FACILITY FORM 602

N65-19927 (ACCESSION NUMBER)

(THRU)

19 (PAGES)

1 (CODE)

CR-57515 (NASA CR OR TMX OR AD NUMBER)

14 (CATEGORY)

[redacted]

GPO PRICE $ _____

OTS PRICE(S) $ _____

Hard copy (HC) $1.00

Microfiche (MF) $0.50

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

CONTRACT 950615

FINAL ENGINEERING REPORT

THE COSMIC RAY TELESCOPE FOR THE MARINER-MARS MISSION

TO

JET PROPULSION LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

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1. INTRODUCTION

The development of a cosmic ray experiment was undertaken at The University of Chicago on the basis of a letter contract originated by Jet Propulsion Laboratory on 5 June 1963. The letter contract was definitized on 25 August 1963.

This program involved the design and fabrication of an engineering prototype, a proof test model, a temperature control model and four flight units in addition to three sets of bench checkout instruments.

This report is a final engineering report covering the activities leading up to the successful launch of Mariner IV on 28 November 1964.

2. SUMMARY OF EFFORTS AND MAJOR EVENTS

The detailed design of the cosmic ray experiment was undertaken officially on 3 June 1963 based upon information obtained during a meeting held at JPL during 24 and 25 April 1963. At that time, only vague information was available for both mechanical and electrical interfaces. As a result of this meeting, a representative list of components to be considered for use in the program was submitted to JPL via the cognizant contracting officer on 3 May together with normal University of Chicago screening specifications. As of this writing, only two components in the entire list have been specified as formally acceptable to JPL. These are the Allen Bradley resistors and JPL-furnished 350D Sprague capacitors. Our requested potting procedures were approved formally on 19 August 1963 after first having been formally denied. No formal approval has yet been received for use of the power converter, or bench checkout equipment, though both were requested during June and July 1963.

Largely, as a result of delays in receipt of approvals and final details required for electrical and mechanical interfaces, the actual equipment delivery was achieved as follows:

1. Interface test system delivered 4 September 1963, never tested at JPL.
2. EP/TA and GSE delivered 8 October 1963
3. MC-1 delivered 24 November 1963

4. GSE No. 2 delivered 6 December 1963
5. TA unit delivered 18 February 1964
6. MC-2 delivered 30 March 1964
7. MC-3 delivered 3 May 1964
8. MC-4 delivered 5 June 1964
9. MC-5 delivered 28 July 1964.

Due to scheduling pressures for the delivery of the EP/TA unit, the instrument was assembled in final form without allowing adequate time for the potting to cure. As a result, removal of the instrument covers at JPL for inspection disclosed a large number of areas in which the foam padding had adhered to the potting. In addition, there were objections to soldering techniques and lead terminations used in the instrument. As a result, the instrument was not accepted by JPL for type approval tests.

In anticipation of a delay in delivery of the EP/TA unit, a breadboard system of the instrument interface was taken to JPL during early September to verify systems compatibility. Due to problems in the completion of OSE equipment, this system operation was never verified.

On 8 October, the EP/TA unit was delivered to JPL. At that time, and after the inspection mentioned above, the unit was subjected to a detailed bench checkout. The first full interface checks were not performed until 1 November due to delays in completion of OSE.

Because of QA rejection of the EP/TA unit, it was not subjected to type approval tests nor flight qualification level tests.

The unit was used, however, in exercises to determine compatibility with a representative spacecraft interface.

A design review was held at The University of Chicago on 21 and 22 August, at which time there was a strong criticism of the thermal stability characteristics of the design being used. This criticism was based upon a paper study conducted at JPL. Subsequent laboratory tests of the system indicated that thermal drifts were acceptably low for flight purposes.

A complete set of mechanical and electrical drawings has been submitted to JPL on at least two separate occasions. In addition, a log book covering details for each individual instrument history has been supplied. The records which are available at The University of Chicago indicate that the MC-4 [spacecraft] presents a significantly more noisy environment than was the case with either MC-2 or MC-3 due to shorter than standard rise time in the S/C power supply lines (6μsec). At the time of the Mariner IV launch, this problem had not been rectified.

A problem was encountered in the fabrication of the MC-5 instrument in which a number of localized areas within the instrument electronics exhibited discoloration after several days. This problem had been encountered over a year earlier in another instrument system. Detailed investigation of the problem through microchemical analysis revealed that the problem was caused by addition of an excess of hardener in the potting process and that the resultant discoloration was due to bleedout of the unreacted amine compounds in the hardener. Analysis was performed by Walter McCrone Associates of Chicago and a detailed report was forwarded to the JPL cognizant engineer. As a result of the problem, the MC-5 unit was not allowed to undergo the required flight qualification

tests at JPL, but was held in reserve for trouble shooting purposes. As of this writing, there has not been any evidence of degradation of the instrument performance.

The following tables of information illustrate the history of each unit except MC-5, for which the information must be supplied at a later date.

Mariner C - Unit 21A1 - The University of Chicago, Cosmic Ray Telescope

Type Approval Unit (TA)

1. General Information

a. Detectors and Sources

i. D_1 - No. 765 - 56.6v — Sm^{147} source no 3EL13
E 1/2 = 2.19mev — Channel 46
R_1 = 4.4

ii. D_2 - No. 764 - 55.6v
R_2 = 2.2 c/min

iii. D_3 - No. _____
R_3 = 2.18

b. Calibration and % Drift (before delivery to JPL)

1. Discriminator levels	25°C	+50°C	-10°C
D_1	.72mv	+7%	-4.1%
D_1'	.75mv	+2.7%	0%
D_2	.78mv	-1%	-3.4%
D_3	.916mv	-3.2%	-3%
D_3'	1.97mv	+6.1%	-2%
2. HTC Channel			
10	1.82mv	-5%	-5%
50	9.5mv	-1.5%	-2%
110	21.3mv	-2%	-3%

2. History

	a. Specific Problems and Failures	b. Solutions
3/3/64	1. Unit became excessively noisy after 2nd phase of shake	1. Apparently due to loss of ground in detector housing due to striped threads on groupin lugs. Unit repaired by putting on stripped thread and realigning cover of power converter 3/7/64. Unit returned to Chicago.
3/12/64	2. Lost all coincidence indications after vibration	2. Lead from D_2 amp had broken off due to improper tie points of lead near D_2 disc input. Unit repaired and new tie points chosen to prevent strain 3/17/64.
3/27/64	3. Unit failed temperature vacuum because of excessive noise (false coincidence)	3. Ground loop caused by thermocouple attached to detector housing and noisy chamber (horizontal) 4/18/64
6/5/64	4. Unit on S/C MC-3 as substituted became excessively noisy - gave overflow pulse every 27 milliseconds	4. Recurrence of problem No. 1 — loss of detector ground on housing coupled with shield of D_2 detector lead loose caused $D_1\overline{D}_2\overline{D}_3$ coin at 2 x 2400 cycles.
6/13/64	5. Unit failed at low temp and vacuum - Word B read out with no holes or one hole only 2^0 punched. Word D okay - 1.	5. Traced to weak signal on word B. 111kc line from GSE. Especially during early part of clock burst. As temperature decreased, buffer threshold increased causing more than 1024 pulses to be in GSE register. The critical level appears to be ~ 2.4vpp at room temperature. All other lines A, C, and D rad. > 3v. Using other GSE unit passed cold portion.
6/17/64	6. After replacement of buffer B and D module (position No. 6) problem recurred in T. Vacuum	
6/18/64	7. Application of freeze bottle to buffer B and D module lead to complete failure of both halves.	7. Short between base of output transistor Q_3 on D word and 7v line lead to Q_3 being on all the time thus shorting out the output to ground through Q_2. Repaired by removing impurity causing short.

6/23/64	8. Unit continues to be intermittently noisy both in chamber and out.	8. Twice to incomplete contact on back cover of module especially in region near rear of telescope and power converter. This, in turn was due to lack of clearance between back cover and telescope back cover. Problem cleared up when thinner back cover plate for telescope was installed 7/6/64.

3. General Remarks

1. Unit has thicker absorber in place. Replaced with correct thickness 7/10/64.
2. Drifts quite large.
3. No cyclotron run made.
4. HTC Gain ~ 15% greater than desired for flight.
5. Thresholds set to ~ 200 kev - Exact values on page 5.
6. Small silicon D_2 detector installed
7. Unit installed on MC-3 S/C became noisy

4. Present Status

6/20/64 Unit undergoing temperature vacuum test at JPL

7/16/64 Unit undergoing modified TA temperature vacuum at JPL. Seems to be working properly.

Mariner C - Unit 21A1 - The University of Chicago, Cosmic Ray Telescope

MC-1

1. General Information

a. Detectors and Sources

i. D_1 - No. 687 - 41.5v — Sm^{147} Source No. 3EL12
E 1/2 = 2.06 mev — Channel No. 56
R_1 = 10.4c/min.

ii. D_2 - No. 685 - 41.5v
R_2 = 4.7 c/min

iii. D_3 - No. 570 - 44.9v
R_3 = 14.6 c/min

b. Calibration and % Drift (before initial delivery to JPL)

1. Discriminator levels	25°C	-20°C
D_1	.86mv	-.5%
D_1'	.975mv	+2%
D_2	.83mv	+1%
D_3	.89mv	+4%
D_3'	1.89mv	+4%

2. HTC Channel

10	1.82mv	-3%
40	7.27mv	-1%
100	17.7mv	-1.5%

Mariner C - Unit 21A1 - University of Chicago, Cosmic Ray Telescope

MC-2

1. General Information:

a. Detectors and Sources:

i. D_1 - No. 732 - 55v — Am^{241} Source No. _____
R_1 = 7.74 c/min — Channel 108

ii. D_2 - No. 805 - 58.5v — Am^{241} Source No. 8CL-174C
R_2 = 5.1 c/min

iii. D_3 - No. 780 - 55.4v — Am^{241} Source No. 8CL175C
R_3 = 3.9 c/min

b. Calibration and % Drift (measured before delivery to JPL)

1. Discriminator levels	25°C	+50°C	-10°C
D_1	.80mv	+5%	-1%
D_1'	.85mv	+1.8%	+1%
D_2	.79mv	+5%	-1%
D_3	.88mv	+4%	+.05%
D_3'	2.00mv	+4%	+2%
2. HTC Channel			
10	2.07mv	+1%	-1.5%
50	10.2mv	0%	-1%
110	22.7mv	0%	-2%

2. History

a. Specific Problems and failure		b. Solutions
4/15/64	1. Temp. vacuum failure due to excessive number of false coincidences	1. Difficulty traced to noisy system and a ground loop caused by attachment of thermocouple to detector housing. Unit passed in vertical chamber after removal of thermocouple. 4/17/64
5/5/64	2. DAS did not reset calibrate toggle	2. Interface error concerning isolation of DAS and OSE. Calibrate reset lines (missing capacitor) caused excessive loading of reset pulse. Modification made to insure compliance with interface specs on all units. 5/18/64
6/5/64	3. DAS could not put instrument into calibrate	3. OSE Reset line found to be noisy at card in isolation box thus resetting toggle to normal state. 6/6/64
6/5/64	4. Calibrate set line more sensitive to noise than reset line.	
6/6/64	5. D_3 count rate on S/C measures 8.7 c/min - too high.	5. Rates measured on bench 6/23/64. D_1 - 2.2 c/min D_2 - 2 c/min D_3 - 4 c/min Noise must be due to level on S/C.
7/4/64	6. S/C system test, Single rates high on S/C	
7/4/64	7. NAMG causes anomalous low channel analysis - no rates	
7/14/64	8. T.V. test on S/C again shows anomaly above	

3. General Remarks

1. No major logic on detector failures yet reported (6/14/64).
2. Drift is negligible towards low temp.
3. Gain of D_1HTC combination is approximately 10% higher than originally desired.

4. Detailed cyclotron run performed on this unit 3/24/64.

5. Unit installed on S/C approximately 5/1/64.

4. Present Status of Unit

6/12/64 Unit on S/C undergoing systems tests--working properly since 5/1/64.

6/23/64 Unit removed from S/C and bench tested.

6/29/64 Unit reinstallation S/C.

7/3/64 S/C systems test

7/13/64 Unit on S/C begin temp. vacuum test.
Part one with sources and OSE connectors.

7/15/64 Vacuum broken to replace Canopus tracker.

7/16/64 Pump down again to continue test.

Mariner C - Unit 21A1 - The University of Chicago, Cosmic Ray Telescope MC-3

1. General Information

a. Detectors and Sources:

i. D_1 - No. 804-50v — Am^{241} Source No. 10 L-192L
E 1/2 = 4.16 mev — Chan 92
R_1 = 5.48 c/min

ii. D_2 - No. 802 - 50v — Am^{241} Source No. 8C2-183C
R_2 = 3.27 c/min

iii. D_3 - No. 757 - 50v — Am^{241} Source No. 862 - 181C
R_3 = 2.8 c/min

b. Calibration and drifts (before initial delivery to JPL)

1. Discriminator Level	+25°C	+40°C	-10°C
D_1	.875mv	+3.7%	-2.9%
D_1'	.855mv	+4.1%	-1.8%
D_2	.836mv	+2.3%	-1.4%
D_3	.868mv	+2%	-1.5%
D_3'	1.76mv	+2%	0%
2. HTC Channel			
10			
50	11.3mv	-4%	-1.5%
110	24.3mv	-2%	-2%

2. History

	a. Specific Problems and Failures	b. Solutions
5/1/64	1. Detector D_1 failure prior to initial delivery to JPL in temp. vacuum test.	1. D_3 detector was replaced and retested in temp. vacuum
5/8/64	2. Unit failed in thermal vacuum test at JPL. Words A and C did not print out. Unit recovered on bench and problem never reproduced.	
5/25/64	3. Word B readout printed identification only (no other holes punched) at higher temp. Recovered at low temp. and did not recur again going back to high temp. Unit passed but problem may still exist.	3. May be same problem as TA
6/2/64	4. Gold found to be flaking on detector housing. Waived mechanical QA requirements and installed on S/C.	

6/10/64	5. D_1 rate on S/C found to be 6.7 c/ min (too high)
6/28/64	6. D_2 rate on S=C much too high. D_1 original D_3 questionable
7/7/64	7. Disc lever measures for bench. D_2 much too low (160kev)

3. General Remarks

1. Drift acceptable toward low temperature.

2. 1 1/2 hours cyclotron run with telescope 0^o with respect to beam performed 4/25/64.

3. Unexplained failures represent major problems, but unit working properly at present 6/11/64.

4. Present Status

6/2/64 Unit installed on S/C

6/12/64 Unit in S/C undergoing systems tests and working properly.

6/20/64 Unit removed from S/C and bench calibrated.

7/7/64 Unit reinstalled on S/C.

Mariner C - Unit 21A1 - The University of Chicago, Cosmic Ray Telescope MC-4

1. General Information

a. Detectors and sources:

i. D_1 - No. 760	Am^{241} Source No. 10L-191L
E 1/2 = 3.833mev	Channel 85
ii. D_2	Am^{241} Source No. 8C2-196C
R_2 = 2.03¢/ min	
iii. D_3 No. 759	Am^{241} Source No. 8CL - 197C
R_3 3.00 c/ min	

b. Calibration and % Drifts (before delivery to JPL)

1. Discriminator Levels	+25°C	+50°C	-10°C
D_1	.838mv	+.3%	+1.5%
D_1'	.804mv	+5%	0%
D_2	.750mv	+5%	-1%
D_3	.843mv	+5%	0%
D_3'	.893mv	+4%	-1%
2. HTC Channel			
10	2.34mv	-2%	-2%
50	11.3mv	-4%	-4%
110	24.1mv	-2%	-3%

2. History

a. Specific problems and failures		b. Solutions
5/17/64	1. Word A and CB suffer failure after getting condensation on unit.	1. Problem blamed on moisture and dirt. Apparently, no serious permanent damage results. 5/20/64
5/5/63	2. Rates of all individual detectors increased by approximately a factor of two during last few hours of temp. vacuum test and several D_1D_3 coincidences recorded.	
6/6/64	3. Capacitor for weighing one side of calibrate toggle missing (R.J. at JPL)	3. Unit returned to Chicago and addition made.

3. General Remarks

1. Three hours of 0° w.r.t. beam cyclotron run data taken 5/28/64.

4. Present Status

6/12/64	Unit delivered to JPL and is awaiting FA testing
6/20/64	Unit undergoing FA temp. vacuum test.
7/4/64	Rates measured on bench
7/7/64	Unit delivered to SAF. awaiting installation on S/C.

3. DISCUSSION OF TECHNICAL PROBLEMS

Probably the most annoying problem encountered during the course of this program has been that of properly obtaining formal approval for various activities for which formal approval is contracturally required. These points are covered by Article I(a)(5) of the contract, which may be interpreted as covering all items used in the fabrication of instrumentation and bench checkout equipment. Many of the approvals which were requested in writing have not yet been answered except on a verbal basis.

The spacecraft interface definition led to a number of apparent failures due to a lack of clarity in the description presented. Once resolved, the failure was no more than a reversal of signal polarity in the calibrate command lines which was then rectified by an interchange of leads at the instrument connector. The problem was made more difficult by the fact that reliable OSE operation was not available until late in the program.

A series of problems were encountered in thermal vacuum testing of the instruments. These problems were resolved as having arisen from two prime sources:

1. Detector failure which resulted in part from the mounting system employed and, in other cases from the detectors becoming excessively noisy.

2. The problem of ground loops and excessive electrical noise related to the thermal vacuum system itself resulted in the issuance of failure reports for the TA unit, MC-1 and MC-2. These three units had been previously subjected to successful thermal vacuum tests at The University of Chicago.

The use of Chem-Electro capacitors in the U of C modular construction led to quite lengthy discussion due to apparent cracks in the capacitor body. Even though this visual problem was traced to the cracking of the identifying paint, these units were deemed to be unacceptable.

This problem was finally remedied by application of additional epoxy material to the body of the capacitor after painting. The possibility of substitution of other capacitors was ruled out due to a need for extensive redesign to accommodate the larger body sizes.

Denial of the use of TI thin film binaries in the instrument as originally planned required that the system be redesigned at a time when the system design and layout had been completed. This decision proved to be a wise one in that the units have since

proven unreliable for a number of reasons related to construction techniques. Their use has since been abandoned entirely and suitable substitutions made.

Respectfully submitted,

James E. Lamport

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(Technical Services)