CARDE T.N. 1637/64

UNCLASSIFIED

PROJECT D46-02-10-01

DESCRIPTION OF THE INSTRUMENTATION OF CARDE BLACK BRANT ROCKETS CC II-29 AND 30

O. Bourque

CANADIAN ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

CENTRE CANADIEN DE RECHERCHES ET PERFECTIONNEMENT DES ARMES

DEFENCE RESEARCH BOARD

CONSEIL DES RECHERCHES POUR LA DEFENSE

Valcartier, Quebec

December, 1964

NOTE

CARDE Technical Notes are prepared for timely reporting of various types of information which may be tentative or in a form which does not justify a Technical Report.

CARDE TECHNICAL NOTE 1637
PROJECT: D46-02-10-01

UNCLASSIFIED

DESCRIPTION OF THE INSTRUMENTATION OF CARDE BLACK BRANT ROCKETS CC II-29 AND 30

by

O. Bourque

CANADIAN ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

Valcartier, Que.

December, 1964

ABSTRACT

This Technical Note records information regarding the instrumentation of Propulsion Test Vehicles CC II-29 and 30. These test vehicles were fired in January of 1964 at the U.S.A.F. Churchill Research Range in Manitoba.

The specifications of transducers, the telemetry system and power sources are listed and explained. Also included, is a list of pertinent drawings and self-explanatory photographs.

TABLE OF CONTENTS

1.0 INTRODUCTION

This Technical Note describes the instrumentation mounted in the Test Vehicles CC II-29 and 30 in the series of dynamic tests of the BLACK BRANT II rocket engines.

The two vehicles, in the main, carried identical instrumentation systems.

CC II-29 and 30 were fired at the Churchill Research Range on January 20th, 1964. The telemetry was very satisfactory in both tests and provided complete information from take-off to impact.

2.0 MEASUREMENTS

2.1 List of Measurements

From both Vehicles 29 and 30 the following information was obtained:

a) rocket engine pressure
b) trajectory and dispersion
c) acceleration along X, Y and Z axes.
d) nose cone temperatures on both the conical and the cylindrical sections.
e) vehicle attitude
f) angle of attack in pitch and yaw
g) temperature of chosen spots in the electronic assembly
h) comportment of the RF power of the telemetry system
j) DC monitoring of the bias current on the antenna blades
k) battery and voltage supplies.

2.2 NRC Micrometeorite Detectors

The National Research Council requested that two circuits be mounted in vehicle 30 for the purpose of detecting micrometeorites. It had been intended to mount a meteorite detector in Vehicle 29 but, on test, it was found that the noise level from the motors contained in the instrumentation system precluded the possibility of any information at the desired low levels of impact energy.

3.0 INSTRUMENTATION

The airborne instrumentation may be divided into two parts: the sensing devices or transducers, and the encoding and transmitting systems.

4.0 TRANSDUCERS

4.1 Engine Pressure Measurements

Two independent pressure sensors were mounted at the igniter end of the rocket motor to measure the pressure developed inside of the combustion chamber.

The first sensor is a Statham unbonded strain gage transducer coupled to a Statham amplifier.

Statham Pressure Transducer.

Model:	PA 707TC - 1.5 M - 350
Range:	0 - 1500 psia
Frequency response:	0 - 2000 cps
Pressure limits:	200% of rated range or 7500 psia whichever is less.
Resistive element:	350 ohms
Combined linearity and hysteresis:	Deviation less than ± 0.25% of F.S. output.
Temperature limits:	-100°F to +275°F

A Statham amplifier, Model CA9-0, is used with the above sensor:

Model:	CA9-0
Output:	0 to +5v DC
Power:	28v DC ± 5% at 35 ma
Freq. Resp.	Flat ± 5% from 0 to 2000 cps
Oper. Temp.	-40°F to +165°F

This combination had been used, in the past, on Vehicles CC II-17 and 18. It had been noted, on reduction of the flight data, that a part of the pressure curve during boost, for both vehicles, was missing or garbled. The CA9-0 amplifier had been mounted on the cylindrical section of the skin, whereas the sensor was mounted on the motor head. This separation had necessitated a long lead between sensor and amplifier. This long lead dangled inside of the vehicle when the nose cone was coupled to the motor.

The position of the amplifier was to be the same in CC II-29 and 30, but during preliminary instrumentation tests, it was seen that the pressure transducer and amplifier would not function when placed in a strong RF field. The RF energy picked up by the lead swamped the small signal (in the order of 5 millivolts) between the transducers and the amplifier, even though the lead was shielded.

As a result of this observation, both transducer and amplifier were mounted on the engine head and the interconnecting lead made as short as convenient and tied down so as to permit a minimum of flexing during flight. With the new disposition of sensor and amplifier, the pressure curves obtained on both CC II-29 and 30 were excellent from a telemetry point of view.

The second sensor was a Bourns potentiometer type transducer having a much lower frequency response and used mainly as a back-up.

Bourns Pressure Transducer

Model:	304
Frequency:	140 cps
Temp. Limits:	-65°F to 212°F.
Input:	+5v DC

4.2 Accelerometers

Acceleration is measured along the X, Y and Z axes of the vehicle. The bracket holding the sensors is at about Station 100, as near as possible to the CG of the vehicles. The accelerometers are Statham's Model A5. These accelerometers are also used with CA9-0 amplifiers as described above.

Ranges: X axis:	± 25g limited to give -5 to +25
Y and Z axes:	± 5g
Nominal Bridge Resistance:	350 ohms
Type:	Resistive, balanced, complete, unbonded strain gage bridge.
Damping:	Viscous fluid, 0.7 of critical at room temperature.
Ambient temperature:	-40°F to +200°F
Overload:	three times rated range.
Nonlinearity and hysteresis:	less than 1% F.S.
Response:	for ± 5g, 190 cps. for ± 25g, 375 cps.

4.3 Aspect Sensors

4.3.1. Gyroscopes

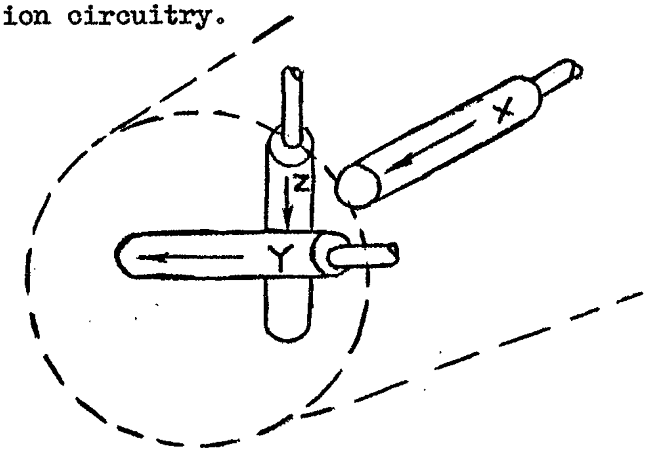
Two Iron Fireman Model NF 4111E gyros were used. These are cageable two-axis free gyros. The gyros are mechanically fixed in such a manner that one measures pitch and roll attitude and the other yaw and roll attitude.

Angular roll potentiometer	± 175° ± 1% from the caged position
Outer gimbal freedom	± 360°
Drift (Static & Scorsby)	0.5°/minute maximum
Pitch or yaw potentiometer	± 15° ± 1% from caged position
All potentiometers are linear	± 1% with a resolution ± 0.1%
Inner gimbal freedom	± 85° minimum
Drift (Static & Scorsby)	0.5°/minute maximum.

The gyro motors (400 cps) are operated from self-contained static inverters and require +28v DC ± 2v. The starting power required is 20 watts and running power 10 watts. The duty cycle is 30 minutes on, 30 minutes off. The caging mechanism power requires +28v DC at 28 watts maximum, with a caging time of 15 seconds maximum. The uncaged solenoid requires +28v DC at 60 watts maximum for 0.01 second. There are separate circuits to indicate a "caged" or "uncaged" situation.

4.3.2. Magnetometers

The magnetometer assembly is placed in the nose cone of the vehicle at about Station 38. This assembly is composed of three separate magnetic probes placed parallel to the three missile axes. Each probe has its own excitation and detection circuitry.



The probes and their associated electronics are Model RAM-5C produced by the Schonstedt Instrument Company.

Sensitivity:	.004v per millioersted
Range:	± 600 millioersteds
Input voltage:	+28v DC ± 4v
Biased at	+2.4v DC and output signal from 0 to +5v DC
Linearity:	3% of F.S.

4.4 Angle of Attack Sensor

The pitch and yaw angle of the attack sensor is a modified Giannini Aerohed transmitter with a CARDE designed graphite cone.

Range:	± 5°
Resolution:	0.2°
Natural Frequency:	30 cps (limiting response of V.C.O.)
Repeatability:	0.2°
Linearity:	2% of F.S. reading.

4.5 Temperature Gages.

Temperatures throughout the vehicle are measured by means of RdF Stikon gages, Types MH400 and MH200. These consist of a coil of Hytemco wire, the ohmic value of which varies as shown in the following table:

°F	°C	R/R70
32	0	0.92
70	21.1	1.00
100	37.8	1.07
200	93	1.30
212	100	1.33
300	149	1.58
400	204	1.88
500	260	2.20

R/R70 = resistance at measured temperature divided by the resistance at 70°F.

Each gage may have a correction factor, in ohms, which must be added or subtracted from the nominal value, e.g. MH400 +4 or MH200 -3.

Except for the one location in the subcarrier telemetry mechanical assembly, where the temperature gage is fixed in place by epoxy, all other temperature gages are held by means of pressure pads against a prepared surface covered with a thin ceramic coating.

4.6 Radar Beacon

To ensure proper radar tracking of the vehicles during flight, both missiles were fitted with transponders or beacons, Model DPN-41. Trajectory and dispersion are calculated from the information supplied by the radar.

5.0 ENCODING AND TRANSMITTING CIRCUITS.

5.1 Telemetry

The telemetry assembly was provided with eleven (ten in CC II-29) FM-FM standard IRIG subcarrier channels. The composite signal was radiated by a five-watt transmitter operating at 225.7 mc.

IRIG channels 6 to 13 with ± 7.5% deviation and Channel C with a ±15% deviation gave continuous information. These nine channels were calibrated, when desired, by a three-point calibrator. During flight, calibration was planned for every 100 seconds. The programmer was reset at 0 time by pushing a button on the Control Panel a few seconds before firing.

Channel A, ± 15% deviation, was modulated by a non-standard 30 x 5 PAM sampling commutator and transmitted information from 12 temperature gages. A constant current source measured the resistance value of these gages and compared them to a bank of precision resistors (within 0.1%) graduated in 100 ohm steps.

Channel B, deviation ± 15%, had a 30 x 30 standard PDM encoder with 28 subchannels of information; two of these subchannels were for calibration voltages against which all other subchannels were compared.

Note that in a few cases, the actual frequency content of the information is limited by the subcarrier oscillator response rather than by the response of the transducer used to make the measurement. The frequency responses of the telemetry channels are given in Table I.

Channel Information:	See Table I
Telemetry Block Diagram:	CARDE Dwg. #63091003/C
Operating Power:	28 v DC ± 2v at 4.5 amperes
VCO Drift:	± 0.5% after 20 mins. warm-up.
VCO Calibration:	± 5.00 ± .01v DC at 28 v DC ± 2v.

The whole telemetry package was sealed in a pressurized chamber to prevent possible arc-over of the high voltage in rarefied atmospheric conditions.

5.2 Antenna System

The BLACK BRANT antenna system consists of three 50-ohm radiators. The blades are wedge-shaped and swept back 30°. Each radiator has an adjustable stub by means of which a reactive component can be cancelled. The impedance presented to the source is thus resistive.

These radiators are connected together and to the transformer by a coaxial cross. The transmission lines from the antennae to the cross are in lengths of L, L + $1/3\lambda$ and L + $2/3\lambda$ This disposition of leads simulates circular polarization as each blade is fed 120° electrically apart and in a manner of rotation to match the polarization of the helical receiving antenna.

Since the three transmitting antennae are presented to the source in parallel, there is then the problem of transforming this again to a 50-ohm load as required by the transmitter. This is accomplished by a quarter-wave matching line or transformer.

The blades are biased at -90v with respect to the vehicle body and provisions are made to monitor a possible short or currents caused by the pick-up of electrically charged particles in flight.

Again the power transmitted and the reflected power caused by any trouble developing in the antenna system during flight are monitored by a 4100 Thruline RF directional wattmeter. By means of the values Ef and Er, the VSWR for the system can be computed.

5.3 Power Sources

Power for all electrical circuits during flight is obtained from one battery composed of nineteen 1.5v Eagle Picher, Type 1515, silver peroxide-zinc cells connected in series. The capacity of a cell is 200 ampere-minutes (10-minute rate). A load of 4.5 to 5 amps will give an operational time of 40 or more minutes, leaving a very generous margin, as the flight time is estimated at between 5 and 7 minutes.

The interior power supply can be controlled by means of a relay. This permits power to be supplied from the exterior, through the umbilical connector, to warm up and condition the electrical systems such that the internal supply is used only when absolutely necessary for tests or for the actual flight.

6.0 CHECK-OUT EQUIPMENT

A minimum of personnel and equipment is necessary to check-out the instrumentation after transportation to, and handling on, the trial site. Again, a part of this check-out equipment is needed for control of the vehicle circuitry when the launch pad installation is finished.

The check-out station is made up of the following:

1	Nems-Clark Receiver, Model 1432
1	Tunable Discriminator, EMR Model 97D
1	Panoramic Telemetry Indicator
1	PDM/PAM Pulse Converter
2	Tektronix Oscilloscopes Model 503R
1	Digital Voltmeter, HP 5512A
2	Power Supplies, NJE-QR-36-10

The whole station is operated from a Control Panel. This panel also has indicators which show, at a glance, whether the power on the launch vehicle comes from the interior or exterior, and if the free gyros are "caged" or "uncaged". A push-button switch permits the in-flight calibrator to be operated when desired, and at the same time resets its operational cycling to zero time.

TABLE I

1. The Telemetry Channel Allocations for Vehicles CC II-29 and 30 were as follows:

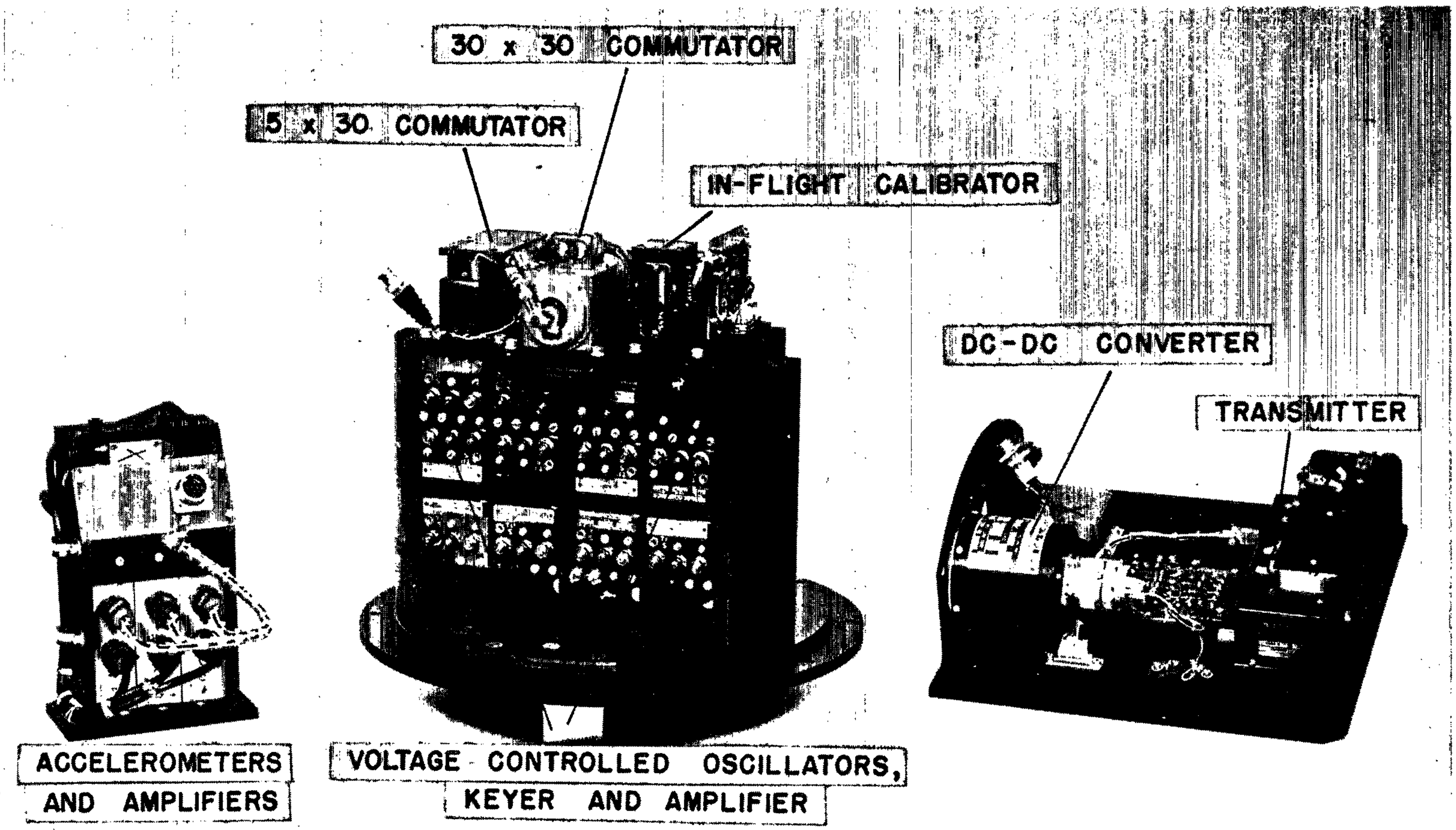
Measurement	Range	IRIG Channel	Frequency Response	30 x 30 PDM Channel No.	30 x 5 PAM Channel No.
See Note	0 to +5v	6	25 cps		
Yaw angle of attack	± 5°	7	35 cps		
Pitch angle of attack	± 5°	8	45 cps		
Roll attitude (P)	± 180°	9	59 cps		
Roll attitude (Y)	± 180°	10	80 cps		
Acceleration, yaw	± 5°	11	110 cps		
Acceleration, longitude	-5 to +25 g	13	220 cps		
Motor Pressure #1	0 - 2000 psi	C	1200 cps		
Acceleration, pitch	± 5g	12	160 cps		
Master Pulse	-	E	30 sps	29-30	
Voltage reference	0 and 5v	E	30 sps	14-15	
X axis attitude (Mag)	0 - 5v	E	60 sps	1-16	
Y axis attitude (Mag)	0 - 5v	E	60 sps	2-17	
Z axis attitude (Mag)	0 - 5v	E	60 sps	3-18	
Spare	-	E	60 sps	4-19	
Pitch attitude (P)	± 15°	E	60 sps	5-20	
Yaw attitude (Y)	± 15°	E	60 sps	6-21	
See Note	-	E	60 sps	7-22	
See Note	-	E	60 sps	8-23	
Motor Pressure #2	0-2000 psi	E	30 sps	9-	
Spares		E	30 sps	24	
X axis bias	+ 2.5v	E	30 sps	10-	
Y axis bias	+ 2.5v	E	30 sps	25	
Z axis bias	+ 2.5v	E	30 sps	11-	
Forward RF power	0 - 5v	E	30 sps	26	
Backward RF power	0 - 5v	E	30 sps	12-	
Ant. bias Mon.	0 - 5v	E	30 sps	27	
Battery TM	0 - 32v	E	30 sps	13-	
Battery M'ors	0 - 32v	E	30 sps	28	
TEMPERATURES:					
Sta 36 330°	0 - 350°	A	5 sps	(Rd F-MH-200)	1
Sta 36 090°	0 - 350°	A	5 sps	(Rd F-MH-200)	2
Sta 36 210°	0 - 350°	A	5 sps	(Rd F-MH-200)	3
Spare		A			7,8,9,16-21
Sta 94 030°	0 - 350°	A	5 sps	(Rd F-MH-200)	10
Sta 94 150°	0 - 350°	A	5 sps	(Rd F-MH-200)	11
Sta 94 270°	0 - 350°	A	5 sps	(Rd F-MH-200)	12
Magnetometer Block	0 - 200°	A	5 sps	(Rd F-MH-400)	4
Gyro frame	0 - 200°	A	5 sps	(Rd F-MH-400)	5

	Range	IRIG Channel	Freq. Resp.	30 x 30 PDM Channel No.	30 x 5 PAM Channel No.
Battery frame	0-200	A	5 sps	(Rd F-MH-400)	6
TM Xmitter	0-200	A	5 sps	(Rd F-MH-400)	13
TM SCO's	0-200	A	5 sps	(Rd F-MH-400)	14
TM Commut.	0-200	A	5 sps	(Rd F-MH-400)	15
Calibrations	100 ohms/ step	A	5 sps		22-29
Sync	1000 ohms	A	5 sps		30

NOTE: In CC II-29, IRIG Channel 6 was removed. On the 30 x 30 commutator modulating IRIG Channel E, the following subchannels were shorted to ground: 4 - 19, 7 - 22, 8 - 23 and 24.

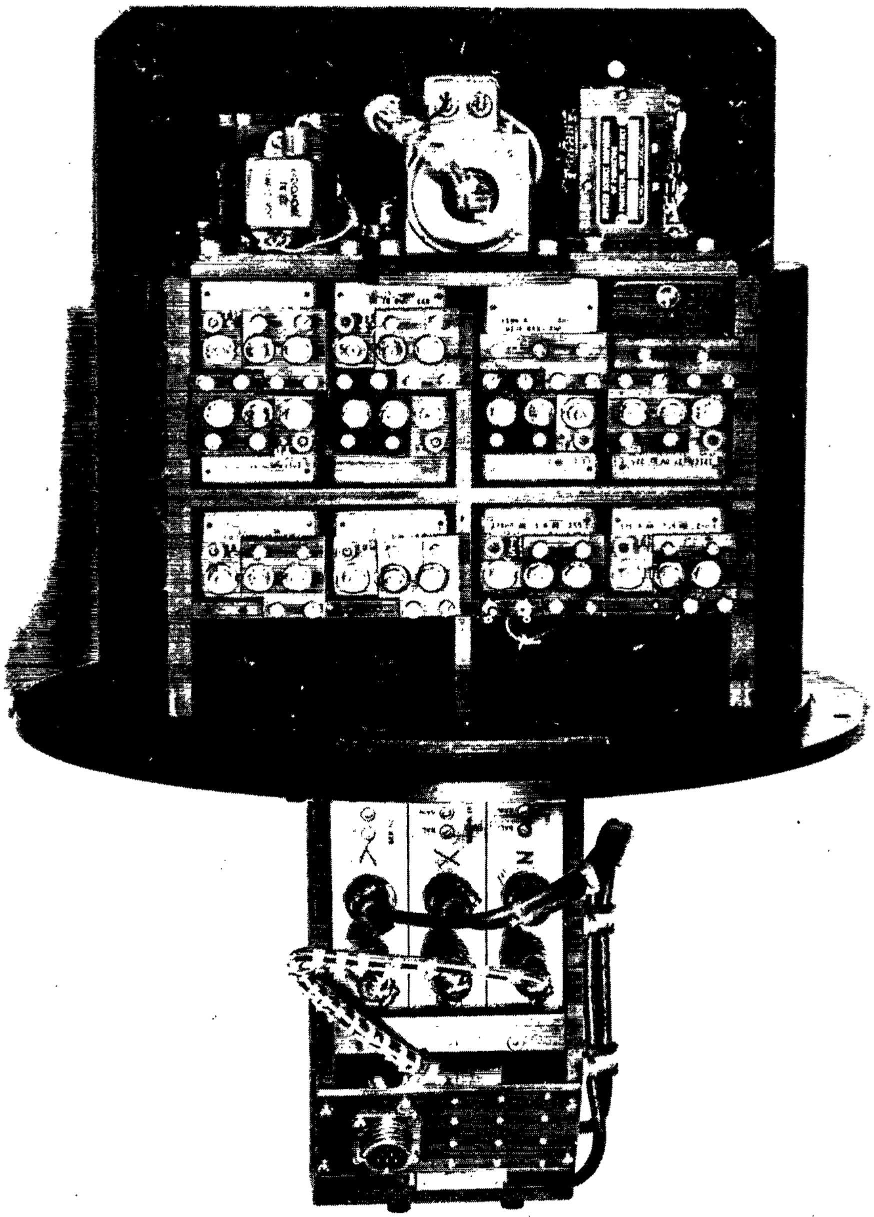
In CC II-30, IRIG Channel 6 was used by NRC for the unprocessed output of the 100 kc micrometeorite detector. On the 30 x 30 commutator modulating Channel E, subchannels 7 - 22 were reserved for the processed output of the 100 kc micrometeorite detector: subchannels 8 - 23 were for the processed output of the 50 kc detector. On the same 30 x 30 commutator, subchannels 4, 19 and 24 were tied to ground.

LIST OF DRAWINGS



DISASSEMBLED TELEMETRY PACKAGE

FIGURE 1



ASSEMBLED TELEMETRY PACKAGE

FIGURE 2

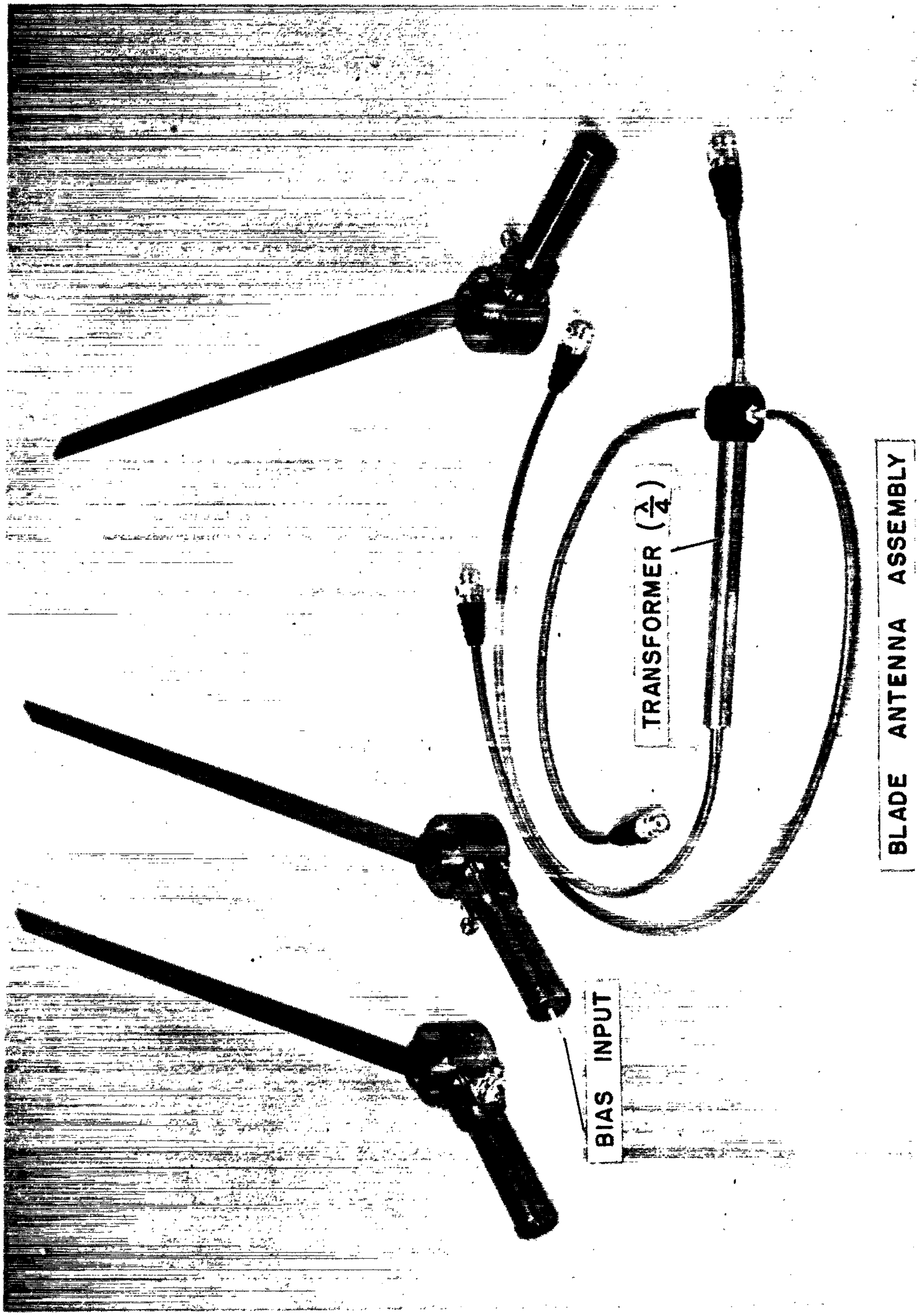

TRANSFORMER ($\frac{\lambda}{4}$)
BLADE ANTENNA ASSEMBLY
BIAS INPUT

FIGURE 3

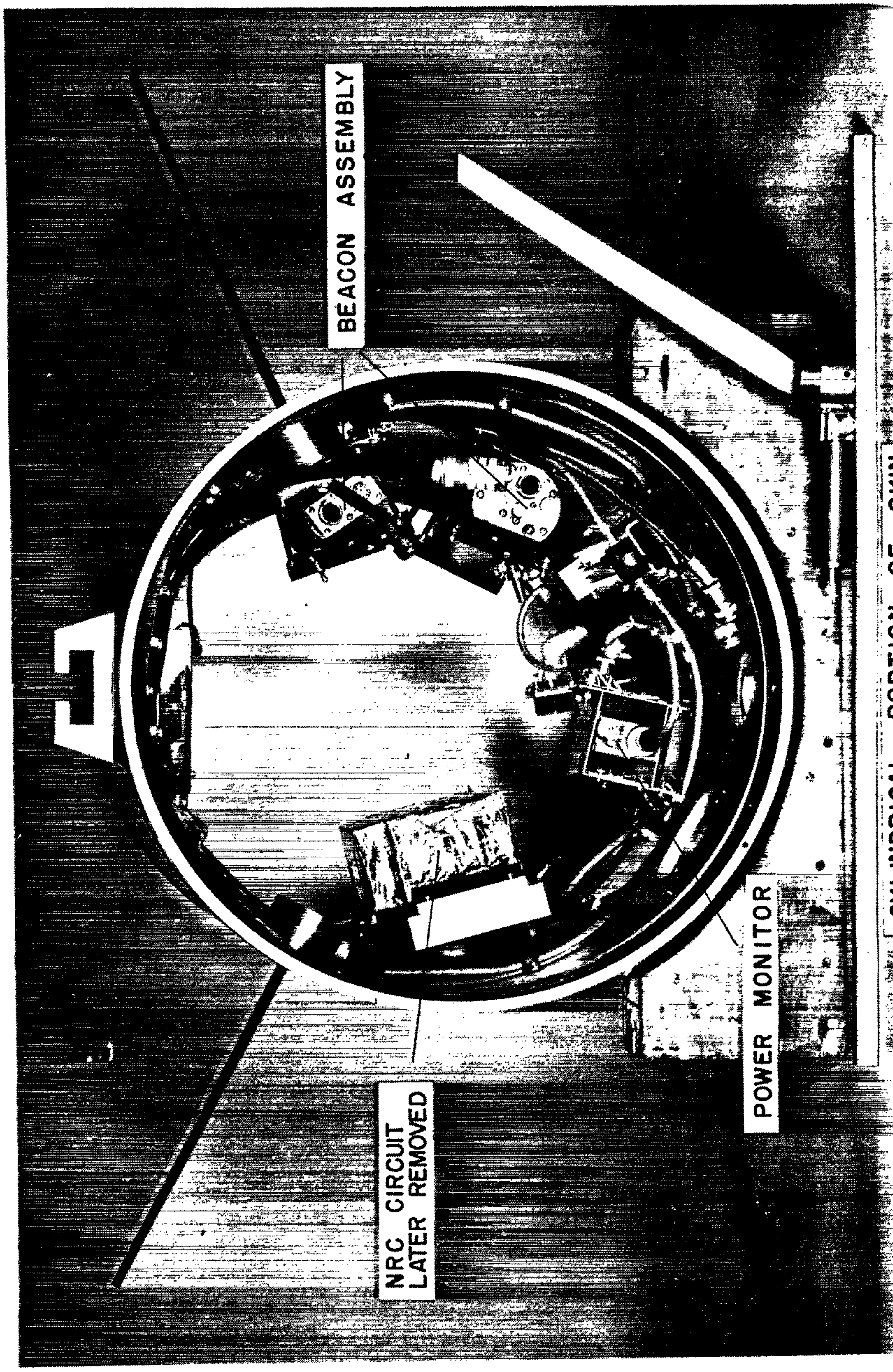

BEACON ASSEMBLY
NRC CIRCUIT
LATER REMOVED
POWER MONITOR
CYLINDRICAL PORTION OF SKIN
CCII-29

FIGURE 4

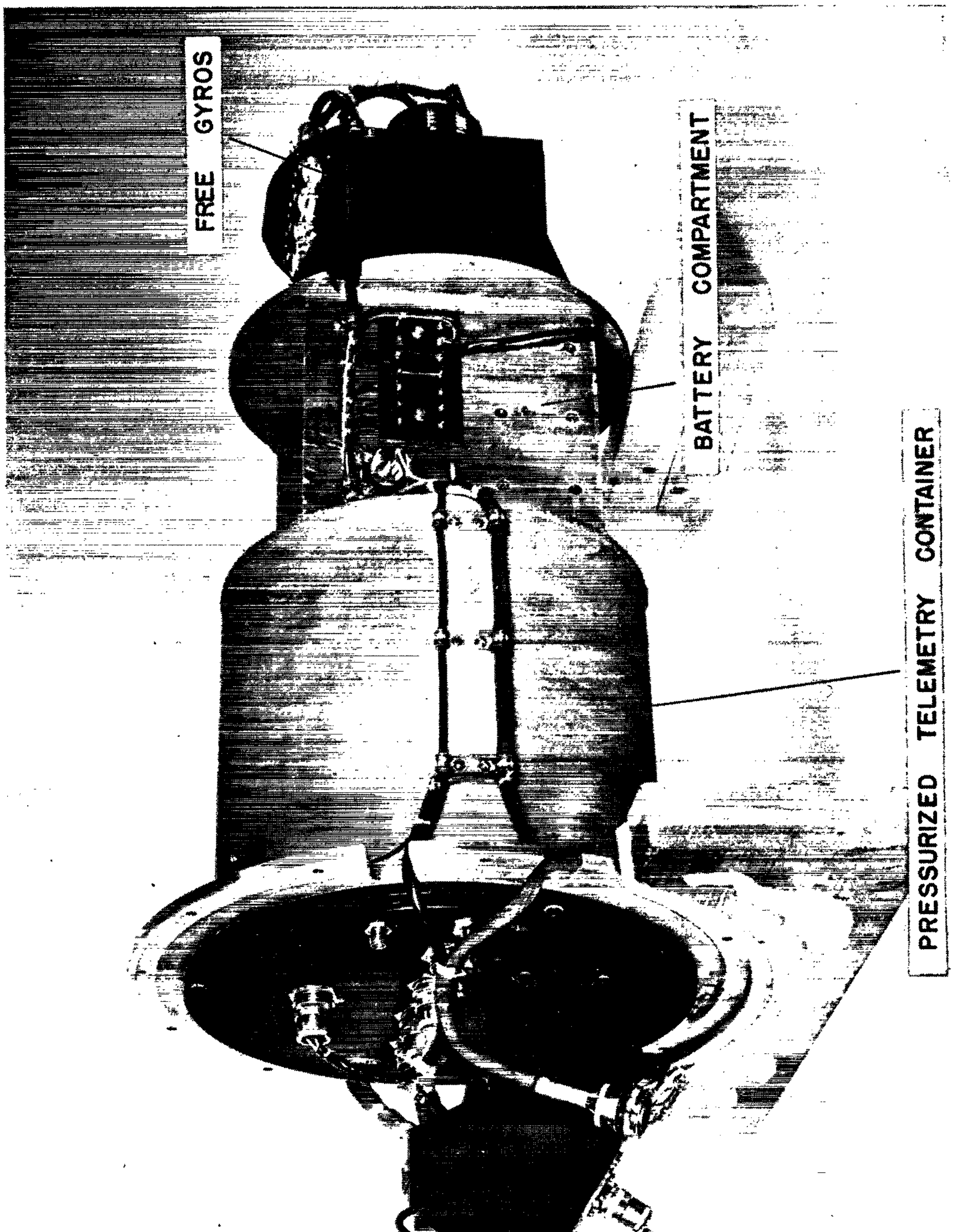

FREE GYROS
BATTERY COMPARTMENT
PRESSURIZED TELEMETRY CONTAINER

FIGURE 5

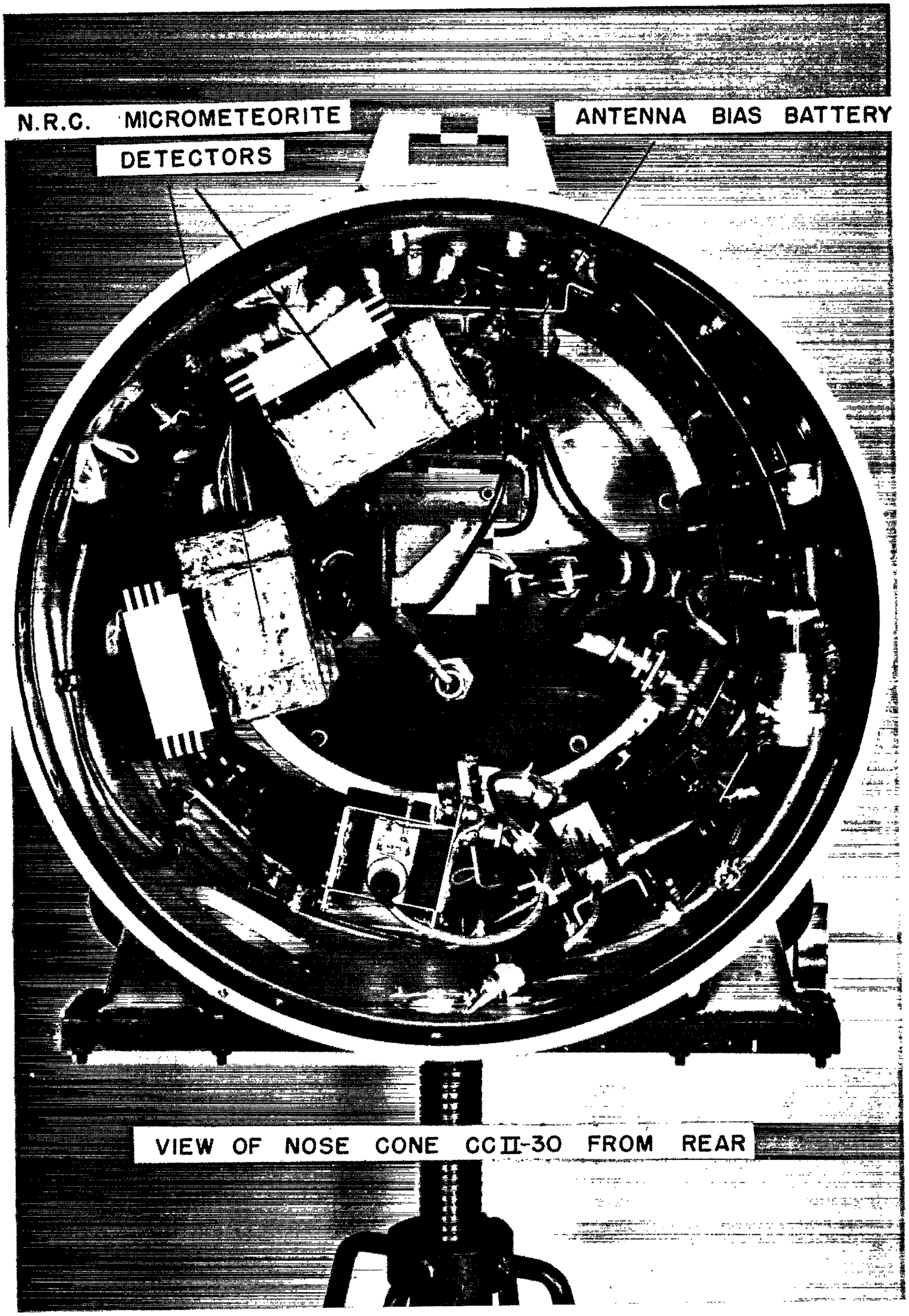

N.R.C. MICROMETEORITE
DETECTORS
ANTENNA BIAS BATTERY
VIEW OF NOSE CONE CCII-30 FROM REAR

FIGURE 6

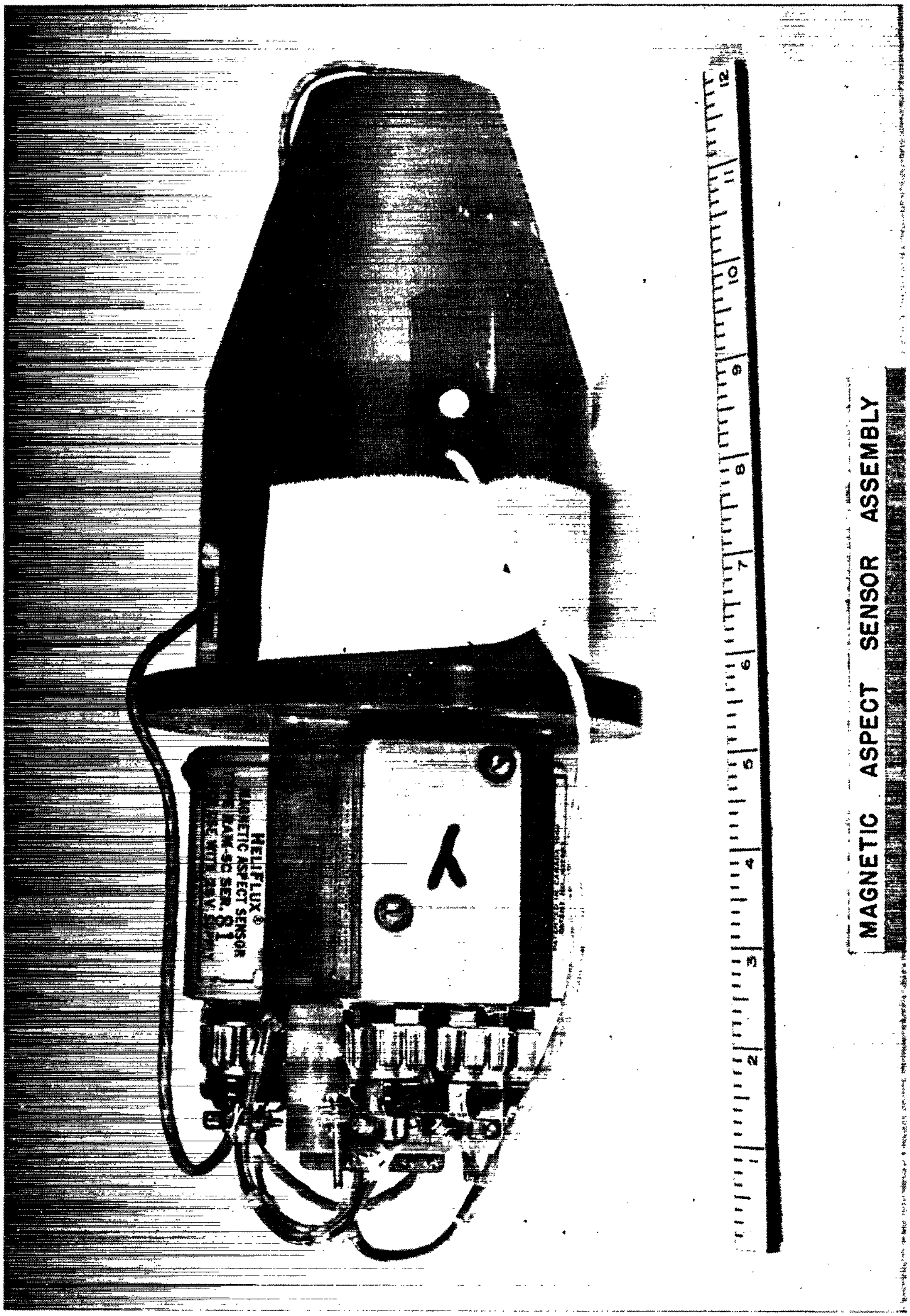
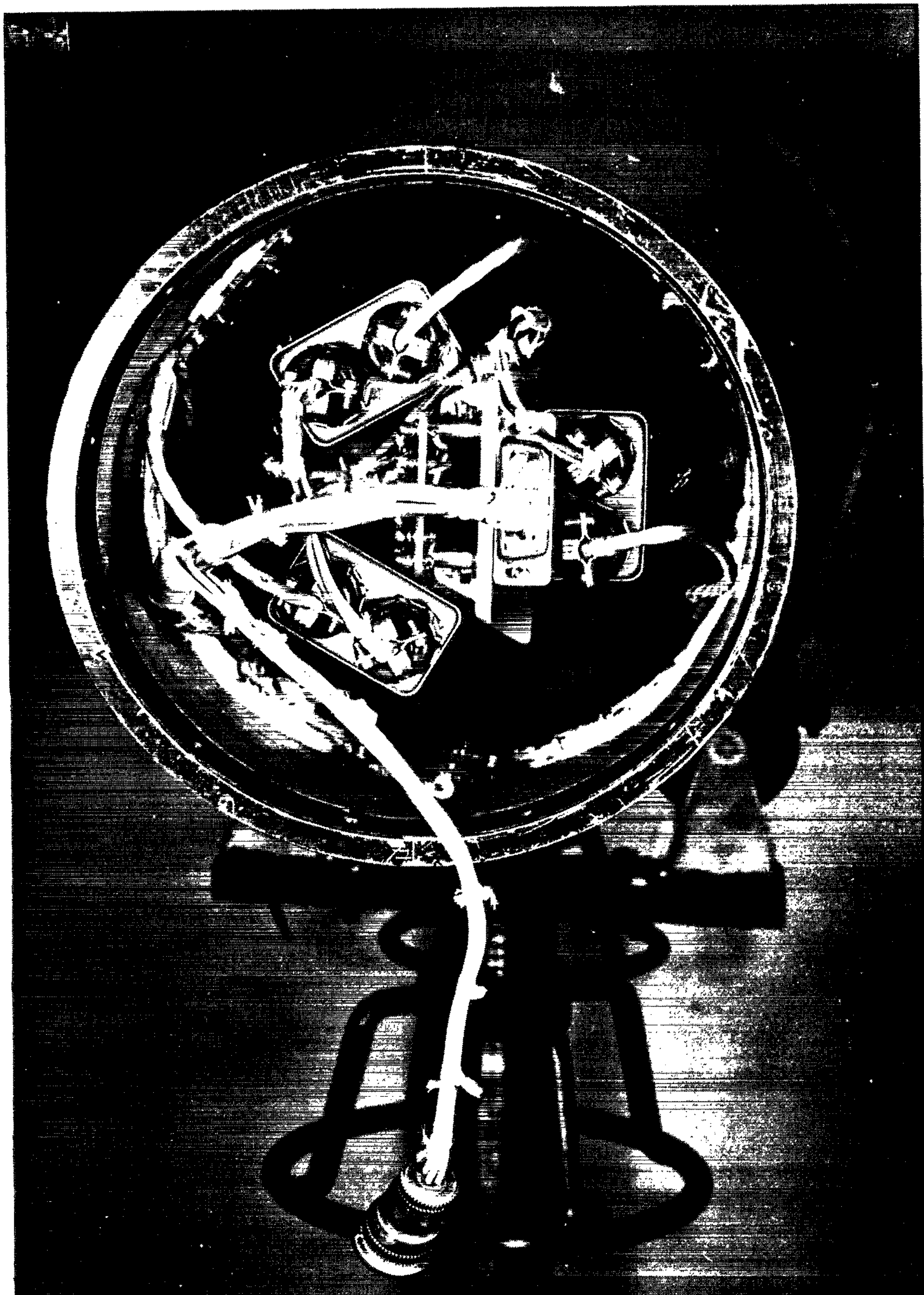

MAGNETIC ASPECT SENSOR ASSEMBLY
HELIFLUX
MAGNETIC ASPECT SENSOR

FIGURE 7



LOCATION OF MAGNETIC ASPECT SENSOR IN NOSE CONE

FIGURE 8

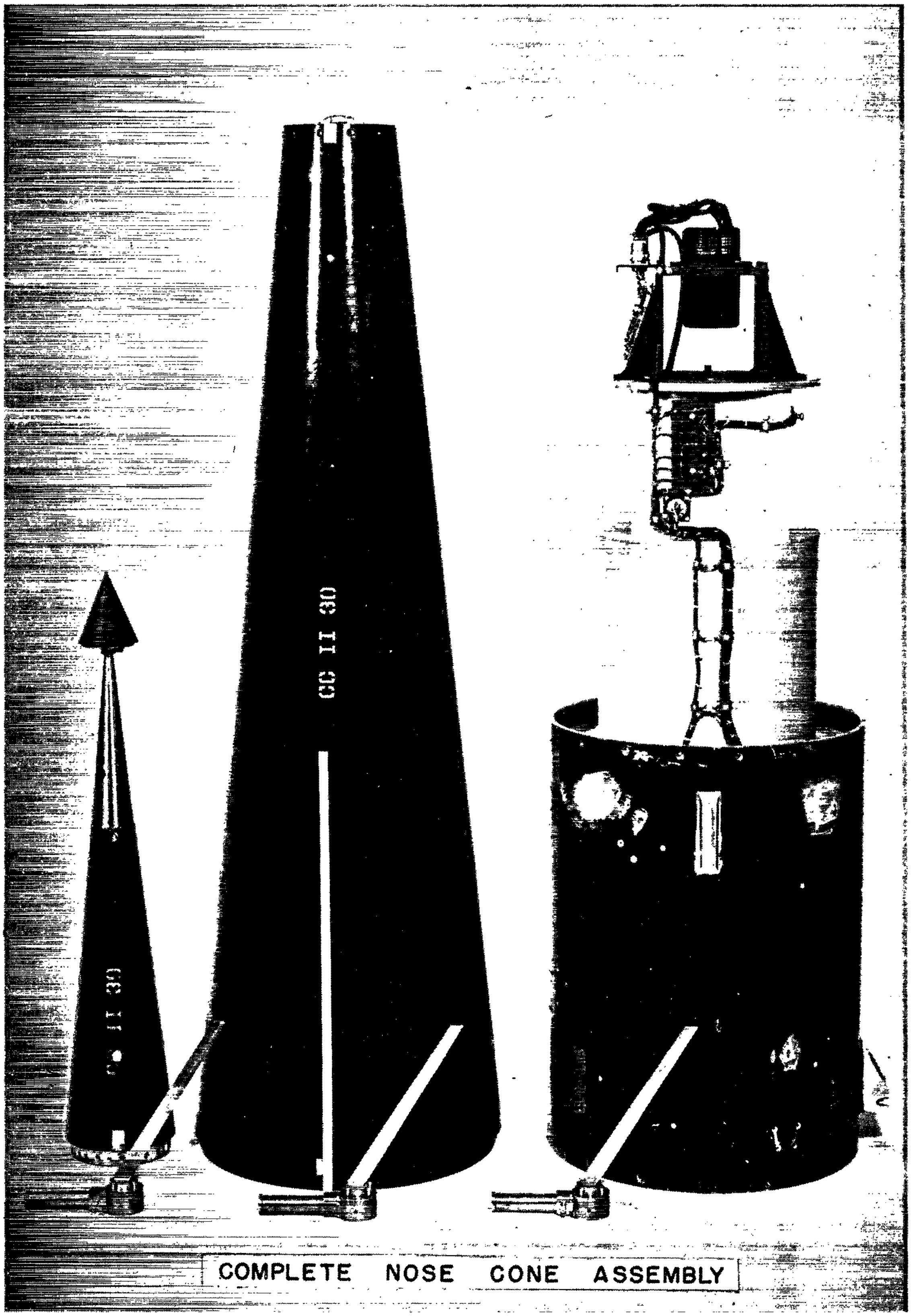


FIGURE 9

UNCLASSIFIED

Copy # 2, 3: DWER (gone)
Dist' 1 copy - Ref. File.