 2. These diagrams are called Reliability Functional Diagrams and serve the purpose of providing (1) system functions which are necessary for mission success; (2) failure modes of components which can cause system failure; and (3) system arrangement for reliability calculations (i.e., parallel and series).

Figure 1 depicts the Enabling and Monitor circuits. The Monitor is included with Enabling functional diagram to illustrate its function prior to lift-off. Since the Monitor is not considered in the reliability analysis for mission success, its reliability analysis is considered separately and is contained in Appendix C.

Figure 2 depicts the Separation and Attitude Control Subsystem for Mode 2.

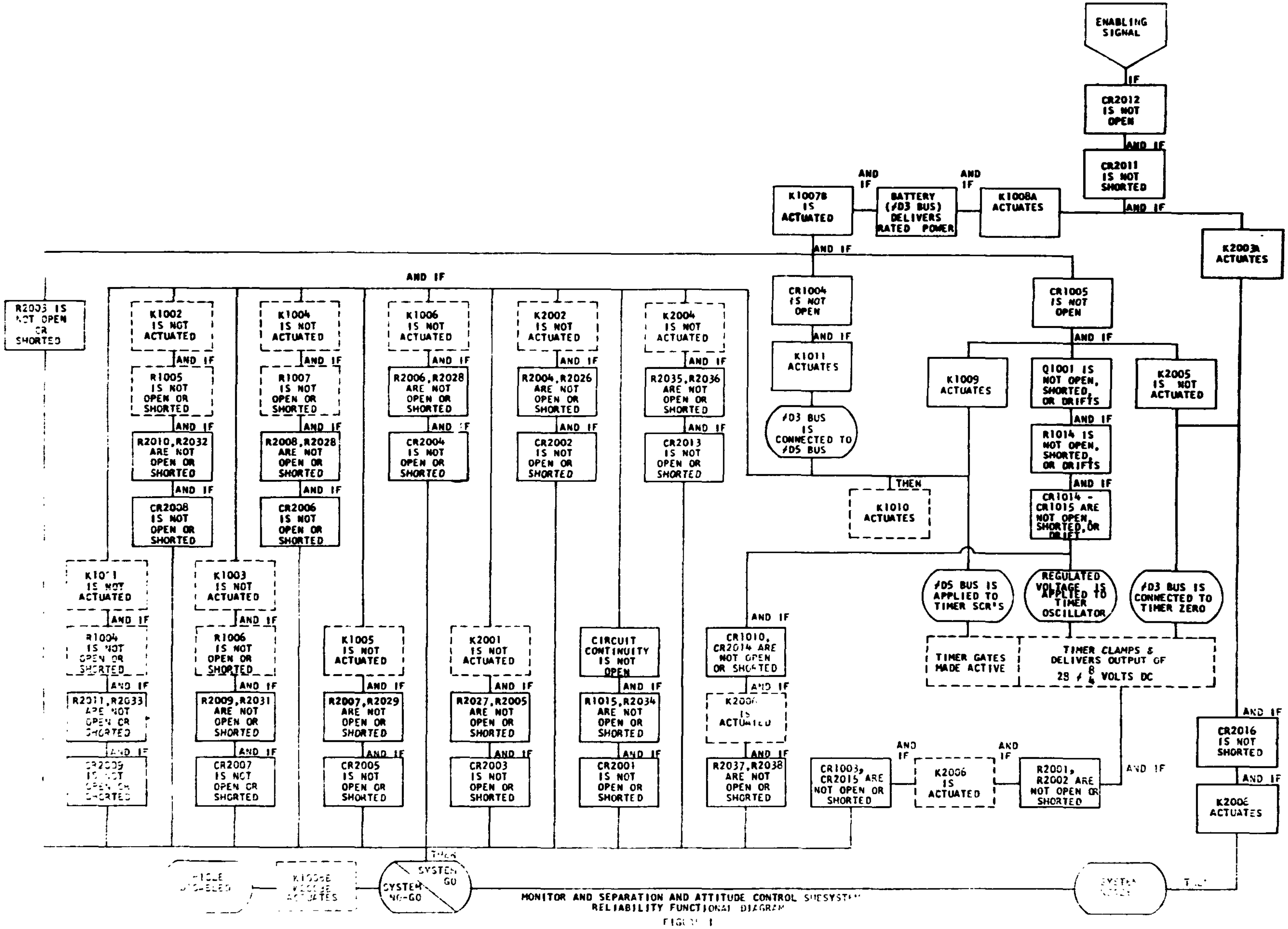
The Reliability Functional Diagram distinguishes pure functional information from reliability information by the use of different symbols. In the functional diagram, it was necessary to depict one component or piece of equipment in several places; therefore, it became necessary to illustrate just where in the diagram the reliability of the component should be considered. This was accomplished through the use of appropriate symbols. The definition of these symbols and terms used in the Reliability Functional Diagram are given in Figure 3.

3. Component Application

Component Application Sheets were used to determine that the application of a component was within its electrical and environmental specifications. The application sheet compares component stress as determined by its electrical and environmental application with allowable component stress as specified by the manufacturer. Electrical stresses were determined from a circuit analysis and environmental stresses were determined from the Environmental Profile as shown in Figure 4. Hence, any component stressed beyond its designed capability, which would in turn effect its reliability, is detected and corrected. Examples of Component Application Sheets for a resistor, diode, and relay are shown in Appendix D.

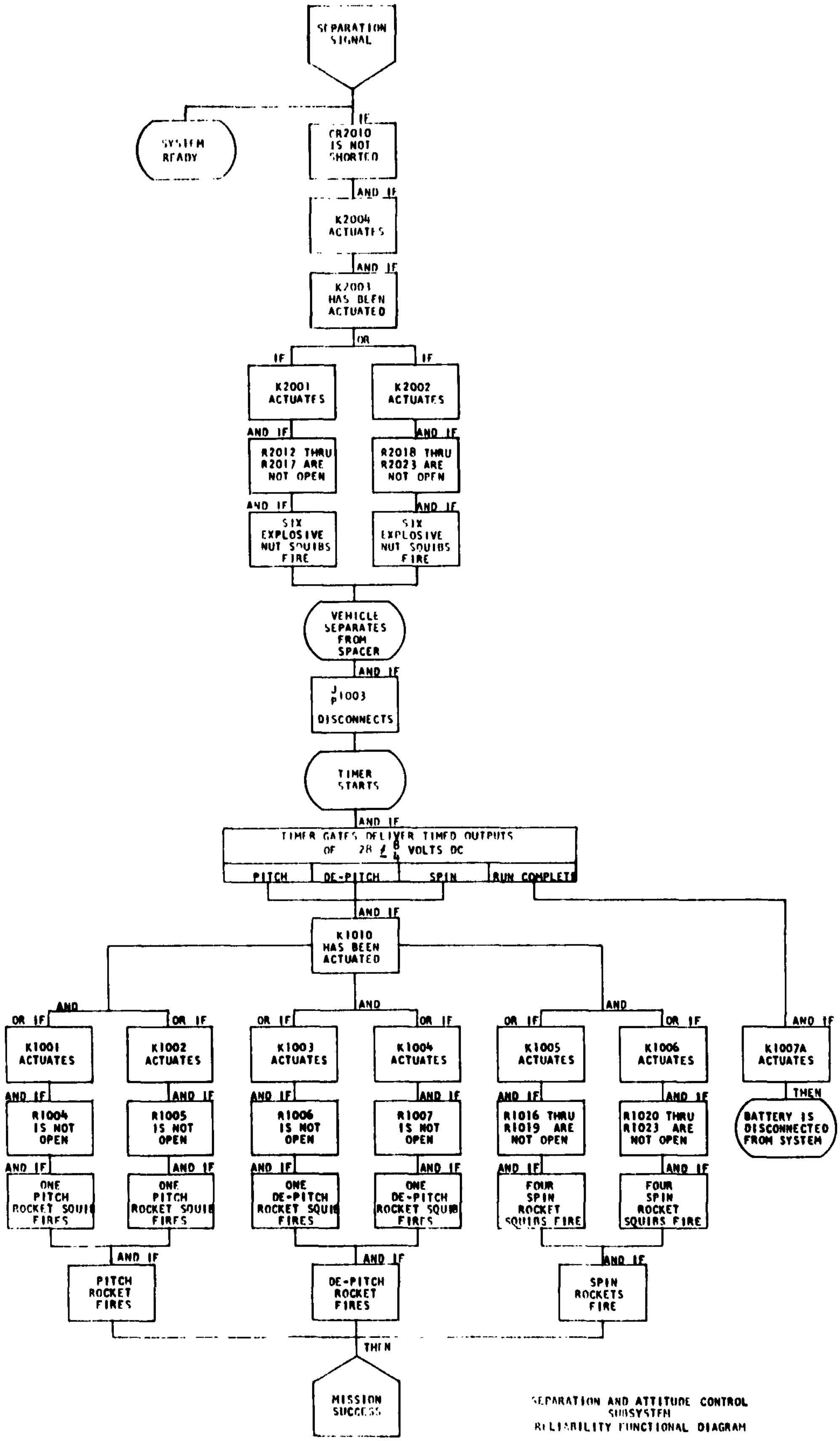
4. Component Operating Period

The operating period during which a component is expected to function successfully is determined by its actual operating period during Modes 1 and 2. If a component is functioning from lift-off to vehicle spin (e.g., the timer), its operating period will be the total time of Modes 1 and 2. If a component only functions for a short duration of Modes 1 and 2 (e.g., the rockets), its operating period will be the time to complete its function.



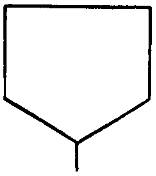
MONITOR AND SEPARATION AND ATTITUDE CONTROL SUBSYSTEM
RELIABILITY FUNCTIONAL DIAGRAM

FIGURE 1



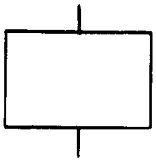
SEPARATION AND ATTITUDE CONTROL SUBSYSTEM
RELIABILITY FUNCTIONAL DIAGRAM

FIGURE 2



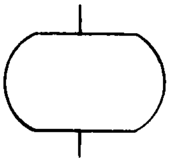
INPUT (INITIAL) BLOCK

Depict initiating signal or action.



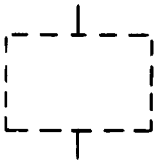
DIRECT ACTION BLOCK

Depicts component operation, the reliability of which is considered at that point in the sequence.



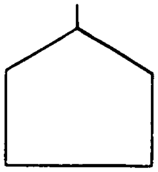
FUNCTIONAL BLOCK

Depicts a functional description, no reliability number associated. This function is the result of other action blocks already shown.



INDIRECT ACTION BLOCK

Depicts component operation, the reliability of which is considered elsewhere in the sequence.



OUTPUT (TERMINAL) BLOCK

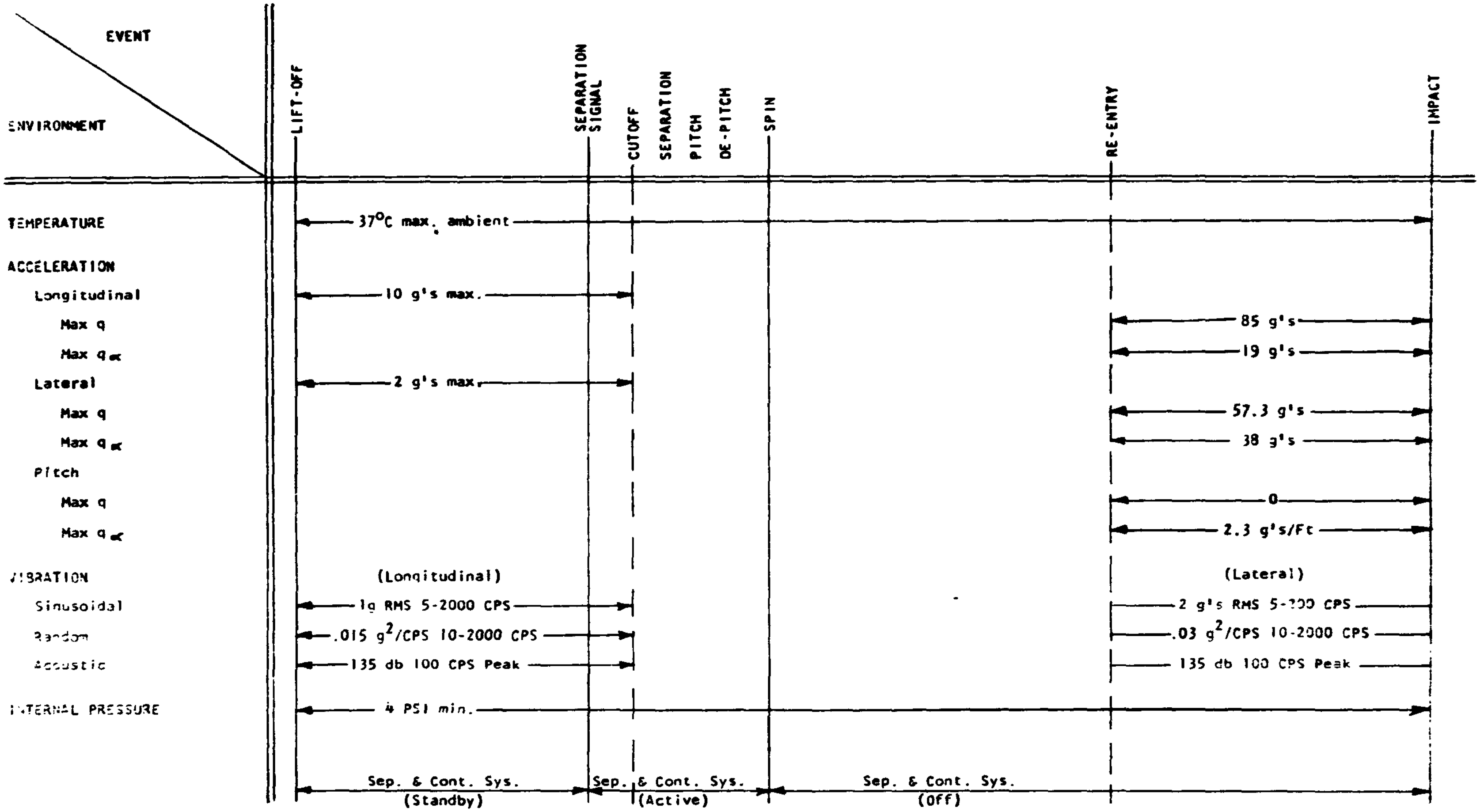
Depicts terminal signal or action.

DEFINITIONS

Actuates	Relay performs without failure, including the closing and opening of required contact sets. Relay coil is not opened or shorted, closed contacts sets pass necessary current and open contact sets break necessary circuits.
Or	Designate redundant circuits (Parallel reliability).
If/And If	Designate series reliability circuits.

SYMBOLS AND TERMS USED IN
RELIABILITY FUNCTIONAL DIAGRAMS

FIGURE 3



PRELIMINARY
ENVIRONMENTAL PROFILE CCS-IFT
ON BOARD COMPONENTS

FIGURE 4

In the case of relays, a more useful computing method is use of the number of cycles to failure instead of time to failure. Most relay manufacturers supply life test information on cycles of operation and failures. This information can be used to determine the expected reliability of the component in its application. During Modes 1 and 2, all relays are only required to operate for 1 cycle.

B. Prediction

1. Reliability Block Diagram

The Reliability Block Diagram for the Separation and Attitude Control Subsystem, Figure 5, is derived directly from the Reliability Functional Diagram. Components in the block diagram are no longer shown in their functional sequence, but are shown in their series or redundant reliability sequence together with their assigned or calculated reliability numbers.

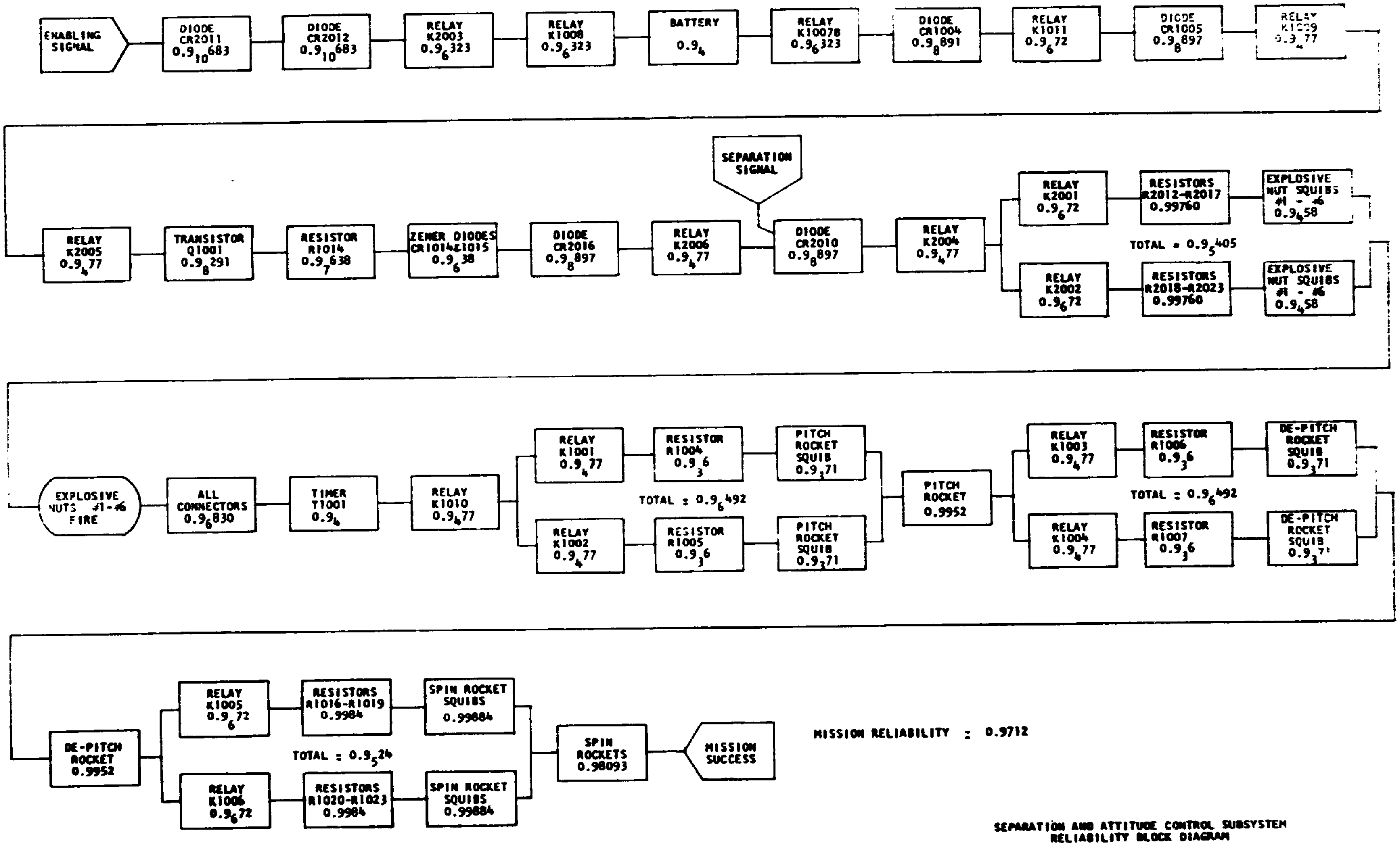
2. Prediction Techniques

In predicting reliability for a component, the availability of reliability test data is limited to testing conducted by the contractor or testing conducted by the manufacturer of the component. Since few reliability tests are being conducted by Chrysler Missile Division within the scope of this product assurance program, then the major portion of the reliability test data is limited to that furnished by the manufacturer. For this reason, the manufacturers of components used in the design of the Separation and Attitude Control Subsystem were contacted and were requested to make available, for our evaluation, reliability and qualification test data which they may have collected.

In determining the manufacturers of components, it was found that the manufacturers of a few Mil Spec resistors could not be identified since they were ordered through an electronic supply house to a Mil Spec for which there are many qualified manufacturers on the Qualified Products List (QPL).

If the manufacturer could not supply reliability information or if the manufacturer was not known, then best engineering judgement and military documents were used in predicting reliability.

The Rome Air Development Center (RADC) Reliability Notebook was considered to have the latest failure rate information based on engineering approximations of reliability characteristics for parts when employed within their specified ratings. Therefore, whenever there was insufficient test data to determine reliability for parts used in the Separation and Attitude Control Subsystem, the RADC Reliability Notebook was used to predict reliability.



SEPARATION AND ATTITUDE CONTROL SUBSYSTEM
RELIABILITY BLOCK DIAGRAM

FIGURE 5

To improve the predicted reliability or failure rate of a component, it is desirable to consider only the portion of the total reliability or failure rate that is associated with a critical failure mode; however, this is only possible when there is sufficient data available to appropriately assign a reliability number or failure rate to a particular failure mode. Since this type of test data is limited and since approximation techniques are questionable, proportioning of reliability and failure rates to failure modes was not done for this reliability prediction.

The computation of reliability and failure rates for components used in the Separation and Attitude Control Subsystem is contained in Appendix A. For convenience, control subsystem components are tabulated on Reliability Evaluation Sheets contained in Appendix B. These evaluation sheets are a compilation of essential data of the reliability analysis and indicates predicted component reliability together with its source.

APPENDIX A

COMPUTATION OF COMPONENT RELIABILITY AND FAILURE RATES

DIODES

There are two types of diodes used in the Separation and Attitude Control Subsystem. These are a general purpose type diode, PS510B, manufactured by Pacific Semiconductor, Incorporated (PSI) and a zener diode, SV1120B, manufactured by Transitron Electronic Corporation. Both of the diodes are manufactured in accordance with Minuteman specifications. PSI has operationally life tested 6,060 PS510 diodes for 1,000 hours with zero failures. PSI uses an acceleration factor of 100 and computes the failure rate (λ) of the PS510 to be $\lambda = 0.00114\%/1000$ hours at 90% confidence. The reliability of the diodes is then computed by -

$$R = e^{-\lambda t} \tag{1}$$

Where: R = Reliability

λ = Failure rate (in failures/hour)

t = Operational time (in hours)

The zener diode, SV1120B, has a failure rate which is taken from Minuteman standard parts books. This failure rate is based only on junction temperature (T_J). The for this part can be computed from the following formula:

$$T_J = T_A + \theta_{JA} P_J \tag{2}$$

Where: T_J = junction temperature

θ_{JA} = thermal resistance from junction to free air

T_A = ambient temperature

P_J = average power dissipated at the junction at temperature T_J

For the SV1120B, T_A is 37°C; θ_{JA} is 0.25°C/milliwatt and P_J is 290 milliwatts maximum. Solving equation (2) for T_J, it is found that T_J is 99.5°C. From graphs in the Minuteman standard parts book, the failure rate is shown to be 0.33%/1000 hours, computed by using equation (1). Additional information on the reliability of the SV1120B has been requested from Transitron.

RELAYS

There are four types of relays manufactured by three different manufacturers used in the Separation and Attitude Control Subsystem. These relays are manufactured by Potter and Brumfield, P/N SLG-11-DA; Babcock Relays, P/N BR7X-300D5-26; and Branson Corporation, P/N's SRB-2C-24A and SRB-4C-24A. Life test data has been supplied by Potter and Brumfield and Babcock Relays. Data has been requested from Branson Corporation. Potter and Brumfield supplied the life test result of 34 similar latching type relays. Each relay was tested for 10^5 cycles with 0 failures. The lower limit of reliability can be calculated based on a binomial distribution by the following equation:

$$R \geq \frac{x}{x + (n - x + 1)\nu^2_{P_1}} \tag{3}$$

Where:

x = Number of Successes

n = Number of Trials

$\nu^2_{P_1}$ = Square of the variance at P_1 % confidence with f_1 and f_2 degrees of freedom, where

f_1 = $2(n-x+1)$, degrees of freedom for the numerator

f_2 = $2x$, degrees of freedom for the denominator Tables for ν^2 can be found in Statistical Tables and Formula by A. Hald, pp. 47-59.

Therefore, using the numerical data as applicable, we obtain:

$x = 3.4 \times 10^6$

$n = 3.4 \times 10^6$

$\nu^2_{P_1} = 2.3$ where $f_1 = 2$; $f_2 = 6.8 \times 10^6$

$P_1 = 90\%$

Substituting these values in equation (3) and solving

$$R \geq \frac{3.4 \times 10^6}{3.4 \times 10^6 + 1 \times 2.3} = 0.9_6 323$$

Babcock Relay has supplied life test results of 190 relays cycled 100,000 operations each, with a total of 2 contact misses. For the use in equation (3), we obtain:

$x = (19 \times 10^6 - 2)$

$n = 19 \times 10^6$

$\nu^2_{P_1} = 1.77$ where $f_1 = 6$, $f_2 = 2(19 \times 10^6 - 2)$

$P_1 = 90\%$

Substituting these values in equation (3) and solving

$$R \geq \frac{19 \times 10^{6} - 2}{(19 \times 10^{6} - 2) + 3 \times 1.77} = 0.9_{6}72$$

Branson Corporation has supplied no data as yet. Therefore, it was necessary to calculate the reliability for the Branson relays based on the MIL-R-5757D life of 100,000 cycles with no failures. These relays were ordered to Mil Spec 5757D. Using these data, the values used in equation (3) are:

$x = 10^{5}$

$n = 10^{5}$

$\nu^{2}_{p_1} = 2.3$ where $f_1 = 2$; $f_2 = 2\ (10^{5})$

$P_1 = 90\%$

Substituting these values in equation (3) and solving

$$R \geq \frac{10^{5}}{10^{5} + 1 \times 2.3} = 0.9_{4}77$$

All relays in this Subsystem are operated only once during the flight. The relays used in the squib firing circuits carry greater than rated contact currents. It is assumed that the ability of the relays, that carry excessive contact current, to close the contact set, for one operation only, was in no way affected by the overload on the contacts. Even if the contacts were to weld this would not impair the relays ability to pass sufficient current for the time required for successful firing of the squibs. Therefore, a reliability equal to that computed for one cycle of operation was used for all relays, whether overloaded or not. To verify operation of relays at excessive contact currents, tests are scheduled to be performed. The results of these tests will be reported in a subsequent report.

RESISTORS

The resistors used in the Separation and Attitude Control Subsystem are either Mil Spec resistors for which the manufacturer is unidentified or resistors manufactured by Dale Electronics, Incorporated. The resistors ordered to Mil Specs are used in the normal manner and their failure rates are taken from the Rome Air Development Center (RADC) Reliability Notebook by using part ambient temperature, stress ratio and appropriate Mil Spec.

The resistors manufactured by Dale Electronics, Incorporated are used as current limiting devices in the squib firing circuits. In this application, they dissipated power in excess of their rated power for short periods of time (i.e., 2 to 5 msecs). A reliability evaluation of these resistors was performed for the CS-1FT (REX-1) vehicle based on the results of ten tests. This resulted in a calculated reliability of $0.9_{3}6$. On the CCS-1FT (REX-3) vehicle, these resistors carry approximately one-half the current they did on the CS-1FT. No additional tests have been performed to date. However, tests of these resistors at their application currents are scheduled. In the absence of test results of the actual application, reliability values from the previous tests were used in this report. The values are probably low by a factor of 4 or greater. The computed reliability for the actual application will be reported in a subsequent report.

CONNECTORS

The connectors used in the Separation and Attitude Control Subsystem are manufactured by Bendix Scintilla Division, The Pyle-National Company, E. B. Wiggins Oil Tool Company, Incorporated, and Viking Industries, Incorporated. All manufacturers were contacted and each supplied qualification test data to the applicable Mil Spec. This data showed that each connector manufacturer was a qualified source for the connectors but the data was not sufficient for computation of failure rates. Therefore, the failure rates used for the connectors was taken from the RADC Reliability Notebook based on the number of active contacts in each connector.

TRANSISTOR

The transistor used in the Separation and Attitude Control Subsystem is manufactured by Fairchild Semiconductor Corporation. This transistor has an established failure rate of .0024%/1000 hours when dissipating 0.8w maximum in free air at an ambient temperature of 25°C. The transistor is used with a heat sink on an aluminum chassis in the REX-3 application and the power dissipated is 1.0725 watts. The manufacturer's rating on this item is 3 watts maximum at a case temperature of 25°C. From the graphs in the RADC Reliability Notebook, a ratio of 3.1 was computed for the increase in failure rate when 1.0725 watts is dissipated instead of 0.8 watts at the appropriate temperature with the transistor in a heat sink. This factor of 3.1 was applied to the Fairchild established failure rate and yielded a failure rate of 0.00744%/1000 hours for this transistor as it is applied in the circuit. Reliability of the transistor is computed by using equation (1).

TIMER

The timer of the Separation and Attitude Control Subsystem is manufactured by Minneapolis - Honeywell. This timer is purchased in accordance with drawings that specify that the timer should have a "predicted reliability of 0.94 for one cycle based upon a parts count analysis". A cycle is defined as the period from timer start to last timed output pulse, in this case approximately 20 seconds. The parts count analysis of the timer as completed by Minneapolis - Honeywell is quoted as follows:

Parts Count Reliability Analysis of the EXG2357B2X2 Timer

Part Name	Stress Ratio	N	λ	N x λ %	Data Source
Transistor, Silicon	1/4	38	0.05	1.900	RADC
Silicon Controlled Recitfier	1/2	4	0.08	0.320	RADC
Diode, Zener, Silicon	---	5	0.021	0.105	RADC
Diode, Blocking, Silicon	---	108	0.021	2.268	RADC
Resistors, Tin-Oxide	1/4	110	0.0083	0.913	Minuteman Via Corning Glass
Capacitors, MICA	1/2	17	0.015	0.255	RADC
Capacitors, Tantalum	1/2	1	0.27	0.270	RADC
Toroid	---	1	0.06	0.060	RADC
Sensitor	1/4	1	0.04	0.040	RADC
	Σ N λ			6.131%	

N = Number of Uses

λ = Percent failure per 1,000 hours

Assume 20 second operating time. (.00556 hours)

$$P = e^{-t(\Sigma N\lambda)}$$

$$p \cong 1 - t(\Sigma N\lambda)$$

$$P \cong 1 - \frac{.00556 \times .06\ 131}{1000}$$

$$P \cong 1 - .00000034$$

$$p \cong .99999966$$

Based on the above calculations, we feel confident that the timer meets the required reliability cf 0.9999. (end of quote)

BATTERY

The battery for the Separation and Attitude Control Subsystem is silver-zinc rechargeable battery manufactured by the Eagle Picher Company. This battery is purchased in accordance with drawings which specify the reliability as "0.94 based on established data". The data upon which this reliability is based has been requested from the Eagle Picher Company. To date, this data has not been received and follow-up with the manufacturer is continuing. The reliability for the battery used in the subsystem computation is the specified reliability of 0.94.

ROCKETS

The rockets used in the Separation and Attitude Control Subsystem are manufactured by Atlantic Research Corporation. These rockets are almost identical to those used on REX-1. There have been four more qualification tests with satisfactory results, but these are not significant enough to change the previous computed reliability. The reliability was computed in Appendix H of PA-TR-1, "Product Assurance Technical Report for the Radar Cross-Section Reduction of Re-entry Vehicles" dated 31 October 1962. These previous computations showed the reliability of the squib to be $0.9_{3}71$ and the reliability of the rocket to be 0.9952. These values of reliability were used in this report.

EXPLOSIVE NUTS

The explosive nuts used in the Separation and Attitude Control Subsystem are manufactured by the Hi-Shear Corporation. These explosive nuts are the same as those used on REX-1. There have been no additional qualification tests which significantly change their previous computed reliabilities. The previous reliability was computed in Appendix G of PA-TR-1 dated 31 October 1962. This reliability was computed to be $0.9_{5}3$ and was used in the computations for this report.

APPENDIX B

RELIABILITY EVALUATION SHEET

FOR

SEPARATION AND ATTITUDE CONTROL SUBSYSTEM

Date 3-6-63 Shet. 1 of 1
Reliability Engineer Kiehler & Zichichi

RELIABILITY EVALUATION SHEET

SYSTEM CCS-IFT
EQUIPMENT Separation and Attitude Control Subsystem
UNIT ____________
UNIT P/N ____________
MODULE ____________
MODULE P/N ____________
REF. SCHEMATIC RX2501

COMPONENT	PART NUMBER	REFERENCE DESIGNATION	SPECIFICATION	MANUFACTURER	MANUFACTURERS PART NUMBER	COMPONENT VALUE	RATED STRESS	RATED TEMP. (°C)	APPLIED STRESS	STRESS RATIO	OPER. TEMP. (°C)	RELIABILITY	NO.	SOURCE
Resistors	RX1219	R1004-R1007 R1016-R1023	MIL-R-18546	Dale Products	RH10-5 ± 1%	5 ± 1% Ω	10W	75	N.A.	N.A.	37	$0.9_{3}6$	12	TESTS
Resistor	70B3920F	R1014	MIL-R-10509	Not Known		392 ± 1% Ω	0.5W	70	245mw	0.49	37	$0.9_{7}638$	1	RADC
Resistors	RX1218	R2012-R2023	MIL-R-18546	Dale Products	RH10-3 ± 1%	3 ± 1% Ω	10W	75	N.A.	N.A.	37	$0.9_{3}6$	12	TESTS
Diode	RX1216	CR1004	RX1217(CCMD)	Pacific Semiconductor	PS510B	N.A.	400mw*	75*	120mw	0.4	37	$0.9_{8}891$	1	MFGR.
Diode	RX1216	CR1005	RX1217(CCMD)	Pacific Semiconductor	PS510B	N.A.	400mw*	75*	231mw	0.578	37	$0.9_{8}897$	1	MFGR.
Diodes	RX1984	CR1014, CR1015	Minuteman	Transitron	SV1120B	12V ± 5%	375mw*	115*	290mw	0.773	37	$0.9_{6}69$	2	MINUTE-MAN
Diodes	RX1216	CR2010, CR2016	RX1217(CCMD)	Pacific Semiconductor	PS510B	N.A.	400mw*	75*	50mw	0.13	37	$0.9_{8}897$	2	MFGR.
Diodes	RX1216	CR2011, CR2012	RX1217(CCMD)	Pacific Semiconductor	PS510B	N.A.	400mw*	75*	150mw	0.375	37	$0.9_{10}683$	2	MFGR.
Transistor	2N1613	Q1001	MIL-S-19500/181	Fairchild	2N1613	N.A.	3W	25	1.0725 w	0.358	37	$0.9_{8}291$	1	MFGR.
Relays	RX1965	K1001-K1004	MIL-R-57570	Branson	SRB-2C-24A	N.A.	N.A.	125	N.A.	One Cycle	37	$0.9_{4}77$	4	SPEC.
Relays	RX1967	K1006,K1007, K1011	MIL-R-57570	Babcock	BR7X-30005-26	N.A.	N.A.	125	N.A.	One Cycle	37	$0.9_{6}72$	3	MFGR.
Relays	RX1221	K1007,K1008, K2003	ABMA-PD-R-187	Potter & Brumfield	SL6-11-DA	N.A.	N.A.	125	N.A.	One Cycle	37	$0.9_{6}323$	3	MFGR.
Relays	RX1965	K1009, K2004-K2006	MIL-R-57570	Branson	SRB-2C-24A	N.A.	N.A.	125	N.A.	One Cycle	37	$0.9_{4}77$	4	SPEC.
Relay	RX1966	K1010	MIL-R-57570	Branson	SRB-4C-24A	N.A.	N.A.	125	N.A.	One Cycle	37	$0.9_{4}77$	1	SPEC.
Relays	RX1967	K2001,K2002	MIL-R-57570	Babcock	BR7X-30005-26	N.A.	N.A.	125	N.A.	One Cycle	37	$0.9_{6}72$	2	MFGR.
Battery	RX2200		RX2200(CCMD)	Eagle Pitcher	MAP-4101-5	N.A.	N.A.	60	N.A.	N.A.	37	$0.9_{4}0$	1	SPEC.
Timer	RX2211	T1001	RX2211(CCMD)	Minneapolis-Honeywell	EXG-2357-B2X2	N.A.	N.A.	160	N.A.	N.A.	37	$0.9_{4}0$	1	SPEC.
Explosive Nuts		Z2210- Z2215	CMPD	Hi-Shear		N.A.	N.A.	75	N.A.	N.A.	37	$0.9_{5}3$	6	MFGR.
Pitch Rocket	RX2071	Z1210	CMPD 2071	Atlantic Research		N.A.	N.A.	55	N.A.	N.A.	37	0.995	1	MFGR.
De-Pitch Rocket	RX2071	Z1211	CMPD 2071	Atlantic Research		N.A.	N.A.	55	N.A.	N.A.	37	0.995	1	MFGR.
Spin Rockets	RX2072	Z1212-Z1215	CMPD 2072	Atlantic Research		N.A.	N.A.	55	N.A.	N.A.	37	0.995	4	MFGR.
Connector	RX1213	J P 1003		Wiggins	WS136-1	N.A.	N.A.	55	N.A.	N.A.	37	$0.9_{7}865$	1	RADC
Connectors	(All Others Combined)			Viking, Bendix, Pyle National								$0.9_{6}843$	-	RADC

*Minuteman Recommended Maximums

APPENDIX C

MONITOR RELIABILITY ANALYSIS AND PREDICTION

I. OBJECTIVE

The objective of this appendix is to provide a reliability analysis of the on board Monitor of the CCS-1FT re-entry vehicle in order to determine its capability in performing the required check-out prior to lift-off.

II. CONCLUSION

It is concluded from the results of this analysis and evaluation that the following numerical reliability prediction for the Monitor can be stated:

Monitor $R_M = 0.9_4895$

III. DISCUSSION

The predicted reliability for the Monitor is based on the following general assumptions:

A. That AGE reliability is 100% reliable and will cause no secondary failure to the Monitor.

B. That the battery and components used in the Separation and Attitude Control Subsystem are 100% reliable.

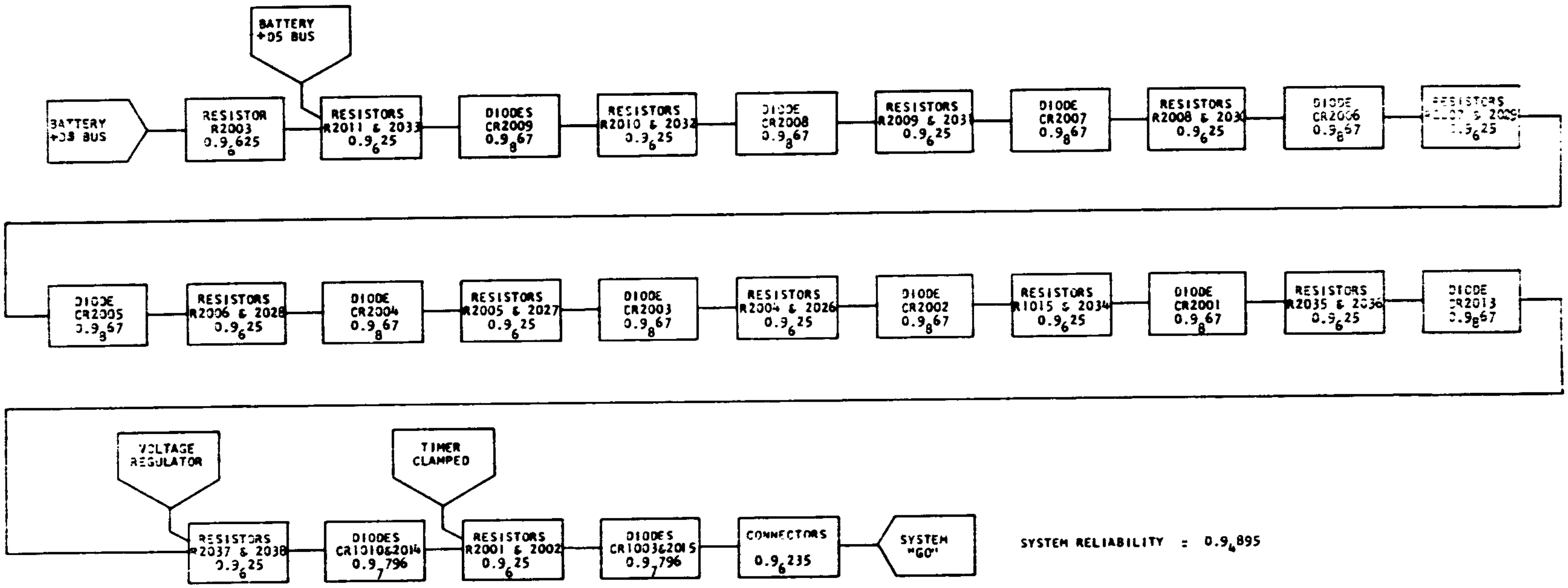
C. That the Monitor operating period is 1.5 hours.

The plan that was followed to establish the stated numerical reliability prediction is identical to the format used for the Separation and Attitude Control Subsystem.

IV. RELIABILITY ANALYSIS AND PREDICTION

The interaction of the Monitor with the control subsystem is shown in the Reliability Functional Diagram, Figure 1. The separation between the Monitor and the control subsystem is based on the philosophy that any component essential for control system success is not included in the Monitor reliability prediction.

The Reliability Block Diagram for the Monitor is shown in Figure 1C, and the Reliability Evaluation Sheet is contained at the end of this appendix.



SYSTEM RELIABILITY = $0.9_{4}895$

MONITOR SYSTEM
RELIABILITY BLOCK DIAGRAM

FIGURE 1C

Date 3-6-63 Sht. 1 of 1
Reliability Engineer Kiehler & Zichichi

RELIABILITY EVALUATION SHEET

SYSTEM CCS-IFT EQUIPMENT Monitor UNIT ____ MODULE ____ REF. SCHEMATIC RX2501

UNIT P/N ____ MODULE P/N ____

COMPONENT	PART NUMBER	REFERENCE DESIGNATION	SPECIFICATION	MANUFACTURER	MANUFACTURERS PART NUMBER	COMPONENT VALUE	RATED STRESS	RATED TEMP. (OC)	APPLIED STRESS	STRESS RATIO	OPER. TEMP. (OC)	RELIABILITY	NO.	SOURCE
Resistor	RN70B6041F	R2001,R2037	MIL-R-10509D	Not Known		6.04K 1%	0.5W	70	57mw	0.114	37	$.9_6625$	2	RADC
Resistor	RN70B5621F	R2002,R2038	MIL-R-10509D	Not Known		5.62K 1%	0.5W	70	52mw	0.1	37	$.9_6625$	2	RADC
Resistor	RN70B3322F	R2003	MIL-R-10509D	Not Known		33.2K 1%	0.5W	70	35mw	<0.1	37	$.9_6625$	1	RADC
Resistor	RN70B825F	R2004-R2011, R2035	MIL-R-10509D	Not Known		8.25K 1%	0.5W	70	55mw	0.11	37	$.9_6625$	9	RADC
Resistor	RN70B562F	R2026-R2034, R2036	MIL-R-10509D	Not Known		5.62K 1%	0.5W	70	37mw	<0.1	37	$.9_6625$	11	RADC
Diode	RX1964	CR2001-2009 CR2013-2015		Pacific Semiconductor	PS760B	N.A.	125mw*	75*	< 12.5mw	<0.1	37	$.9_8670$	12	Mfgr
Diode	RX1216	CR1003, CR1010	RX1217(CCMD)	Pacific Semiconductor	PS510B	N.A.	400mw*	75*	1.38mw	<0.1	37	$.9_7829$	2	Mfgr.
Resistor	RN70B8161F	R1015	MIL-R-10509D	Not Known		8.16K 1%	0.5W	70	<.05mw	<0.1	37	$.9_6625$	1	RADC
Connectors	(All Combined)			Bendix, Pyle National								$.9_6235$	1	RADC

*Minuteman Recommended Maximums

APPENDIX D

EXAMPLES

OF

COMPONENT APPLICATION SHEETS

Component Application Data Sheet

RELAYS - MAGNETIC

PART DESCRIPTION: General Purpose ☐ Sensitive ☐ Power ☐
Other, Describe Latching

STRUCTURE: Crystal Can ☒ Conventional Armature ☐
Plunger ☐ Telephone ☐ Reed ☐
Wet Mercury ☐ Other, Describe ____

ENCLOSURE: Open Type ☐ Enclosed ☐
Hermetically Sealed ☒ Other, Describe ____

REF. DESIGNATION: K1007
DEVICE OR EQUIPMENT: RX2050

PART NUMBER: RX1221
MIL SPEC: ABMA-PD-187

SOURCE OF SUPPLY: Potter and Brumfield (SLG-11-DA)

CIRCUIT OPERATING REQUIREMENT	DESIGN DATA			MANUF. DATA	GENERAL NOTES
	Circuit Requirement				
	Nominal	Max	Min		
Coil Oper. Voltage or current	½ wave 25V peak	½ wave 30V peak	½ wave 20V peak	20VDC	32VDC (maximum cont'd)
Coil Sensitivity	---	---	1A	230mw	
Nature of Load Resist,~~Induct~~,~~Incand~~.	0.296A	0.357A	0.257A	---	2PDT 800ohm + 10% coil @ 25°C
Voltage or Current	28V	32.8V	25.2V	See Contact Rating	
Duty Cycle (Time on and off)	Cont'd	Cont'd	Cont'd	Cont'd	
Required Total No. of Operations	1	2	1	---	
Contact Rating	---	---	---	1A@115V 60 cyc AC 2A@ 30V DC	} Resistive
Operating Ambient Temperature	---	37°C	---	-65° to +125° C	
Shock	N/A	---	---	100G's 11 msec.	
Vibration	---	1G 10-2000CPS	---	30G's to 2000 CPS	
Acceleration	---	85G's	---	400G's	
Failure Rate % / 1000 Hrs.	---	---	---	---	

Most Critical Mode of Failure:
Open, Short, Variation

NOTES & SKETCHES:

Device Packaging: Herm. Seal, Potted,
Spray Coat,
Open, Other ____

Requested by____ Mail Sta. ____ Ext.____
Acct. No.____ Date ____

Part Selection:
Acceptable, Marginal, Unacceptable
Comments:

App.Eng.____ Date ____

Reliability Engr. Notes:
Failure Rate___%/1000 Hrs.Source P&B
Comments: Reliability = $0.9_{6}323$
Based on a single ended
Binomial Distribution @
90% Confidence.
Reliability Eng. Kiehler Date 3/6/63

Component Application Data Sheet
DIODES

PART DESCRIPTION: Silicon ☒ Germanium ☐

MOUNTING TYPE: Lead ☒ Stud ☐ Tunnel ☐

Conventional ☒ Zener ☐ Other, Describe ___

PART APPLICATION: Switching ☐ Blocking ☒ Computer ☐

Arc Suppression ☐ Rectifying ☐ Other, Describe ___

CIRCUIT REF. DESIGNATION: CR1004

NAME OF DEVICE OR EQUIPMENT: RX2050

PART NUMBER: RX1216

SOURCE OF SUPPLY: Pacific Semiconductor, PS510B

MILITARY SPEC.: RX1217 (CCMD)

CIRCUIT OPERATING REQUIREMENT	DESIGN DATA Circuit Requirement			MANUF. DATA	GENERAL NOTES
	Nominal	Max	Min		
Oper. Junct. Temperature (°C)	48	52	43	-40 to +75	
Forward Voltage at Nominal Current	0.95V	0.99V	0.92V	1.25VDC @ I_F =	400 ma
Leakage Current at Nom.Reverse Voltage	0.018 A	---	---	0.2μA DC @V_R=225V	
Leakage Current at Max.Reverse Voltage & Max.Junct. Temperature	---	0.8μA	---	15.0μA DC @V_R= 225V@100°C	
Shunt Capacitance	---	---	---	---	
Power Dissipation	89mw	120mw	70mw	400mw	
Reverse Voltage	28.0V	32.8V	25.2V	180V	
Vibration		2G's 5 to 2000CPS 20G's 40 to 2000CPS			
Shock	---	---	---	1500G's 0.5msec.	
Acceleration	---	85G's	---	20000G's for 1min	
Failure Rate	---	---	---	0.00114%/1000 Hrs. 90% Conf. 200ma @ 100°C	

Most Critical Mode of Failure:
[✓ Open,] Short, Variation

NOTES & SKETCHES:

Device Packaging: Herm. Seal, Potted,
Spray Coat,
Open, Other________

Requested by ________ Mail Sta.____ Ext.____
Acct. No.________ Date____

Part Selection:
Acceptable, Marginal,
Unacceptable
Comments:

App.Eng.________ Date____

Reliability Engr. Notes:
Failure Rate .00114 %/1000 Hours
Source PSI
Comments:

Reliability Eng. Kiehler Date 3/6/63

Component Application Data Sheet
RESISTORS

PART DESCRIPTION: Composition ☐ Carbon Film ☒ Other, Describe

PART APPLICATION: Current Limiter ☐ Voltage Divider ☐ Volt. Drop ☐
Temp. Comp. ☐ Ballast ☒ Other, Describe
Regulator Ballast

CIRCUIT REF. DESIGNATION: R1014 DEVICE: RX2050

MILITARY SPEC.: MIL-R-10509D PART NUMBER: RN70B3920F

SOURCE OF SUPPLY: Radio Specialties

CIRCUIT OPERATING REQUIREMENT	DESIGN DATA			MANUF. DATA	GENERAL NOTES
	Circuit Requirement				
	Nominal	Max	Min		
Operating Temperature (°C)	---	37	---	70	
OHMS	392	395.92	388.08	392 nom.	
Current DC X AC__ CPS__	12.30ma	25.12ma	4.17ma	35.7ma maximum	
Insul. Stress (Volts) DC X AC__ CPS__	28	32.8	25.2	900	
Insulation Resistance (MEGS)	---	---	1	> 10,000	
Moisture Resistance	---	---	---	±3% wet ±1.5% dry	
Shock	---	---	---	50G's 11msec.	
Vibration	---	2G's 5-2000CPS	---	15G's 10-2000CPS	
Resistance Tolerance	---	---	---	±1%	
Temperature Coefficient	N/A	N/A	N/A	±0.05%/°C	
Power Rating	58mw	245mw	7mw	½w	
Power Ratio	0.116	0.49	0.014	---	
Maximum Change % Resistance	N/A	28%	N/A	---	
Failure Rate %/1000 Hours	---	---	---	---	

Most Critical Mode of Failure:
[✓ Open] [✓ Short] [✓ Drift]

NOTES & SKETCHES:

Part Selection:
Acceptable, Marginal, Unacceptable
Comments:

App. Eng.__________ Date____

Reliability Engr. Notes:
Failure Rate .036%/1000 Hours
Source RADC
Comments:

Device Packaging: Herm. Seal, Potted,
Spray Coat,
Open, Other ________

Requested by______ Mail Sta. ____ Ext.____
Acct. No.__________ Date ______

Reliability Eng. Zichichi [illegible] 3/6/

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