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A PROGRAM OF HIGH ANGULAR RESOLUTION STUDIES OF CELESTIAL X-RAY SOURCES

by H. Gursky, R. Giacconi, P. Gorenstein, H. Manko, and J. R. Waters

Prepared by
AMERICAN SCIENCE AND ENGINEERING, INC.
Cambridge, Mass.

for

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FOREWORD

This document is the final report on NASA contract NASW-1505. This contract is part of a continuing program of X-ray astronomy by AS&E and calls for the design, fabrication and flight of an instrumented payload from an Aerobee rocket and preliminary analysis of the resulting data.

ACKNOWLEDGEMENTS

We wish to acknowledge the contributions of the following individuals at AS&E to this program. Mr. A. DeCaprio, the Project Mechanical Engineer; and Mr. S. Mickiewicz were responsible for the design, fabrication and testing of the payloads in their respective areas. Additional engineering support was obtained from Mr. W. Antrim, Director of the Mechanical Department, Mr. B. Johnson, Director of the Electronics Department, and Mr. G. Sinnamon, Director of the Systems Department.

We also wish to acknowledge many fruitful discussions with Dr. Martin Annis, Dr. Jack Carpenter, and Dr. Oscar Manley of AS&E and Professor Bruno Rossi of MIT.

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1. INTRODUCTION

The rocket experiment described in this report was conceived during late spring, 1966. The actual design and construction of the payload was carried out in the summer and the Aerobee rocket carrying the payload was successfully flown on 11 October 1966.

The status of X-ray astronomy has been markedly altered since the beginning of this year on the basis of two observational results. These results are:

1. The precise location of ScoX-1, the bright X-ray source in Scorpio, and the subsequent identification of its visual counterpart.

2. The report that X-ray sources appear to coincide with Cygnus A and M-87, the well known extragalactic radio sources.

These represent qualitative advances in X-ray astronomy. In the first case, the visual object coinciding with ScoX-1 has many of the characteristics associated with old novae. Its light output which is marked by substantial irregular variations, shows an emission line spectrum superimposed on a flat continuum that has no absorption features. One must now consider the possibility that the remaining, unidentified galactic X-ray sources are associated with similar objects and conversely that all such known visual objects are X-ray sources to some degree.

In the second place, the possibility that extragalactic objects are emitting measurable fluxes of X-rays is staggering. The power level reported from Cygnus A is about 10^{-9} ergs/cm^2-sec, which would require the emissivity in X-rays of that object to be the order of 10^{45} erg/sec which is as much as the total light output from the most luminous galaxies. Even from M-87, which is less remote than Cygnus A, the required emissivity would still be 10^{44} erg/sec. This X-radiation cannot be an extension of the synchrotron spectrum from the radio emission because of the rapid decrease in power with increasing frequency that is observed in these objects.

If the emission is by collission bremsstrahlung, a hot (5×10^{7} °K) plasma is required that permeates the galaxy and has a density of the order of 1 to 10 cm^{-3}. The mass of the plasma would be comparable to the total stellar mass present in the galaxy. If the plasma is restricted to a much smaller region (e.g., the galactic center with a radius of several hundred par sec) the required density increases to between 100 to 1000 cm^{-3} but the mass requirement drops significantly. In any event the implications for those particular galaxies that emit measurable fluxes of X-rays is that they represent a new class of objects in which the bulk of the mass is involved in X-ray production.

On the basis of the above considerations and considering the limitations of the Aerobee sounding rocket, we set the following objectives for the planned experiment:

1. Precise location of the X-ray sources in Cygnus.

2. Is the tentative identification of Cygnus A with an X-ray source correct?

Cygnus was chosen as the area to be observed for the following reasons:

1. Besides Cygnus A, the region contains several X-ray sources.

2. The region is favorably located for optical observation from the Northern hemisphere. It is thus one of the most intensively studied parts of the Milky Way.

3. Compared to the region of the sky at low galactic longitude that contains many X-ray sources, Cygnus should be relatively less obscured for visual observations.

2. EXPERIMENT PLAN

Given the objectives stated in the introduction, we planned the following experiment. By looking out the side of the rocket payload, we maximized the available detector area. The detectors were located behind slat collimators which limited the view angle to 1° x 19° full width at half maximum. A camera was used to record stars in order to determine the actual view angle of the collimators in the sky.

The rocket was to be equipped with an ACS which allowed pointing (or scanning) any axes with a precision of about $\pm$ 2°. The system was programmed to spend the bulk of the observational times scanning through Cygnus; a secondary objective was achieved by programming a scan along the galactic equator from about ℓ^{II} = -20° to ℓ^{II} = +70.

The Cygnus region could be scanned at a rate of about 0.2°/sec; thus 5 sec of observing time was available per resolution interval. Given the available detector area (700 cm^2) and the background counting rates (0.25 cts/cm^2-sec), the minimum detectable source (3σ above background) would be one that yielded in counting rate of about 0.03 cts/cm^2-sec which is about 10^{-3} ScoX-1. The strength of the sources in Cygnus were reported to be in the range between 0.4 to 1ct/cm^2-sec.

A source as intense as 1 ct/cm^2-sec would yield about 3000 cts, which is adequate to determine the energy distribution of the X-rays making use of the pulse height information of the counter pulses.

The combination of X-ray data and star photographs would be used to determine the celestial location of the observed X-ray sources. Since the precision requirement was relatively low (a few arc minutes), many of the techniques used in previous experiments (e.g., fiducial lights) were not necessary.

3. HARDWARE DESIGN

The NASA Aerobee Rocket 4.149 CG payload was a refurbished version of the payload flown on Aerobee 4.148 CG, thus keeping the new design effort to a minimum. New design efforts were put into a moveable door, on the side, which opened and closed during the flight. Two banks of proportional counters with greatly increased window area were used, thereby requiring new collimators. Design of the camera and the electronics circuitry, such as preamps, logic boards and high voltage power supplies only involved repackaging, since no circuit changes were made except for minor modifications on the logic boards. No changes of any consequence were made in the housekeeping unit. All instruments were designed to look out the door. A description of the instruments flown in this cone cylinder payload follows:

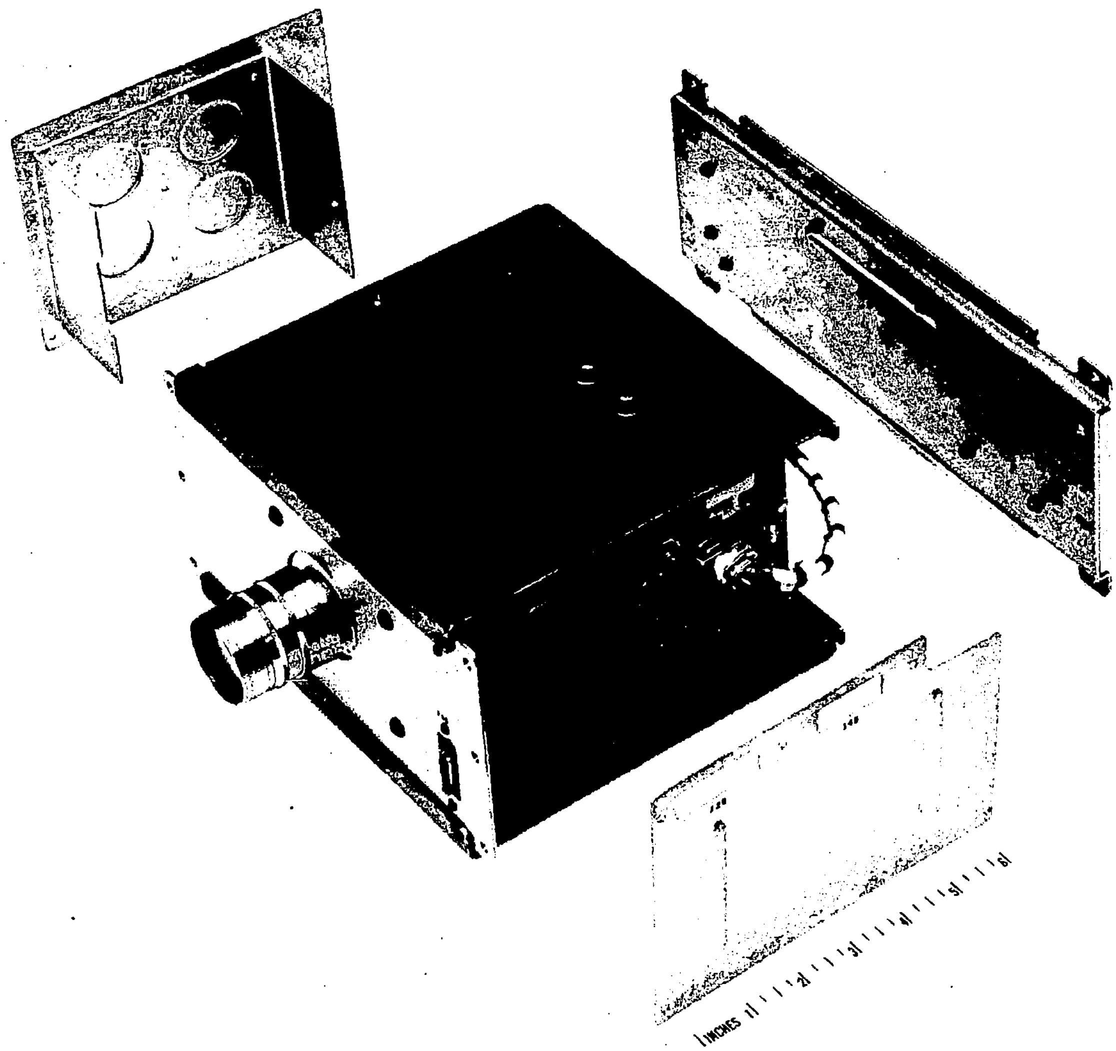
3.1 Aspect Camera

The camera which had been flown previously, and performed to expectations, was a 16 mm Milliken Model DBM-3C, with an Angeniux f/.95, 25 mm focal length lens. This lens was used to increase both the field of view and the exposure density. Figure 1 is a picture of the camera and associated hardware.

3.2 Proportional Counters

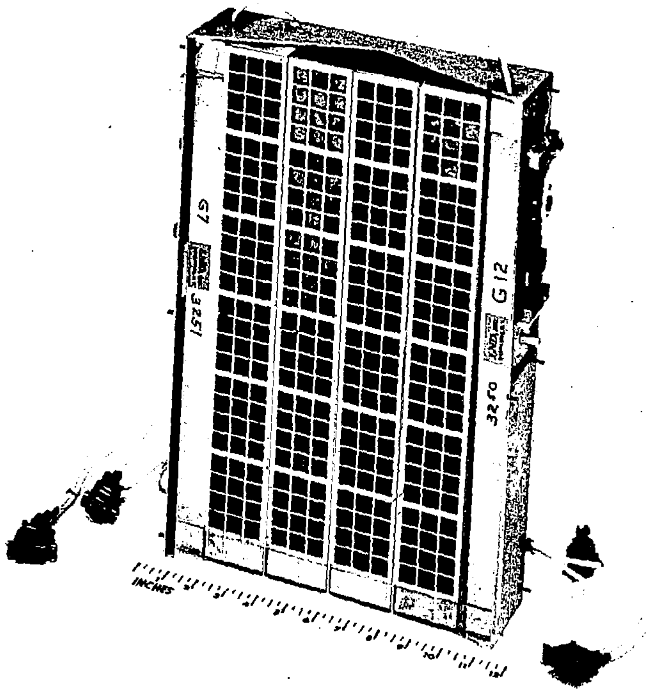
Two types of proportional counters were used on this flight. Of the twenty counters flown, eight had 2 mil Beryllium windows and 12 had no windows. The Beryllium window (active) counters were filled with P10 (90% Argon and 10% Methane) and had overall dimensions 16" x 2" x 2" with an effective window area of 14.81 x 1.75". The windowless (guard) counters were filled with Xenon and had overall dimensions of 16" x 2" x 1". The counters were set up in two banks with 4 active counters in front, enclosed by 6 guard counters on 3 sides in each bank. Figure 2 shows the layout of an active counter bank with a guard counter on each side. Figure 2 also shows the layout of the remaining guard counters which are mounted directly behind the active counters. Location of the preamp for each proportional counter can also be seen.

ASPECT CAMERA ASSEMBLY



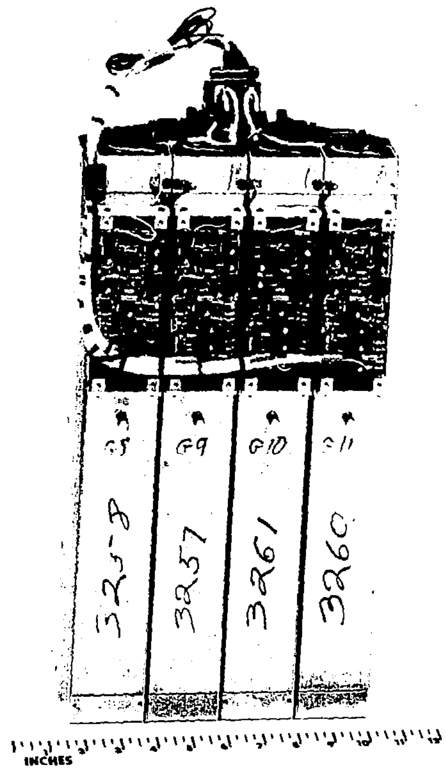
00-006

Figure 1



DO-017

FRONT COUNTER ASSEMBLY



DO-018

BACK COUNTER ASSEMBLY

PROPORTIONAL COUNTER ASSEMBLIES

Figure 2

Any cosmic ray event which was able to penetrate the active counters and reach the guard counters would produce a veto signal which would block out the corresponding signals generated in the active counters. A 3μs delay line was added to the logic circuitry to compensate for any delays which might occur in the development of the veto signal in the guard counters. Figure 3 is a block diagram of the proportional counter logic used. Digital information was supplied by each active counter and two active counters were combined for the pulse height information. Two scalers, one pulse height analog channel and two log count rate meter outputs were supplied by each of four separate logic circuits. Figure 4 is a block diagram of the preamp circuit used for each of the counters.

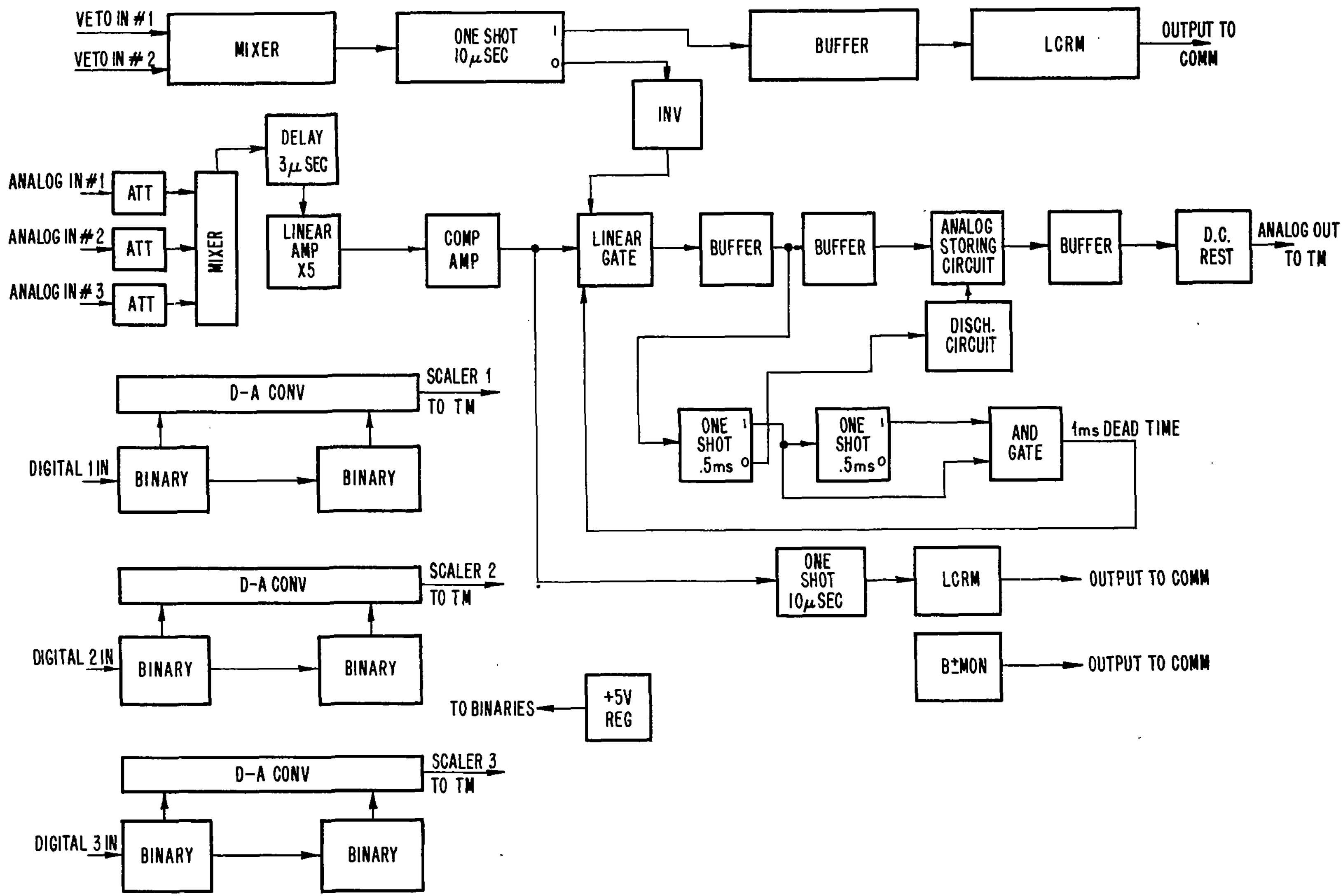
3.3 Collimators

Two slat-type collimators, one in front of each bank of counters, were used to limit the acceptance directions of the X-rays. The overall dimension of each collimator bank was 15" x 8-1/2" x 5-1/2". The slats were .002" thick latex rubber, 2-1/2" long. The latex rubber was circular and stretched across 2 rods, 4" apart. Spacing between slats was .086". Slats were mounted 2 deep with the field of view perpendicular to the thrust axis. There were a total of 312 slats per collimator. Figure 5 shows a partially and fully assembled collimator. Figure 6 shows the sides of the completely assembled payload and Figure 7 shows the location of some of the subassemblies.

3.4 Telemetry

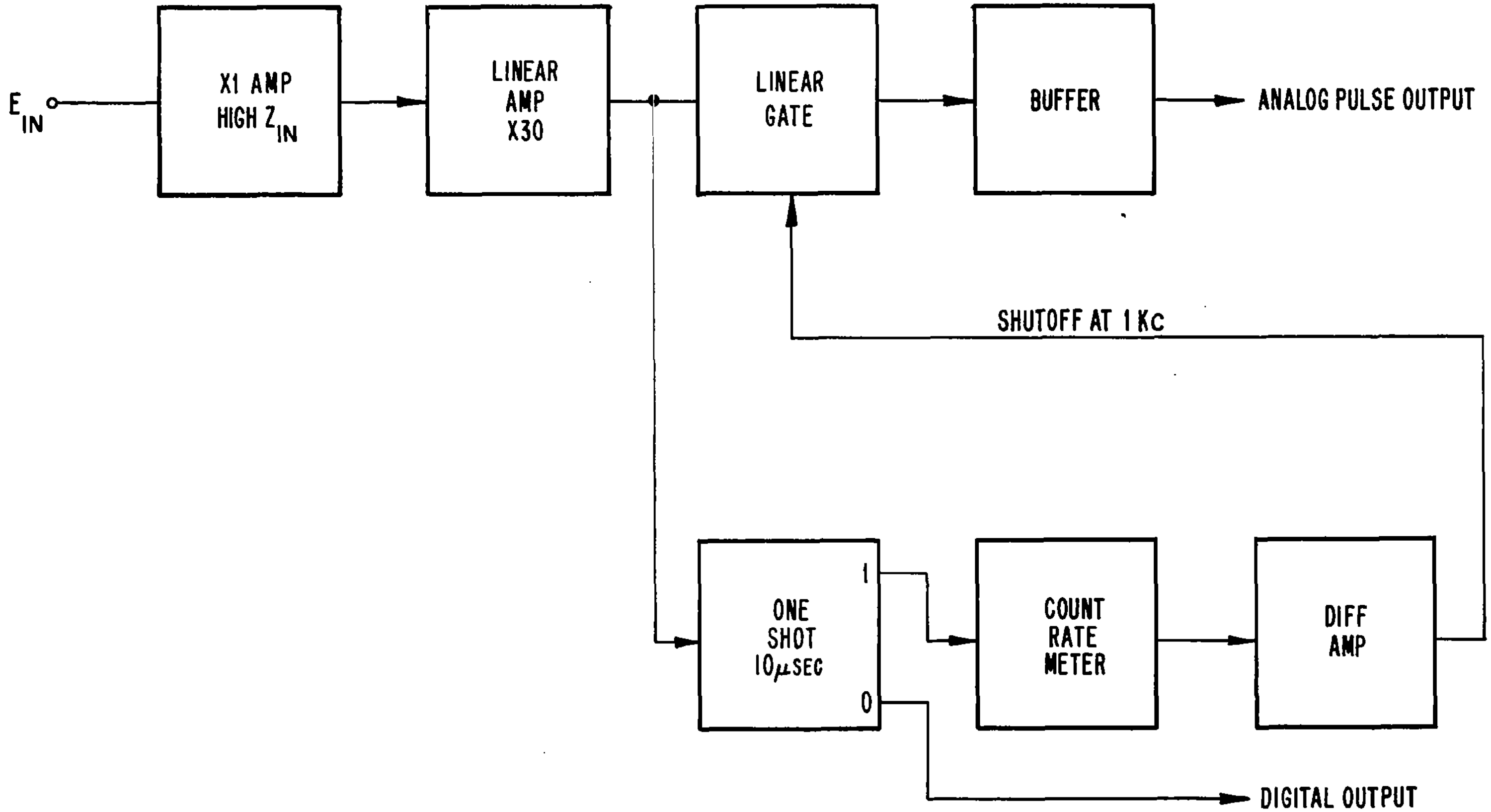
The telemetry system used on this payload was the same as used previously and supplied by NASA/GSFC. The TM system contained two transmitters (#1 on 234.0 mHz and #2 on 248.6 mHz) with 11 VCO's per transmitter on IRIG bands 18 through 8. Table I contains a list of information transmitted on the various channels. Channel 11 on both transmitters contained AS&E commutated data and Table II shows the data received on these two channels.

The layout of the TM information was such that the PHAb consisted of counters 2 and 4 on the top and PHAc consisted of counters 5 and 7 on the bottom bank on transmitter #1. Transmitter #2 had PHAa which was fed by counters 1 and 3 on the top and PHAd which was fed by counters 6 and 8



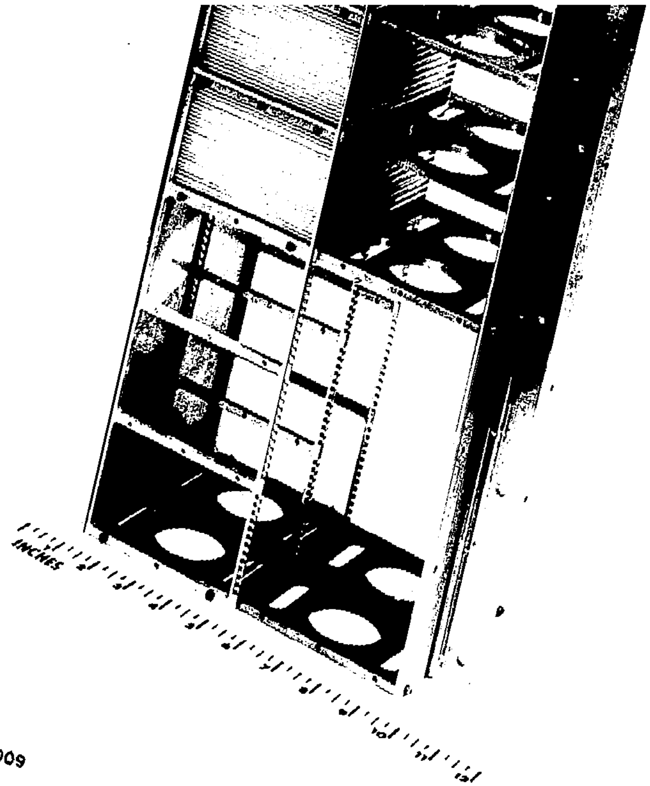
PROPORTIONAL COUNTER LOGIC

Figure 3

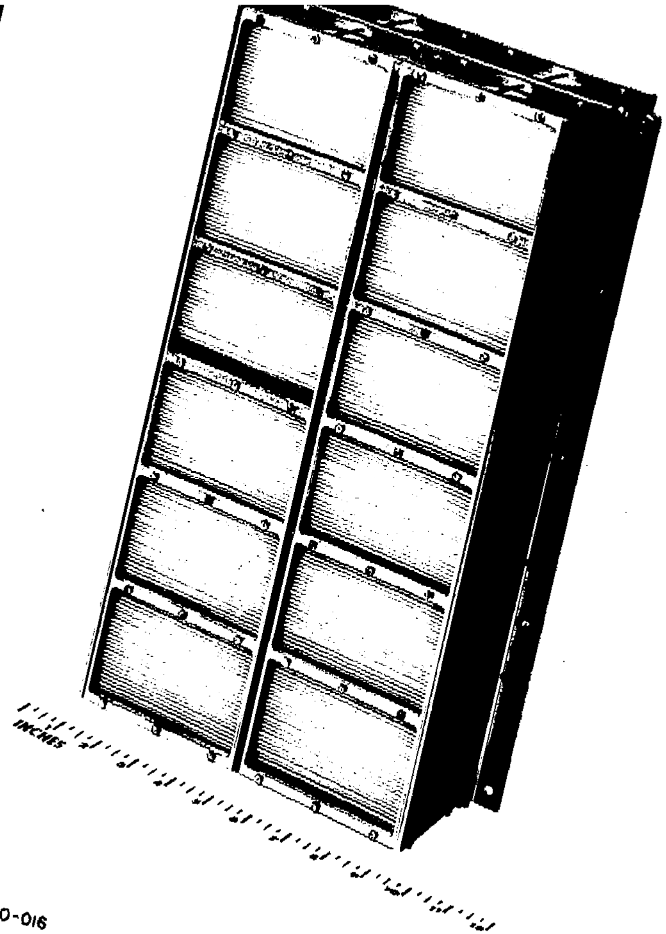


PROPORTIONAL COUNTER PREAMP

Figure 4



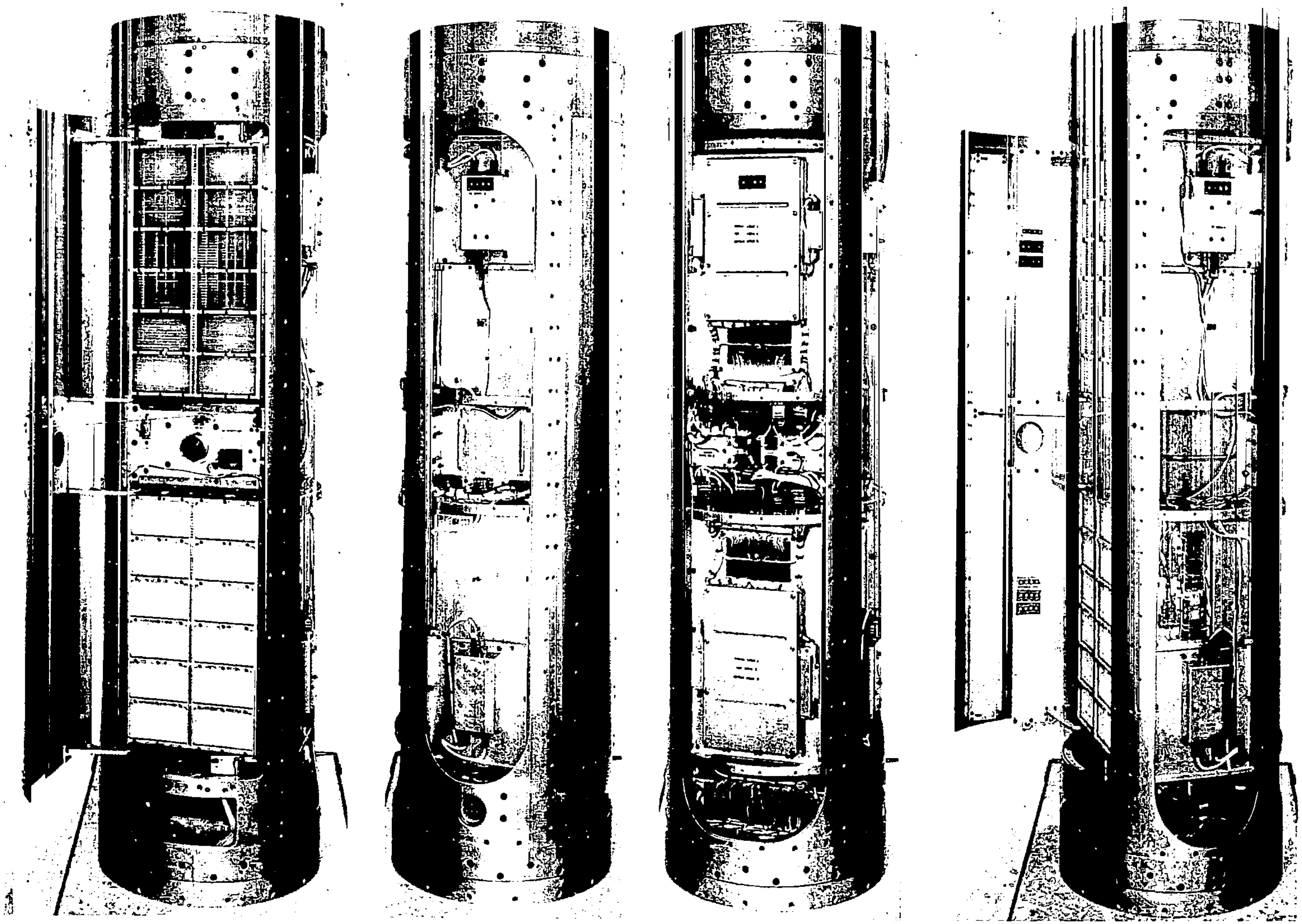
PARTIAL BANK ASSEMBLY



FULL BANK ASSEMBLY

SLAT TYPE COLLIMATOR

Figure 5



DO-024 SIDE 1

DO-026 SIDE 2

DO-027 SIDE 3

DO-025 SIDE 4

VIEWS OF ASSEMBLED PAYLOAD

Figure 6

ASSEMBLED PAYLOAD

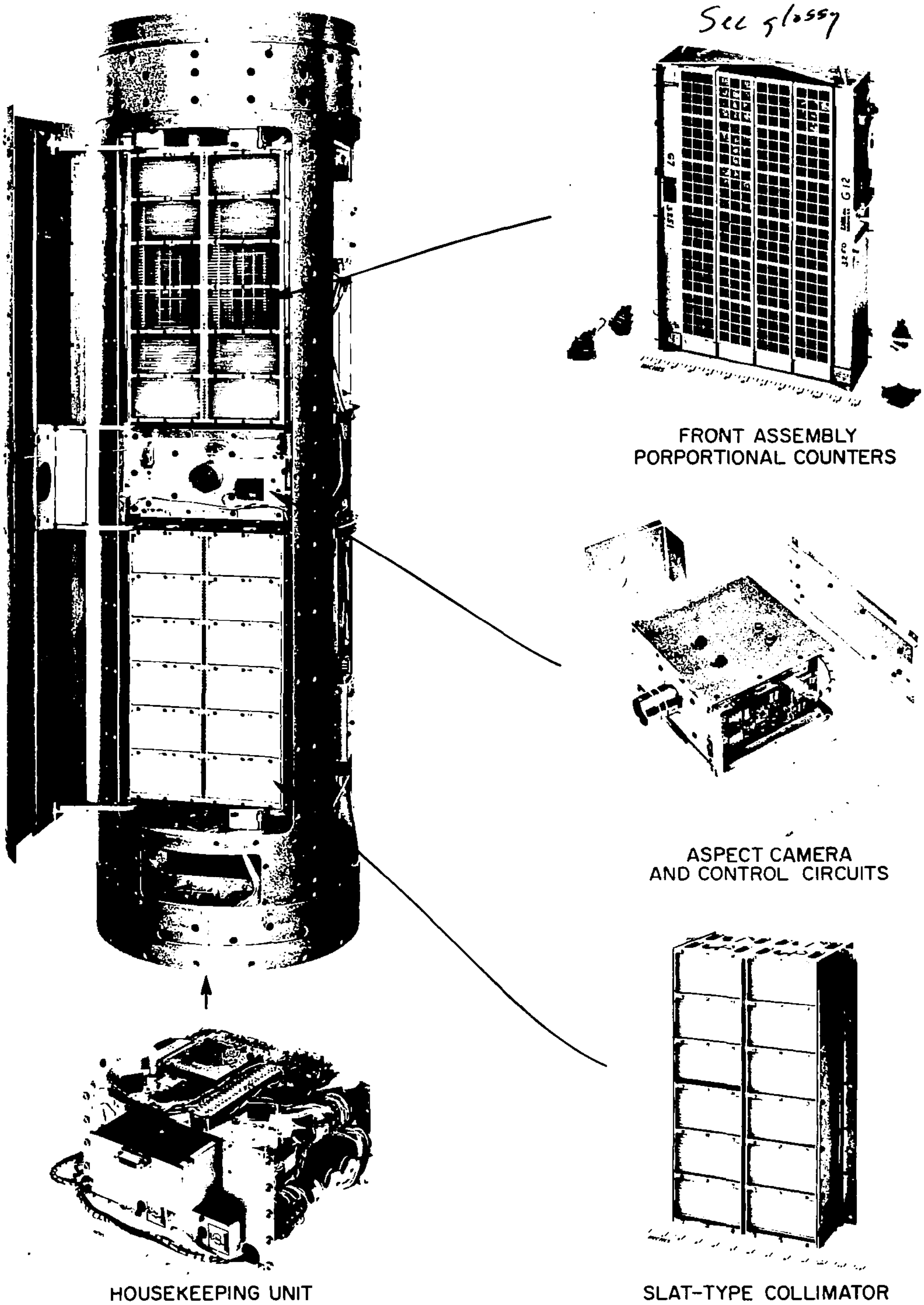


Figure 7

TABLE I

#1 Transmitter (234.0 mHz)

FREQUENCY	IRIG BAND	DATA	GAUSSIAN FILTER
70.0 kHz	18	PHA_b	1050
52.5 kHz	17	PHA_c	790
40.0 kHz	16	Scaler #3	600
30.0 kHz	15	Scaler #7	450
22.0 kHz	14	Scaler #5	330
14.5 kHz	13	Scaler #1	220
10.5 kHz	12	Roll & Despin	160
7.35 kHz	11	Commutator (ASE)	110
5.4 kHz	10	Accelerometer & Pitch Valves	81
3.9 kHz	9	Roll Position	59
3.0 kHz	8	FID Light	45

#2 Transmitter (248.6 mHz)

FREQUENCY	IRIG BAND	DATA	GAUSSIAN FILTER
70.0 kHz	18	PHA_d	1050
52.5 kHz	17	PHA_a	790
40.0 kHz	16	Scaler #4	600
30.0 kHz	15	Scaler #8	450
22.0 kHz	14	Scaler #6	330
14.5 kHz	13	Scaler #2	220
10.5 kHz	12	ACS Commutator	160
7.35 kHz	11	Commutator #2 (Exp)	110
5.4 kHz	10	Pc/Yaw Valves & Ledex	81
3.9 kHz	9	Clock	59
3.0 kHz	8	Yaw Position	45

TABLE II

COMMUTATED CHANNEL

Transmitter #1 (234.0 mHz)

Segment	Data
1 - 9	Synchronization Pulses
10	Spare
11	7.5 V Internal Power Monitor
12	Door Open Monitor
13	Spare
14	Spare
15	Spare
16	Spare
17	Spare
18	Spare
19	Spare
20	Spare
21	P.C. LCRM-A
22	P.C. LCRM-C
23	P.C. HV Monitor B
24	P.C. HV Monitor D
25	Guard No. 1 HV Monitor
26	Guard LCRM-A
27	Guard LCRM-C
28	P.C. Cutoff Mon. No. 1
29	P.C. Cutoff Mon. No. 3
30	P.C. Cutoff Mon. No. 5
31	P.C. Cutoff Mon. No. 7
32	Spare
33	Spare
34	B+ Mon. A
35	B+ Mon. C
36	+6.75 V Monitor No. 1
37	Door Batt. No. 1 Mon.
38	+9 V Monitor

TABLE II - cont'd

COMMUTATED CHANNEL

Transmitter #1 (234.0 mHz)

Segment	Data
39	Timer No. 1 Operate Mon.
40	28 V Monitor No. 1
41	28 V Camera Batt. Mon.
42	+6.75 V Reg. No. 1 Monitor
43	5.0 V Calibrate
44	2.5 V Calibrate
45	0 V Calibrate

COMMUTATED CHANNEL

Transmitter #2 (248.6 mHz)

1 - 9	Synchronization Pulses
10	Spare
11	7.5 V Internal Power Monitor
12	Door Closed Monitor
13	Spare
14	Spare
15	Spare
16	Spare
17	Spare
18	Spare
19	Spare
20	Spare
21	P.C. LCRM-B
22	P.C. LCRM-D
23	PC HV Monitor A
24	PC HV Monitor C
25	Guard No. 2 HV Monitor
26	Guard LCRM-B

TABLE II - cont'd

COMMUTATED CHANNEL

Transmitter #2 (248.6 mHz)

Segment	Data
27	Guard LCRM -D
28	PC Cutoff Monitor #2
29	PC Cutoff Monitor #4
30	PC Cutoff Monitor #6
31	PC Cutoff Monitor #8
32	Spare
33	Camera Monitor
34	B+ Monitor B
35	B+ Monitor D
36	6.75 V Monitor #2
37	Door Batt. #2 Monitor
38	Not Used (2V)
39	Timer #2 Operate Monitor
40	28 V Monitor #2
41	28 V Instr. Batt. Mon.
42	+6.75 V Reg. #2 Monitor
43	5.0 V Calibrate
44	2.5 V Calibrate
45	0 V Calibrate

located on the bottom bank of proportional counters. This was done for maximum redundancy in case of any failure in the experiment or the TM system.

3.5 ACS

The maneuvers scheduled by the ACS system are listed in Table III, along with the time-in position and the T+ time the maneuver occurred. Ledex position refers to positions on a stepping switch that control the ACS function.

The first nine maneuvers are involved in correcting for the actual launch attitude in order to line up the rocket axes at the desired starting point. At the beginning of position 10, the vehicle was programmed to be oriented with its pitch axis (nominally the look-axis of the detectors) at a position R.A. = $16^{hr}\ 45^{m}$, $\delta = -45.4^{\circ}$, which is on the galactic equator at a longitude of about -20°. The yaw axis was oriented to the galactic pole, thus maneuvers 1 and 2 (Ledex positions 10 & 11) carried the pitch axis along the galactic equator. Maneuver 3 began the slow scan of the Cygnus region. The remaining maneuvers were arranged so that each portion of Cygnus that was reported to contain an X-ray source, was traversed during three separate maneuvers.

TABLE III

4.149 ACS PROGRAM

The ACS maneuvers were as follows:

Ledex Position	Function				Time in Position (sec)	Elapse Time (T+)
						53
1	Start				11.1	64.1
2	Coast				12	76.1
3	Despin				12	88.1
4	Erect				2	90.1
5	Coast				3	93.1
6	Roll Remote Adj. - Subroutine Roll			11.6°CCW	3	96.1
7	Pitch Remote Adj.				3	99.1
8	Yaw Remote Adj.				2.6	101.7
9	Coast				25	126.7
10	Maneuver	#1	Yaw 47.3° CW	1.9°/sec	10.1	136.8
11	Maneuver	#2	Yaw 40.1° CW	4.0°/sec	25	161.8
12	Maneuver	#3	Yaw 12.3° CW	0.5°/sec	25	186.8
13	Maneuver	#4	Pitch 90.0° CCW	2.6°/sec	10.1	196.9
14	Part 2	#4			25	221.9
15	Maneuver	#5	Yaw 10.0° CW	0.2°/sec	25	246.9
16	Part 2	#5			10.1	257
17	Maneuver	#6	Roll 8.0° CCW	0.8°/sec	25	282
18	Maneuver	#7	Yaw 25.0° CCW	0.5°/sec	25	307
19	Part 2	#7			10.1	317.1
20	Maneuver	#8	Pitch 40.0° CCW	4.0°/sec	25	342.1
21	Maneuver	#9	Yaw 90.0° CW	1.5°/sec	25	367.1
22	Part 2	#9			8.75	375.85
23	Part 3	#9				
24	Off					

4. TESTING AND CALIBRATION

4.1 Testing

Work was initiated on the payload early in June, 1966. A pre-shoot conference was held at NASA/GSFC on 21 June 1966. Fabrication of all parts was complete by the end of August and the completely assembled payload was available by 10 September 1966. The following schedule was adhered to until the launch date:

13 September 1966	Completion of all System Testing
14 September 1966	Vibration Testing
16 September 1966	Vacuum Testing
21 September 1966	Start Integration at GSFC
26 September 1966	Start Instrument Alignment at AS&E
29 September 1966	Static Load Test
3 October 1966	Personnel and Equipment arrive at WSMR, N. M.
11 October 1966	Launch

Prior to 10 September 1966, there was extensive testing of all subassemblies. This included vacuum testing of all high voltage circuitry.

The proportional counters were checked electronically and vacuum cycled upon delivery, and before and after assembly. The response of the counters with respect to linearity, stability, noise and strength of multiplication was measured frequently during the testing phase.

System Tests

The system tests were conducted on the completely assembled payload. This was a complete functional test showing proper operation of (a) all instruments, (b) power and control system, (c) door operate mechanism, (d) TM data readout at the TM interface including commutated data, and (e) compatibility and operation of the GSE. Satisfactory completion of this test was a prerequisite for any further testing.

Vibration Test

The payload was subjected to a random noise vibration test at the following levels:

Payload Axis	Freq. Range	Level	Duration	PsD Level
Thrust	20-2000 cps	10g rms	60 sec.	$.05g^2/cps$
2-Lateral	20-2000 cps	6.2g rms	60 sec.	$.025g^2/cps$

The payload was operated in the same mode as during powered flight and performance was recorded on strip charts. A complete functional test was performed immediately after the vibration test.

The only electrical failure observed was in one of the two voltage regulator circuit boards and this circuit board was replaced. A thorough mechanical inspection of the payload showed no irregularities or failures.

Vacuum Test

The payload was subjected to a vacuum test to 2×10^{-4} mmHg. All instruments, including high voltage, were on during the entire run from atmosphere to vacuum to assure there would be no corona or arcing problems. After reaching a hard vacuum, a complete electrical system test was conducted including the door operate mechanism. The door did not open during this test. Inspection of the door showed that threads on one of the door retainer bolts had caught. A bolt with turned down threads at point of severance was designed and the door was tested a number of times with no further problems.

Integration Tests

Payload/TM/ACS integration tests were conducted at GSFC. Before mating of the payload, the TM can had 16 new holes drilled so that the payload and ACS system would be properly aligned. A complete simulated flight was conducted and data recorded by the GSFC telemetry ground station. All systems functioned properly.

Static Load Test

At the request of NASA/GSFC a static load test was performed at AS&E after return from the integration tests. The test was run with the load as shown in Figure 8. Total deflection was .118 in. Permanent set, if any, was less than .02 in. Figure 9 shows the static load test

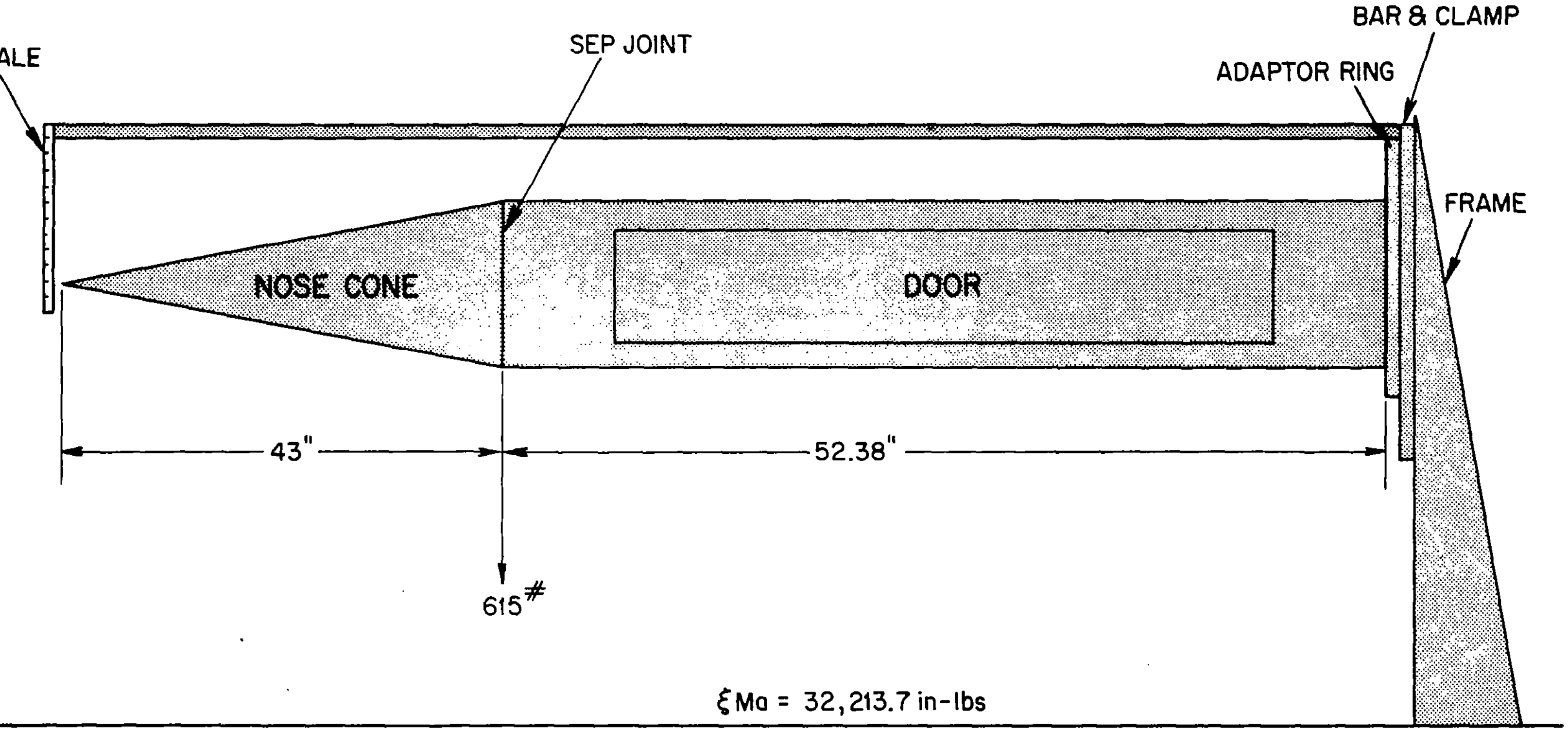


Figure 8

4.149 CG NASA AEROBEE LOAD TEST

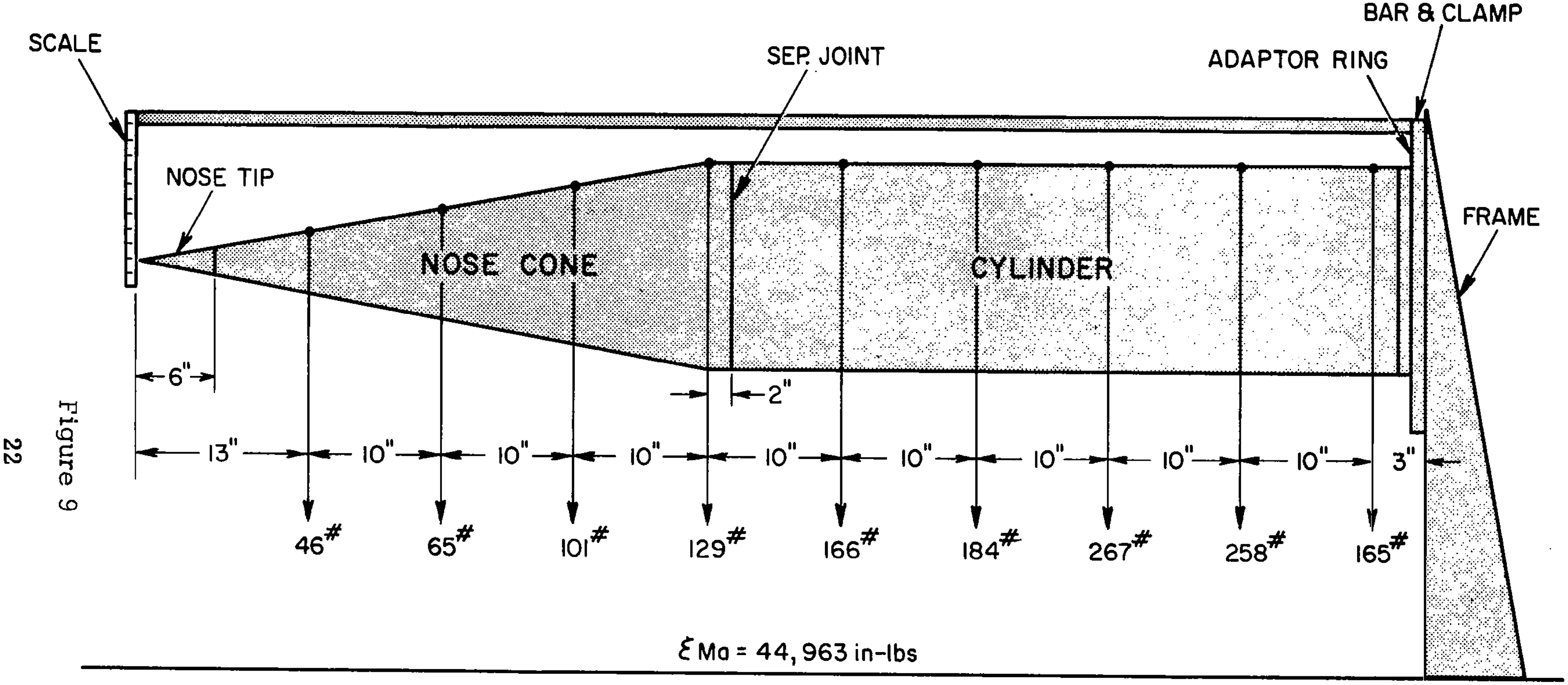


Figure 9

4.148 CG NASA ROCKET BENDING MOMENT TEST

performed on this same cylinder prior to flight of 4.148 CG. Deflection and permanent set were well within prescribed limits.

4.2 Calibration and Alignment

Calibration of the X-ray proportional counters was carried out by exposing each detector to a series of radioactive X-ray sources ranging in photon energy from 1.5 to 22 kev. In this manner the overall response of the counters and amplifiers were measured, the desired gain and bias were established and the energy resolution of the system was determined over that range of energy.

The X-ray collimator consisted of a series of slats measuring .087" by 5" x 4" (2 adjoining 2-1/2" x 2-1/2"). It was constructed of 2 mil latex rubber. The resultant field of view was $1^{\circ} \times 19^{\circ}$ (full width at half maximum). Transmission of a large area collimated beam of X-rays through the collimator as a function of the angle between the X-ray beam and the collimator is shown in Figure 10. An addition to the central maximum two side lobes are seen. These result from a slight gap between the two 2-1/2" slats of the 5" sides. While this effect was not desired, it represents less than 10% of the maximum flux transmitted and is not a major source of difficulty.

The rigidity of the payload was such that the alignment of the aspect camera and X-ray collimator would be maintained throughout the launch and duration of the flight. However, it was essential to measure the alignment of these two in the laboratory prior to flight. By knowing the alignment, the location of an X-ray source could be determined from the observance of a counting rate peak at a certain time and the aspect photographs. This was achieved by setting up an "X-ray" star in the laboratory. Several light beams and an X-ray beam were made parallel to each other by collimating each through the same two rigid plates. The entire payload was set upon a rotary table with both the aspect camera and X-ray detectors in operation, as shown in Figure 11. The payload is positioned such that the camera views one of the light beams. As the rotary table is turned, a maximum is observed in the counting rate. At exactly that point a photograph is taken. Inspection of the photograph reveals where on the photograph the X-ray star will appear. The camera registration was sufficiently precise, such that the sprocket holes of the

RESPONSE OF COLLIMATOR TO COLLIMATED X-RAY BEAM

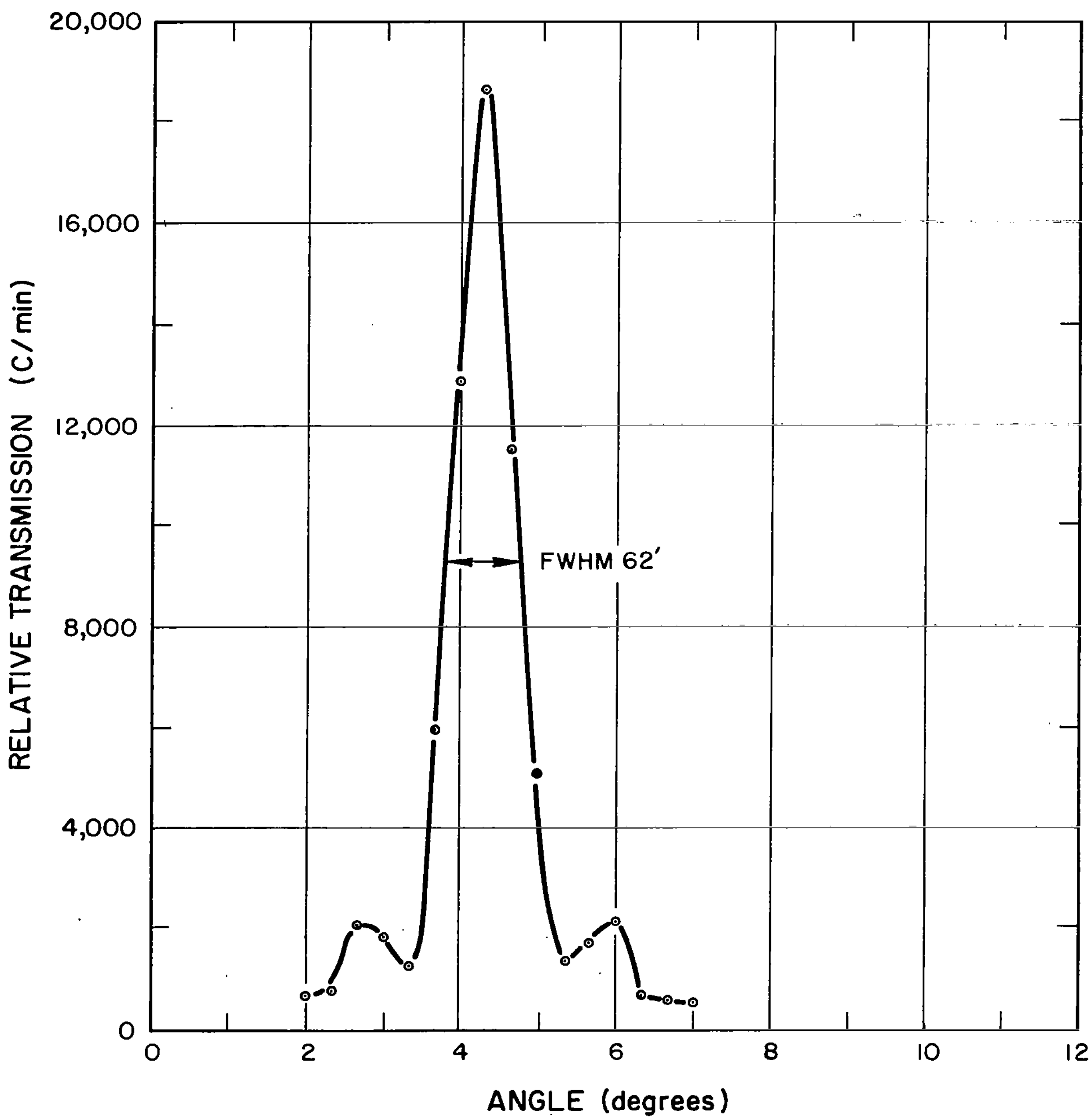


Figure 10

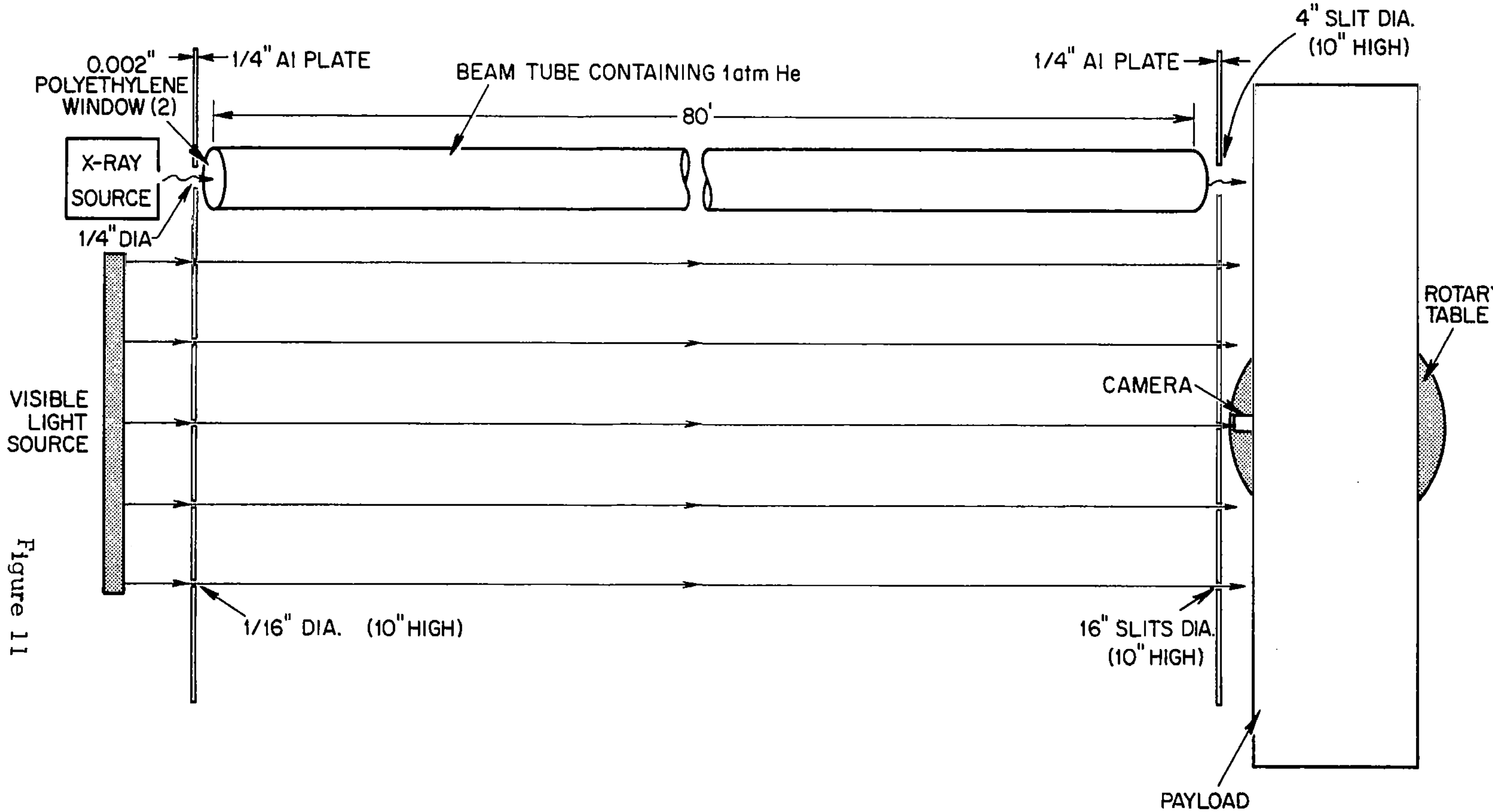


Figure 11

MEASUREMENT OF CAMERA-COLLIMATOR ALIGNMENT

film could be used as a reference. This technique enabled us to establish the alignment to within about 2 arc minutes.

Collimator plate #1 consisted of a series of holes (1/4" dia for X-ray, 1/16" dia for visible light), spaced 3" apart. Collimator plate #2 was a series of slits 10" high whose spacing matched that of plate #1. It contained a 4" opening for the X-rays and several 1/16" openings for the light.

The X-ray and light sources were removed 80' from the payload. Consequently, the X-ray beam was collimated to 17 arc min. by the 4" opening and the light beams were collimated to less than 1/2 arc min. Several passes were needed to sample the entire 32" of collimator length. As the low energy X-ray flux would be utterly attenuated by 80' of air, a beam tube containing 1 atmosphere of helium was used between the plates as the means of transmitting the X-rays.

5. FLIGHT 4.149

On 3 October 1966, the payload and personnel arrived at WSMR. A schedule of events to launch follows.

4 October 1966	Pre-flight Conference
7 October 1966	Horizontal Check
7 October 1966	Rocket Installed in Tower A
10 October 1966	Vertical Check
11 October 1966	Launch

The calibration of the instruments was checked daily, and additional star pictures were taken with the payload camera during the week to verify operation of the camera and film.

The payload was successfully launched at 18:52 MST on 11 October 1966. The flight did not reach the anticipated peak altitude of 101 miles. Available data indicate a maximum altitude of 90 miles was reached. Payload separation occurred at 326 seconds and information was obtained from all instruments to that time. All instruments functioned normally and the door opened as expected at 79 seconds. The door close command was given at 326 seconds, but since no information was transmitted beyond this time, no confirmation was available.

Recovery of the payload was delayed for four days because the payload could not be located. Radar lost the payload at about 10,000 feet over mountains near Salinas Peak. Due to strong air turbulance, search helicopters were limited to about two hours of flying time per day. The following conditions were observed when the payload was recovered:

1. The door had been ripped off.

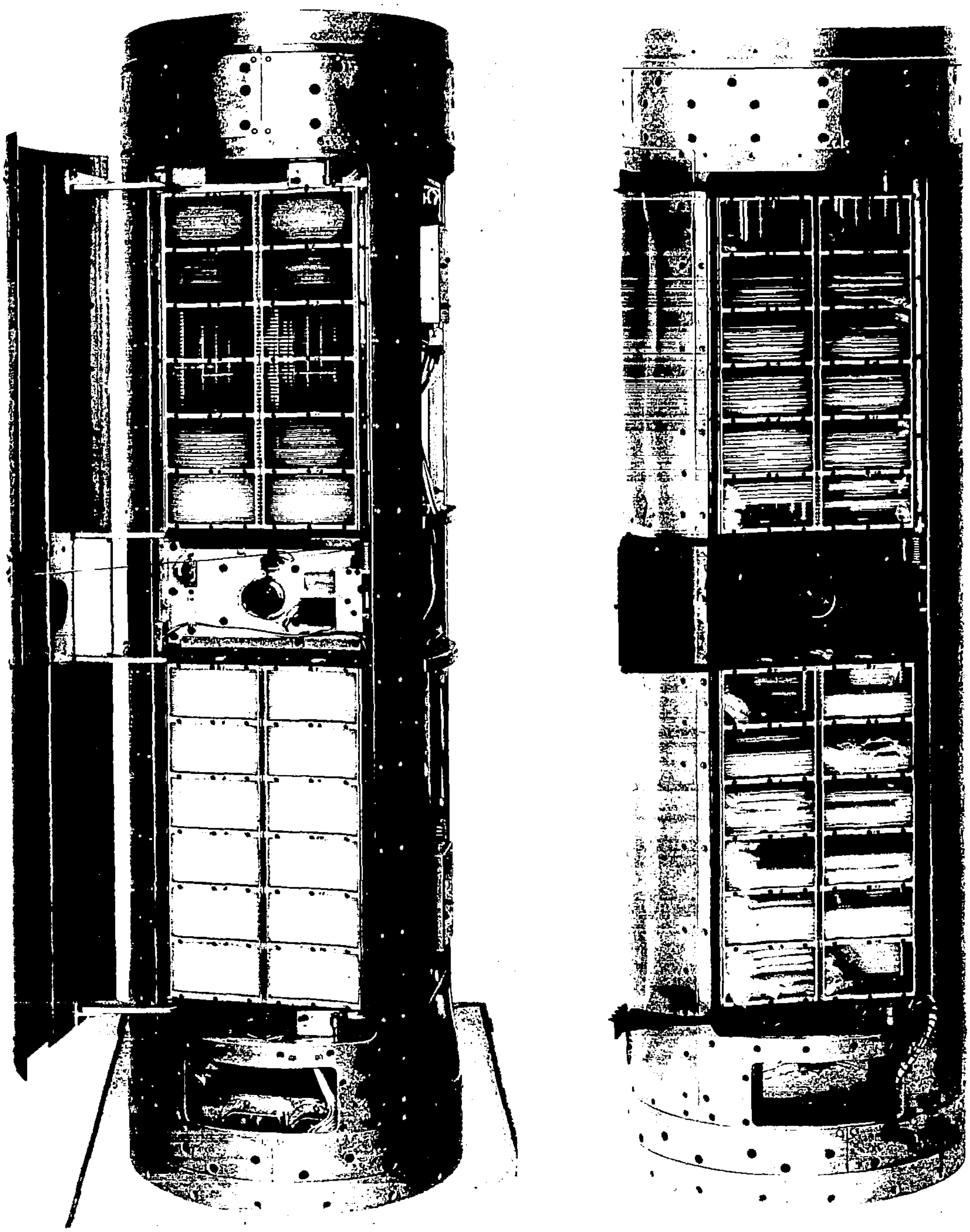
2. The 6" nose tip had been broken off.

3. A number of severe dents, in the nose cone, the top support ring, and on the panels.

Immediate conclusions were that the door might not have closed and was ripped off. However, after further investigations, examination of the flight film, and tests at AS&E, conclusions point to the fact that the door did close but was later ripped off, due to lifting at the upper and lower door corners and pulling the support cable off the reel. Figure 12 shows a picture of the recovered payload and the payload prior to leaving AS&E. The black areas on the camera and hinges on the recovered payload were painted prior to launch to eliminate light reflections.

There was no apparent structural damage to the payload. With the exception of one of the eight active counters, all the instrumentation was functioning normally after the recovered payload was returned to AS&E. The flight film was developed and indicated that the camera had functioned correctly during the flight. The developed film showed the expected density of stars.

AEROBEE PAYLOAD FOR X-RAY OBSERVATIONS FLOWN ON VEHICLE 4.149, Oct. 1966



DO-024 DO-057

BEFORE FLIGHT AFTER FLIGHT

Figure 12

6. PRELIMINARY DATA ANALYSIS

A preliminary analysis of the data from this flight indicated that the experimental objectives were successfully fulfilled. The telemetry records show that all the X-ray detectors functioned properly throughout the entire flight. The aspect photographs were recovered and indicate that the targets were attained by the attitude control system of the vehicle.

A portion of the telemetry data is shown in Figure 13. Several peaks above background are evident corresponding to celestial X-ray sources. Two aspect photographs of the target areas are shown in Figure 14. The first of these is of the stars of the galactic center region; the second of some of the stars in the constellation of Cygnus.

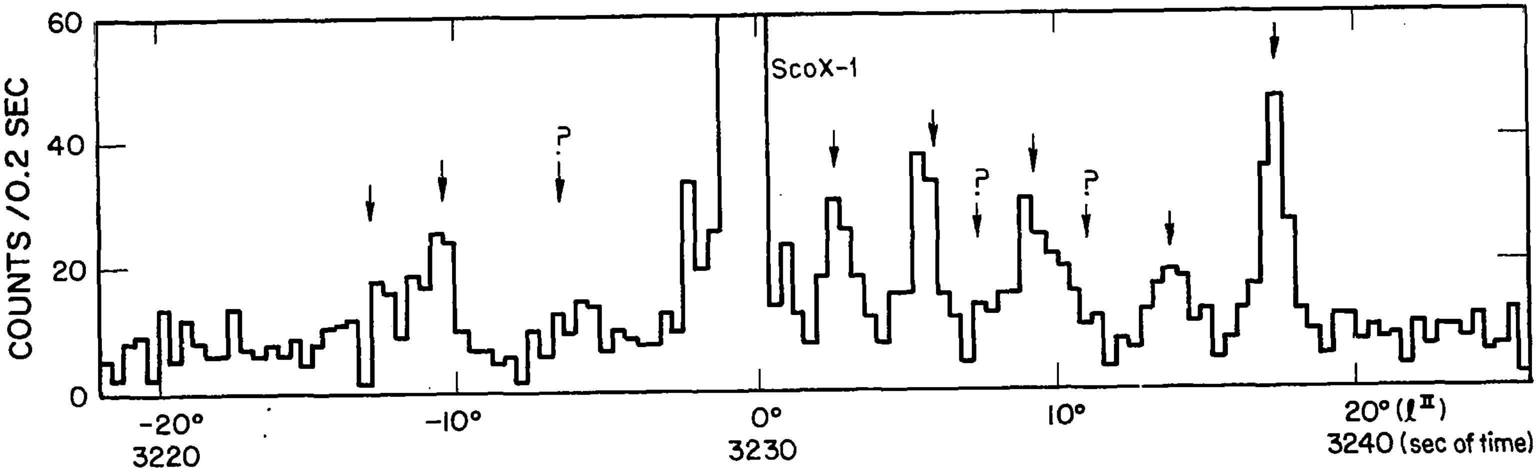
Ultimately we expect to obtain the following results from the analysis of the data:

1. The distribution of X-ray sources in
   - a. the galactic center region, and
   - b. the Cygnus region.

2. Location of the stronger sources to within several minutes of arc; of the weaker sources to within 10 minutes.

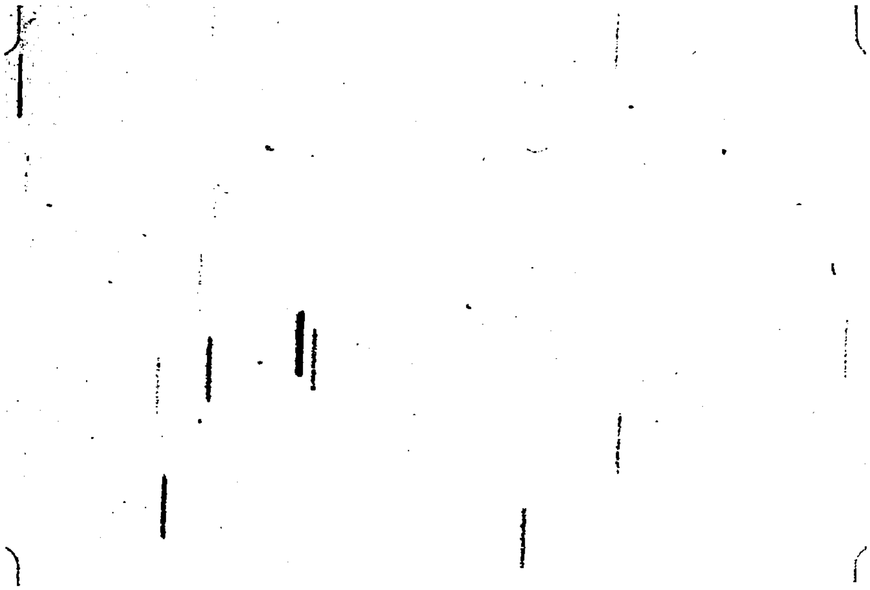
3. The energy spectra of the stronger sources.

Figure 13



DISTRIBUTION OF COUNTS ALONG GALACTIC EQUATOR

TYPICAL ASPECT PHOTOGRAPHS OBTAINED IN FLIGHT 4.149 (ONE SECOND EXPOSURE)



DO-060-26

GALACTIC CENTER REGION
ROCKET MOTION 2°/sec

DO-071-209

CYGNUS REGION
ROCKET MOTION 0.4°/sec

Figure 14

NASA-Langley, 1967 —— 14 CR-752