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THE ARIEL I SATELLITE

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NASA, GODDARD SPACE FLIGHT CENTER

GREENBELT, MD.

SOT 11381

THE ARIEL I SATELLITE

by

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The Ariel I Satellite (Figure 1) is an integrated scientific laboratory specifically designed to obtain knowledge of the ionosphere and its complex relationship to the sun.

This scientific laboratory in space is completely self-contained and other than a single command function operates independently of external control.

There are no opportunities to repair or adjust the instrumentation in this laboratory once the rocket leaves the launching pad. Consider being unable to service your automobile, adjust your television set, have your washing machine repaired, for a period of a year. How many items in everyday use would be operative after one year with no maintenance? I will give data on Ariel's operation status later in my presentation.

Let us now turn our attention to the components that go into making this laboratory in space. First we shall look at the electronics, then briefly at the structure and associated hardware.

The various electronic sub-systems are represented by the Ariel I functional diagram (Figure 2). I will not go into detail on the various probes, sensors, or experiment conditioning circuits since they are considered part of the experiment instrumentation. I will, however, go into limited detail on the other sub-systems indicated.

The power system for Ariel consists of four solar paddles, two battery packs of 10 Nickel-cadmium cells each, a shunt voltage limiter, a battery charging current limiter, a battery switching network, an undervoltage detector system and four converters.

The four solar paddles are covered with p on n silicon solar cells and, prior to radiation damage in space, were capable of providing, depending on Ariel's aspect to the sun, from 0.5 to 2 amperes at 15 volts, which is 7.5 to 30 watts of power.

The shunt voltage limiter regulates the solar paddle-battery charging voltage to 14.5 volts.

The battery charging current limiter regulates the battery charging current to a value not in excess of 0.5 ampere.

The battery switching network selects the battery with the highest voltage to operate the satellite.

The undervoltage detector system includes an undervoltage detector, a converter, a relay and the shut-down timer. Operation of this system turns off Ariel entirely, with the exception of the timer, for approximately 18 hours, to provide maximum power for recharging the batteries.

The converters are DC to DC converters which supply regulated voltages to Ariel's electronic subsystems.

Ariel contains a high speed and a low speed encoder system. For increased reliability, operation of the HS encoder is independent of the operation of the LS encoder. However, the two are synchronized to facilitate correlation of data.

The high speed encoder information is transmitted continually while the low speed encoder information is recorded on the tape recorder.

To give you an indication as to the complexity of the Encoder subsystems they contain:

520	transistors
860	resistors
59	diodes
125	capacitors
4	digital oscl.
7	analog oscl.

TOTAL - 1575 electronic components

Ariel contains a programmer whose main function is to control the transmission of the HS and LS encoder data to the ground.

To transmit the data stored by the tape recorder, an RF command is sent to Ariel from a ground station. The data which has been recorded during the 100-minute orbit is played back in approximately 2 minutes. The tape recorder automatically goes back into the record mode.

A means for automatically removing the tape recorder drive motor power is incorporated in the system to protect against overloads. The RF command from the ground resets the circuit so that if the overload is removed the system will again function.

Ariel's Command Receiver is basically a double-super-heterodyne unit with an amplitude-modulation detector. It performs the single command function of tape recorder playback.

Ariel's phase modulated transmitter is fully transistorized and delivers 260 milliwatts of power to the antenna system at a frequency of 136.410 megacyles.

Let us now turn briefly to the structure and associated hardware.

In the orbital configuration the satellite weighs 133.8 lbs. Ariel's basic structure is 23 inches in diameter by 22 inches high. It is constructed primarily of epoxy-bonded filaments of fiberglass and machined-wrought aluminum alloys.

Figure 3 shows the main structural shelf. Notice the machined braces which perform the dual task of supporting the shelf and structure and provide mounting surfaces for the appendages.

Figure 4 shows the fiberglass upper and lower domes, and the cylindrical mid-skin section prior to thermal coating.

The appendages are shown in Figure 5. Notice the fiberglass inertia booms and the aluminum solar paddle arms. Two of the paddle arms have two hinges, while two only have one. The hinges in all cases allow the appendage to be folded within the nose cone envelope and later to assume orbital configuration.

Figure 6 shows some of the electronic sub-systems, the de-spin mechanism, the tape recorder, one of the battery packs, and the escapement mechanism that was used to restrain the experiment sensor booms erection.

Figure 7 shows the experimenters' sensors and electronics.

Using the various sub-systems mentioned, adding a few others, and wiring these all together gives the integrated scientific laboratory now known as Ariel I.

Figure 8 is a cut-away view of Ariel I. Starting at the top and moving clockwise you can see the location of the various experiment sensors as follows:

The Mass Spectrometer probe
The Cosmic Ray Analyzer
There are three Lyman Alpha detectors, one located on the equator, one 45° above and one 45° below the equator.
The Electron Density boom
The Aspect Sensor Assembly
The X-ray gauge—a second sensor is located on the lower dome directly below the one shown.
The Electron temperature probe–a second sensor is located on the spin axis at the bottom of the satellite.

Over one year ago, on April 26, 1962, Ariel was placed into orbit. Figure 9 shows some of the housekeeping data obtained up to April 15, 1963. The percent time in sunlight, temperature, spin rate, and aspect angle have been monitored. Actual data points are shown as small circles.

The PT 1 payload temperature is the temperature measured in UCL stack #2 on the main shelf of Ariel and is indicative of average satellite temperature. The curve follows the theoretical percent of time in sunlight curve rather well. Ariel's internal temperature has ranged from approximately +20 to +50° C.

The initial spin rate of approximately 38 rpm decayed to approximately 27 rpm and then increased as shown. Solar pressure on the solar paddles, and Ariel's aspect with respect to the sun, contribute to the spin rate increase.

The solar aspect angle is measured from the equator of the satellite. The angle varies from approximately 42 degrees above the equator to approximately 40 degrees below the equator. Initially the actual data was very close to the theoretical data; now, however, current data shows considerable variation, possibly due to radiation damage to the aspect sensor solar cells.

Ariel started to malfunction on July 12, 1962. We on the project feel that this is not completely unrelated to the July 9, 1962 high altitude nuclear explosion.

Information about the satellite's performance since launch is shown on Figure 10.

Low-speed data store lost in mid-August.

The boom electron temperature equipment was functional on April 1, 1963. The base electron temperature equipment started intermittent malfunction at approximately July 9, 1962. Approximately 75% of the boom probe data and 25% of the base probe data was lost upon the malfunction of the low-speed data store.

X-ray spectrometer–suspected calibration change occurred on, or near, May 4, 1962. The existence of this change is not yet confirmed, but a catastrophic failure occurred approximately on November 1, 1962. Approximately 10% of data lost due to loss of low-speed data store.

Cosmic ray – geiger counter lost about September 1. Cherenkov detector started to degrade during first 100% sunlight period due to overheating. Lost in mid-December. 75% of data lost due to loss of low-speed data store.

Electron density – failed March 1963 – approximately 75% of data lost due to loss of low-speed data store.

Lyman alpha failed on launch.

Aspect – functioning.

Spin rate – intermittent operation during first half of August and first half of November. Operating since then.

Of the electronic sub-systems mentioned earlier, the following were operating properly on April 15, 1963.

1. The power system.
2. The high speed encoder.
3. The command receiver – last time tried, February 8.
4. The transmitter.
5. Undervoltage detector.
6. Recycle timer.

Of questionable operating status are the following:

1. The low speed encoder.
2. The tape recorder control circuits.
3. The programmer.

Figure 11 shows the percent of time of operation in the various operational modes.

In conclusion, here are a few statistics related to Ariel I:

The equivalent total number of 24-hour days of operation with modulation, hence, useful data, to 17 April 1963 was 174 days. The tape recorder operated for approximately 100 days. The undervoltage system had operated 62 times as of 17 April 1963, potentially adding 46 days to the satellite's life.

As of April 13, 1963 922 hours of usable data have been digitized, and have been sent to the experimenters. (This is equivalent to approximately 180 million data points.)

On April 11, the satellite made its 5000th orbit of the earth, which is equivalent to approximately 140 million miles.

The satellite has one year "killer" timers, which have a tolerance of ±10% or 36.5 days. One might, therefore, normally expect Ariel I to cease transmitting sometime between now and July 19, provided the "killer" timers work and no undervoltages occur between now and then.

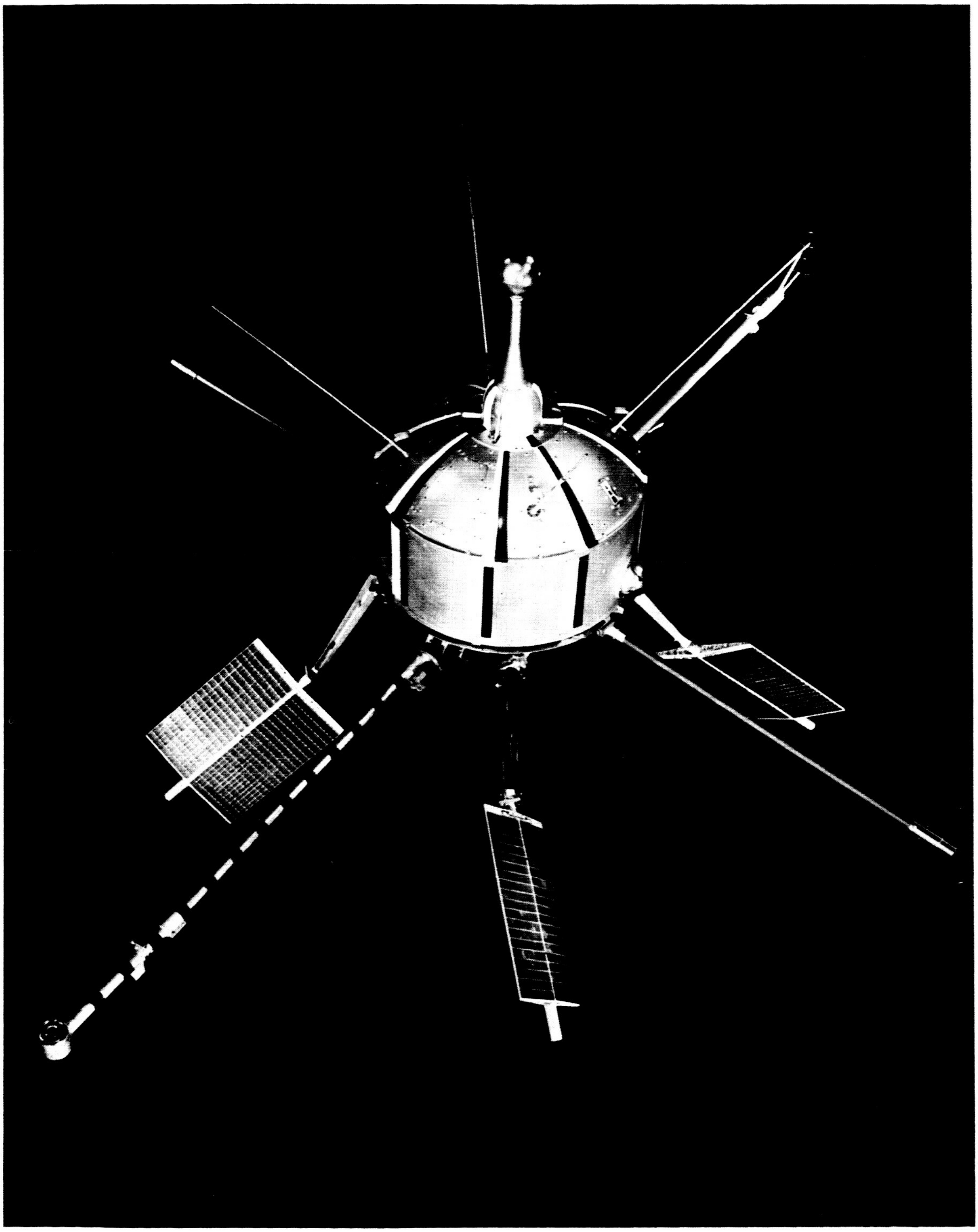


FIGURE 1 - ARIEL 1

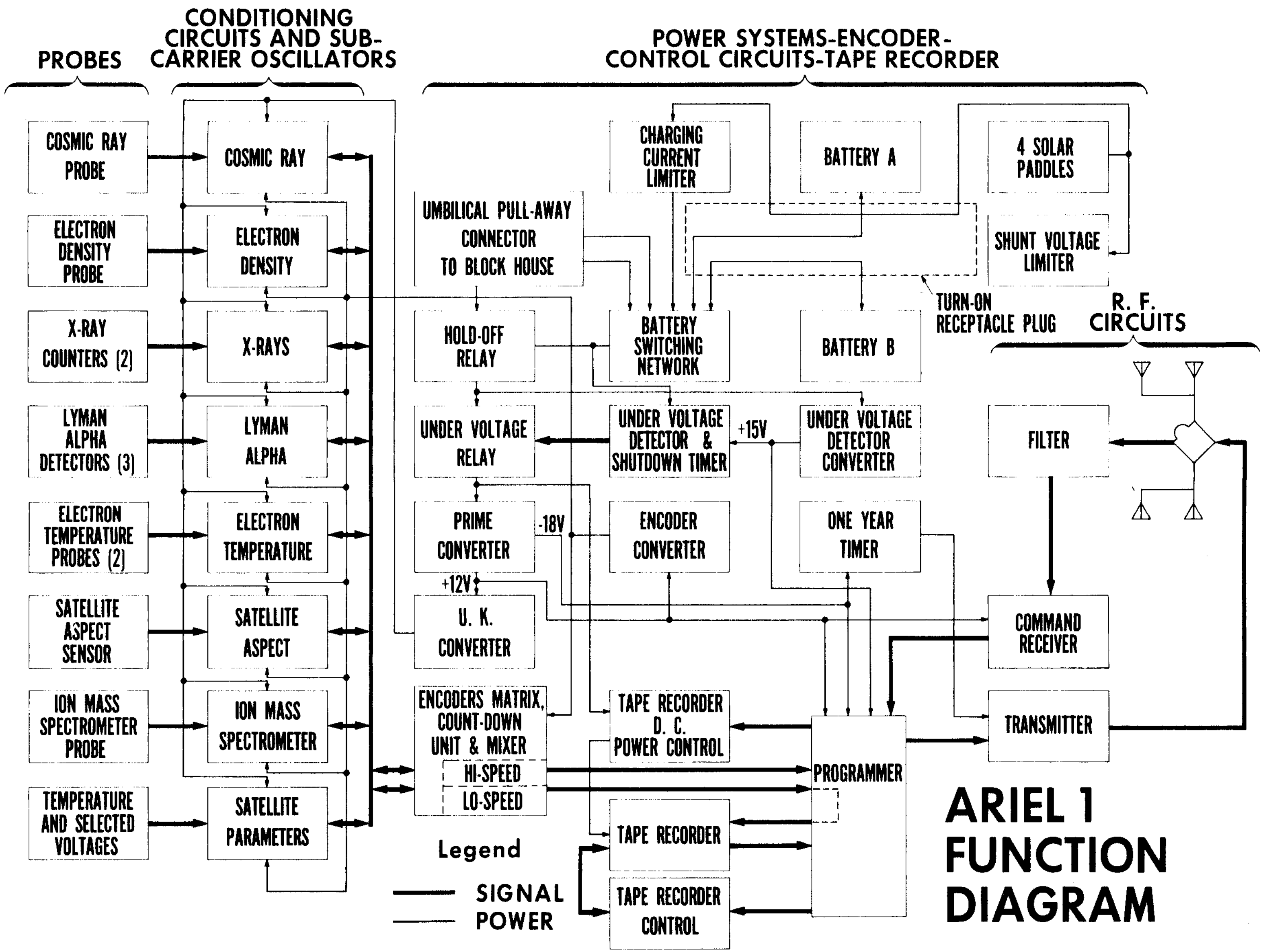
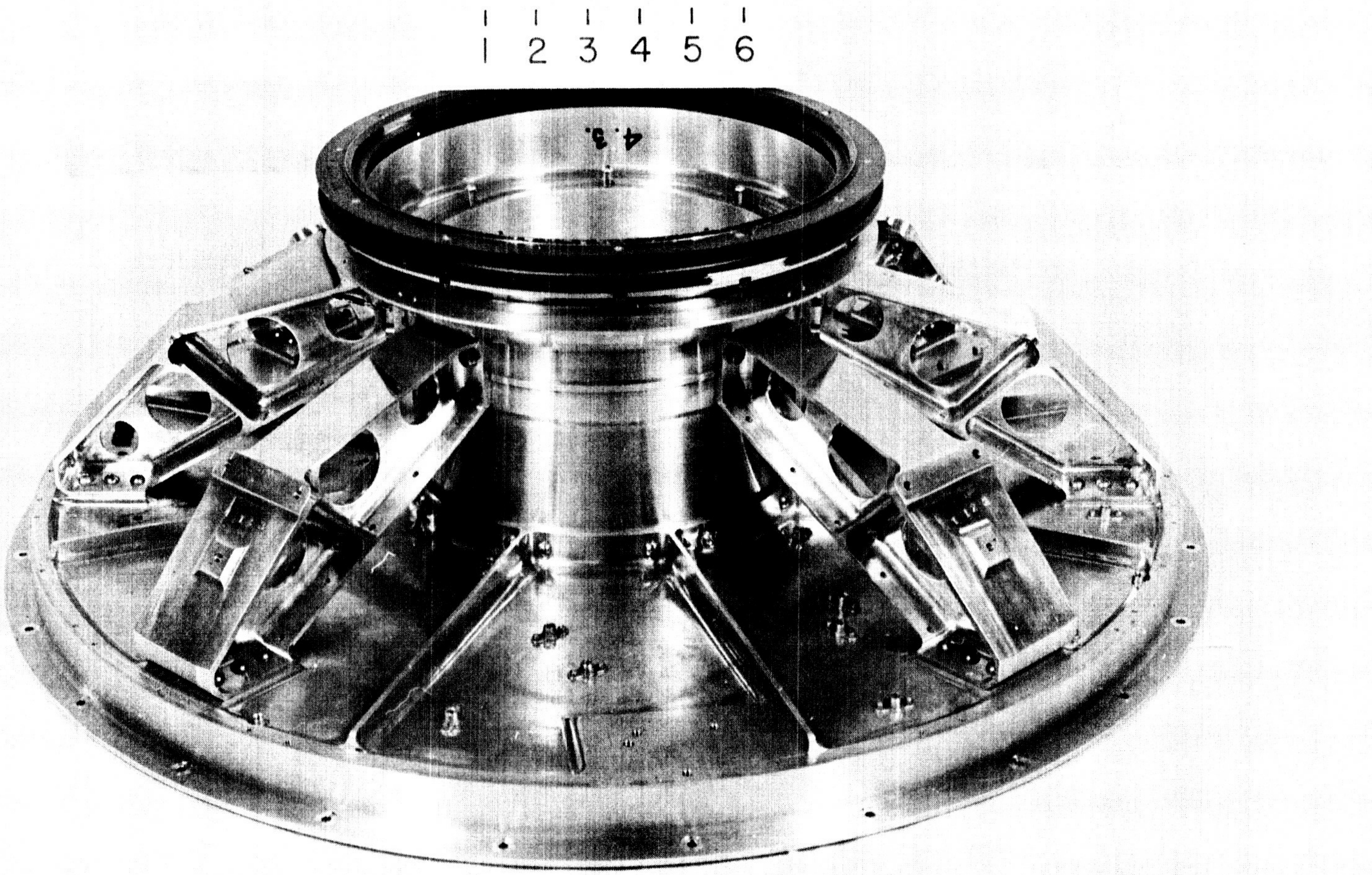

PROBES
CONDITIONING CIRCUITS AND SUB-CARRIER OSCILLATORS
POWER SYSTEMS-ENCODER-CONTROL CIRCUITS-TAPE RECORDER
COSMIC RAY PROBE
ELECTRON DENSITY PROBE
X-RAY COUNTERS (2)
LYMAN ALPHA DETECTORS (3)
ELECTRON TEMPERATURE PROBES (2)
SATELLITE ASPECT SENSOR
ION MASS SPECTROMETER PROBE
TEMPERATURE AND SELECTED VOLTAGES
COSMIC RAY
ELECTRON DENSITY
X-RAYS
LYMAN ALPHA
ELECTRON TEMPERATURE
SATELLITE ASPECT
ION MASS SPECTROMETER
SATELLITE PARAMETERS
UMBILICAL PULL-AWAY CONNECTOR TO BLOCK HOUSE
HOLD-OFF RELAY
UNDER VOLTAGE RELAY
PRIME CONVERTER
-18V
+12V
U. K. CONVERTER
ENCODERS MATRIX, COUNT-DOWN UNIT & MIXER
HI-SPEED
LO-SPEED
CHARGING CURRENT LIMITER
BATTERY SWITCHING NETWORK
UNDER VOLTAGE DETECTOR & SHUTDOWN TIMER
+15V
ENCODER CONVERTER
TAPE RECORDER D. C. POWER CONTROL
TAPE RECORDER
TAPE RECORDER CONTROL
BATTERY A
BATTERY B
UNDER VOLTAGE DETECTOR CONVERTER
ONE YEAR TIMER
PROGRAMMER
4 SOLAR PADDLES
SHUNT VOLTAGE LIMITER
TURN-ON RECEPTACLE PLUG
R. F. CIRCUITS
FILTER
COMMAND RECEIVER
TRANSMITTER
Legend
SIGNAL
POWER
ARIEL 1 FUNCTION DIAGRAM

FIGURE 2



ELECTRONIC SHELF AND BASE-ASSEMBLY

FIGURE 3 - ELECTRONICS SHELF

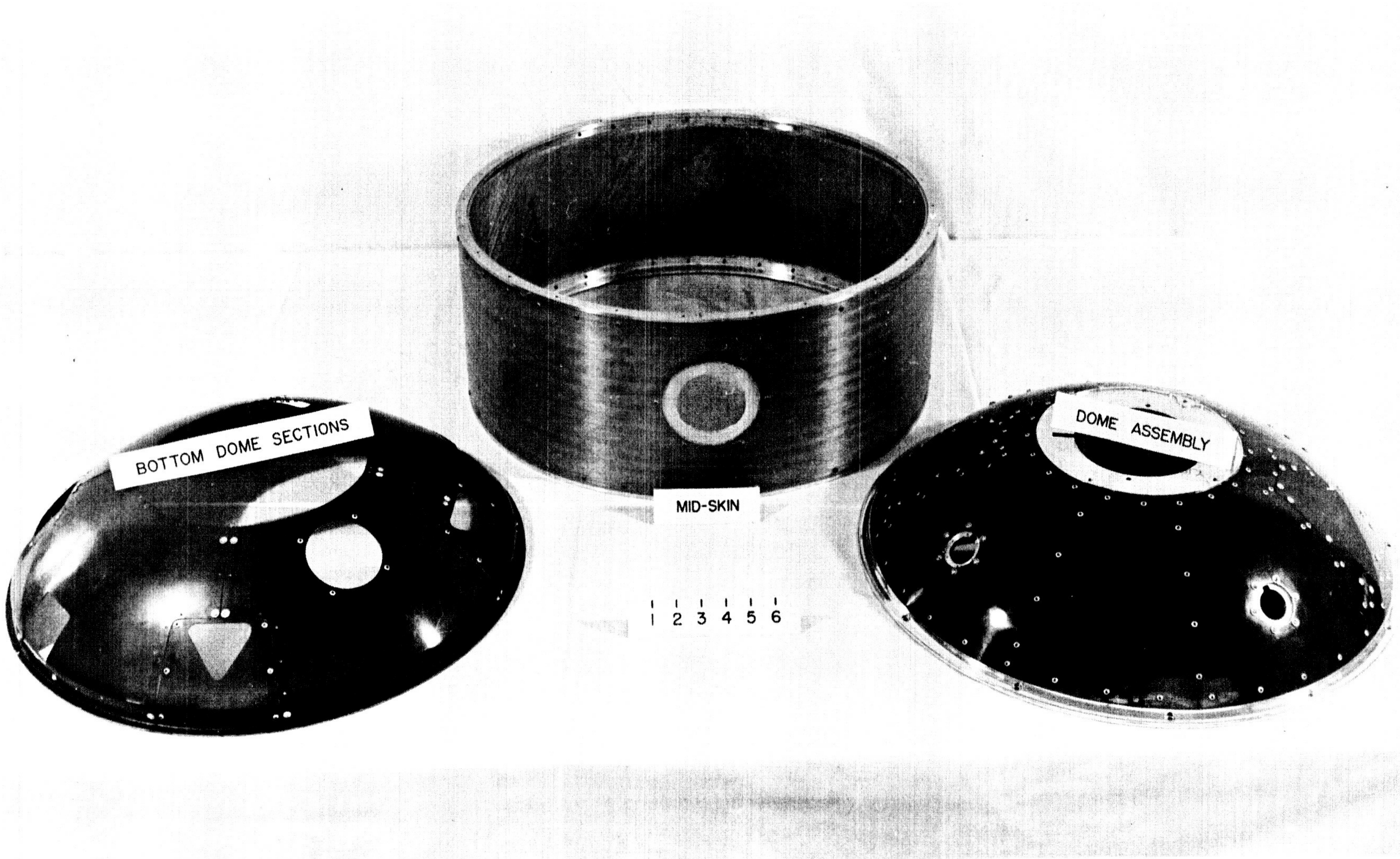


FIGURE 4 - MID SKIN AND DOMES

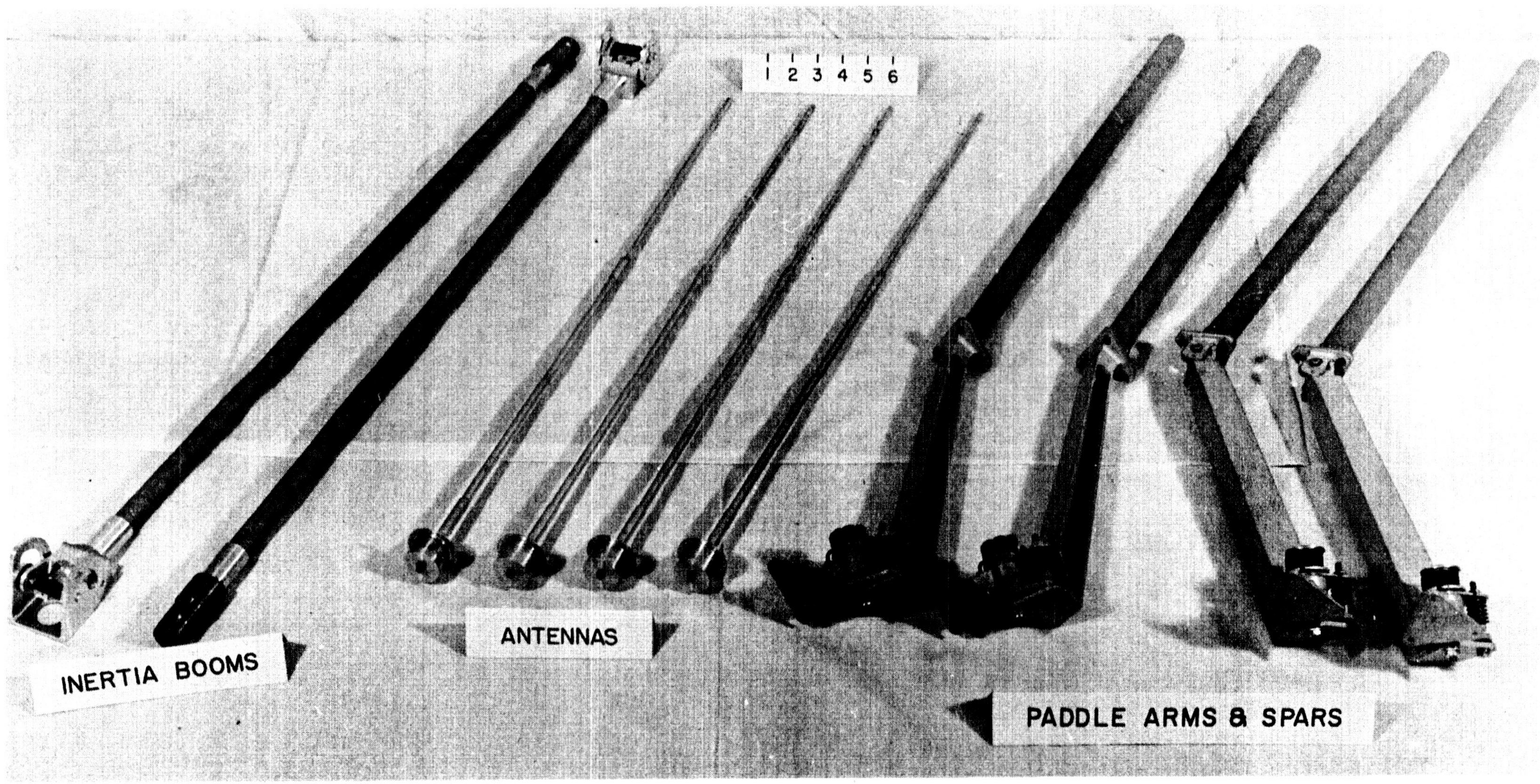


FIGURE 5 - SATELLITE APPENDAGES

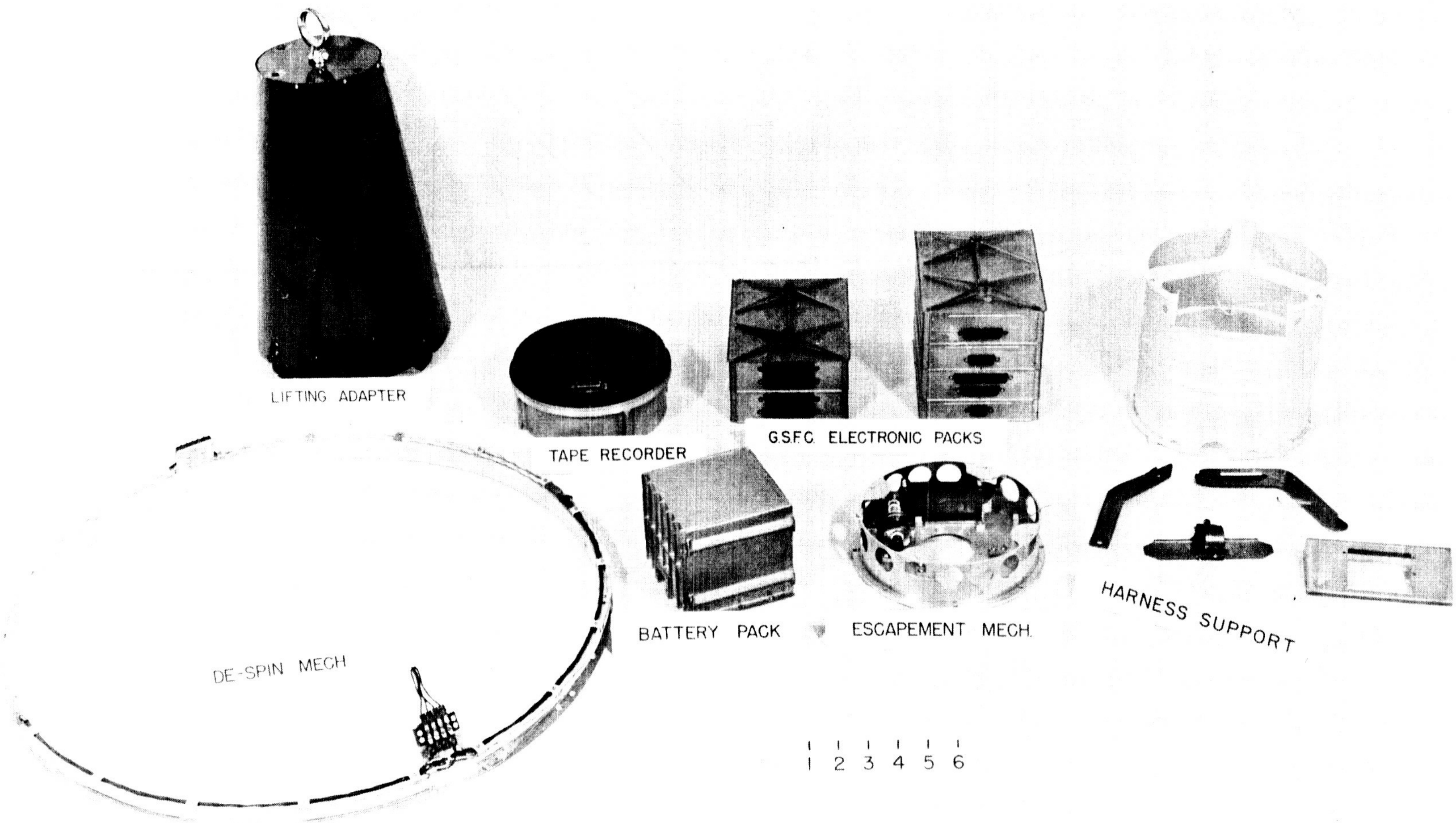


FIGURE 6 - GODDARD ELECTRONICS

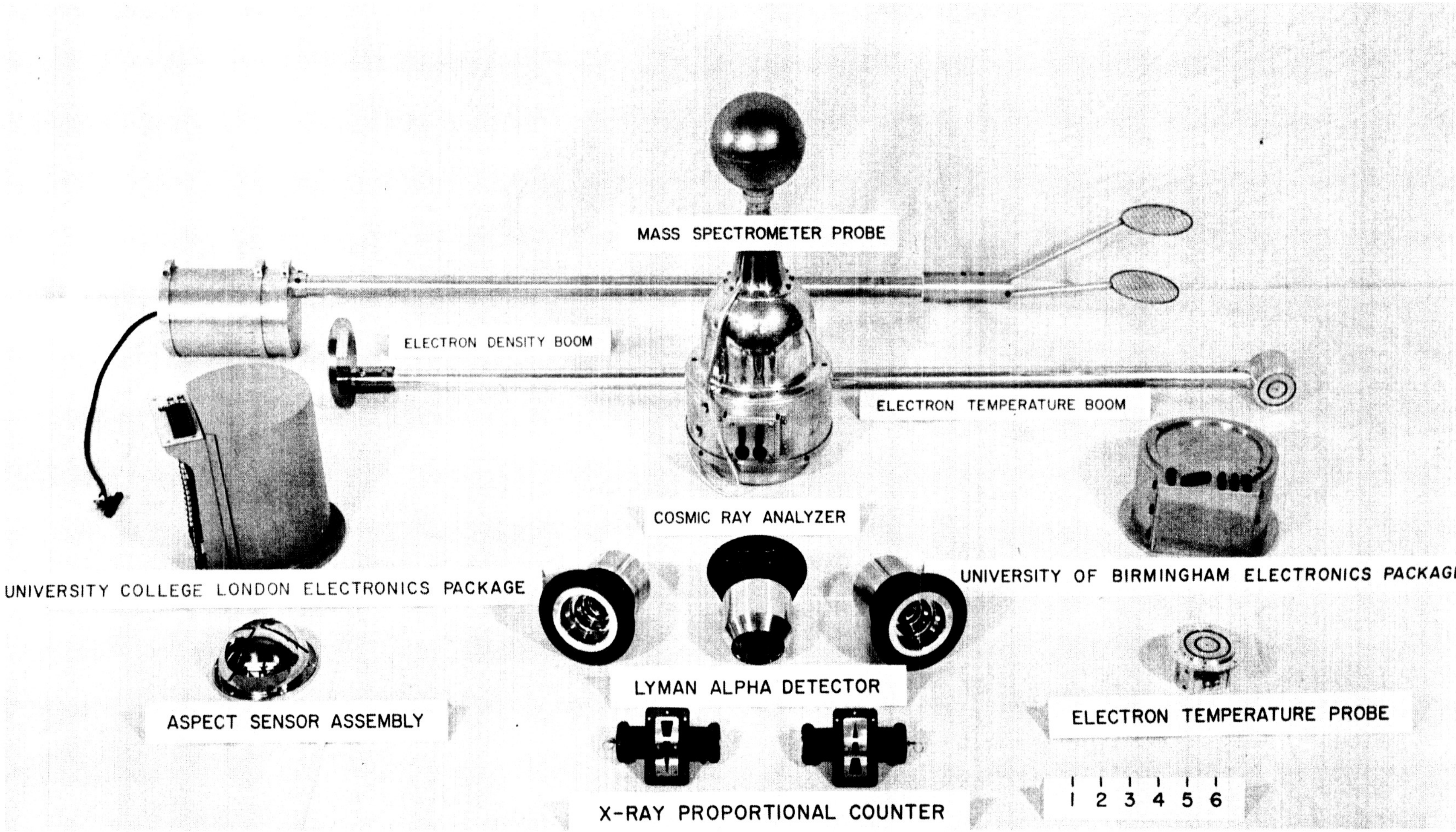


FIGURE 7 - UK ELECTRONICS

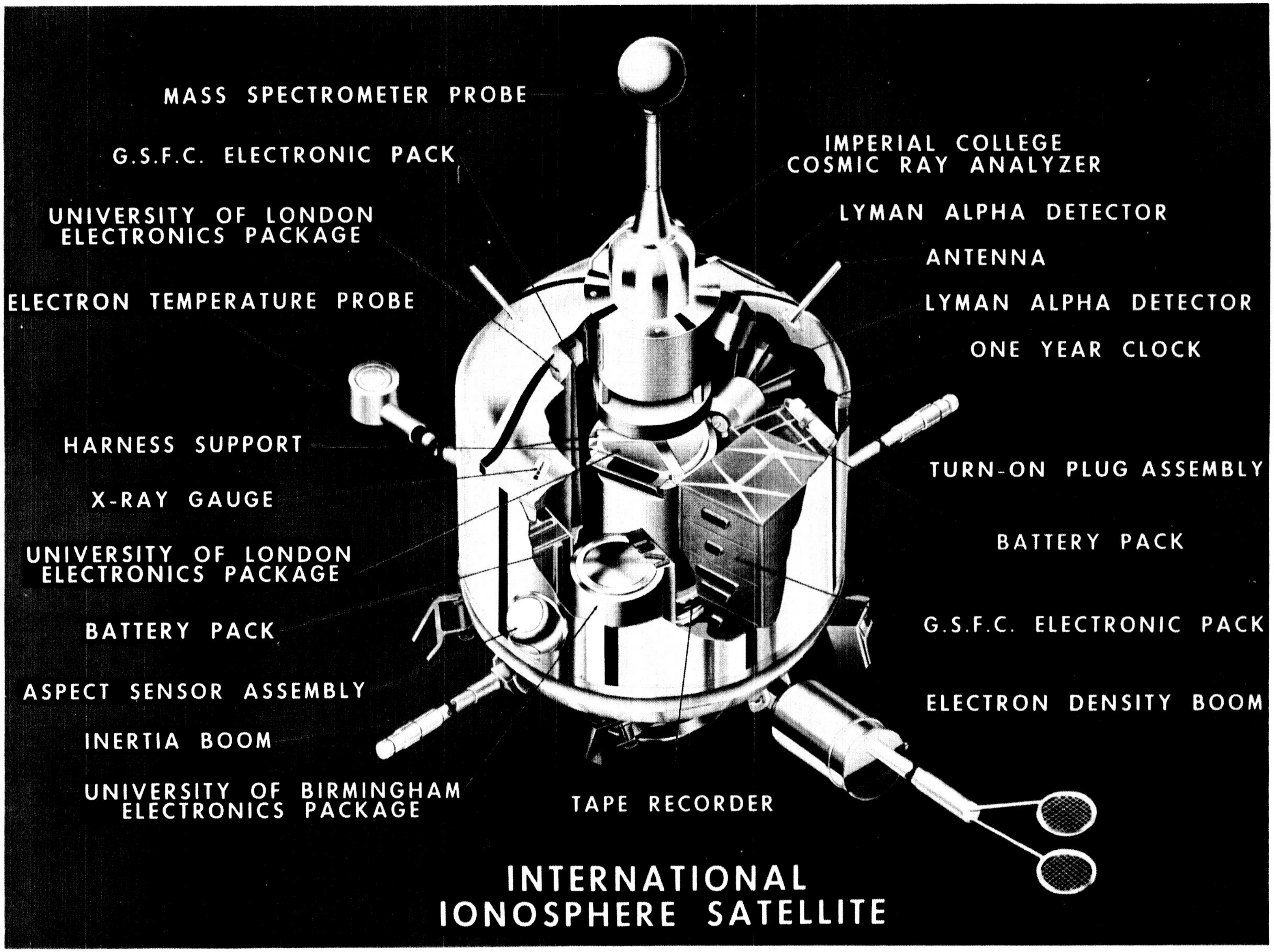

MASS SPECTROMETER PROBE
G.S.F.C. ELECTRONIC PACK
UNIVERSITY OF LONDON ELECTRONICS PACKAGE
ELECTRON TEMPERATURE PROBE
HARNESS SUPPORT
X-RAY GAUGE
UNIVERSITY OF LONDON ELECTRONICS PACKAGE
BATTERY PACK
ASPECT SENSOR ASSEMBLY
INERTIA BOOM
UNIVERSITY OF BIRMINGHAM ELECTRONICS PACKAGE
IMPERIAL COLLEGE COSMIC RAY ANALYZER
LYMAN ALPHA DETECTOR
ANTENNA
LYMAN ALPHA DETECTOR
ONE YEAR CLOCK
TURN-ON PLUG ASSEMBLY
BATTERY PACK
G.S.F.C. ELECTRONIC PACK
ELECTRON DENSITY BOOM
TAPE RECORDER
INTERNATIONAL IONOSPHERE SATELLITE

FIGURE 8

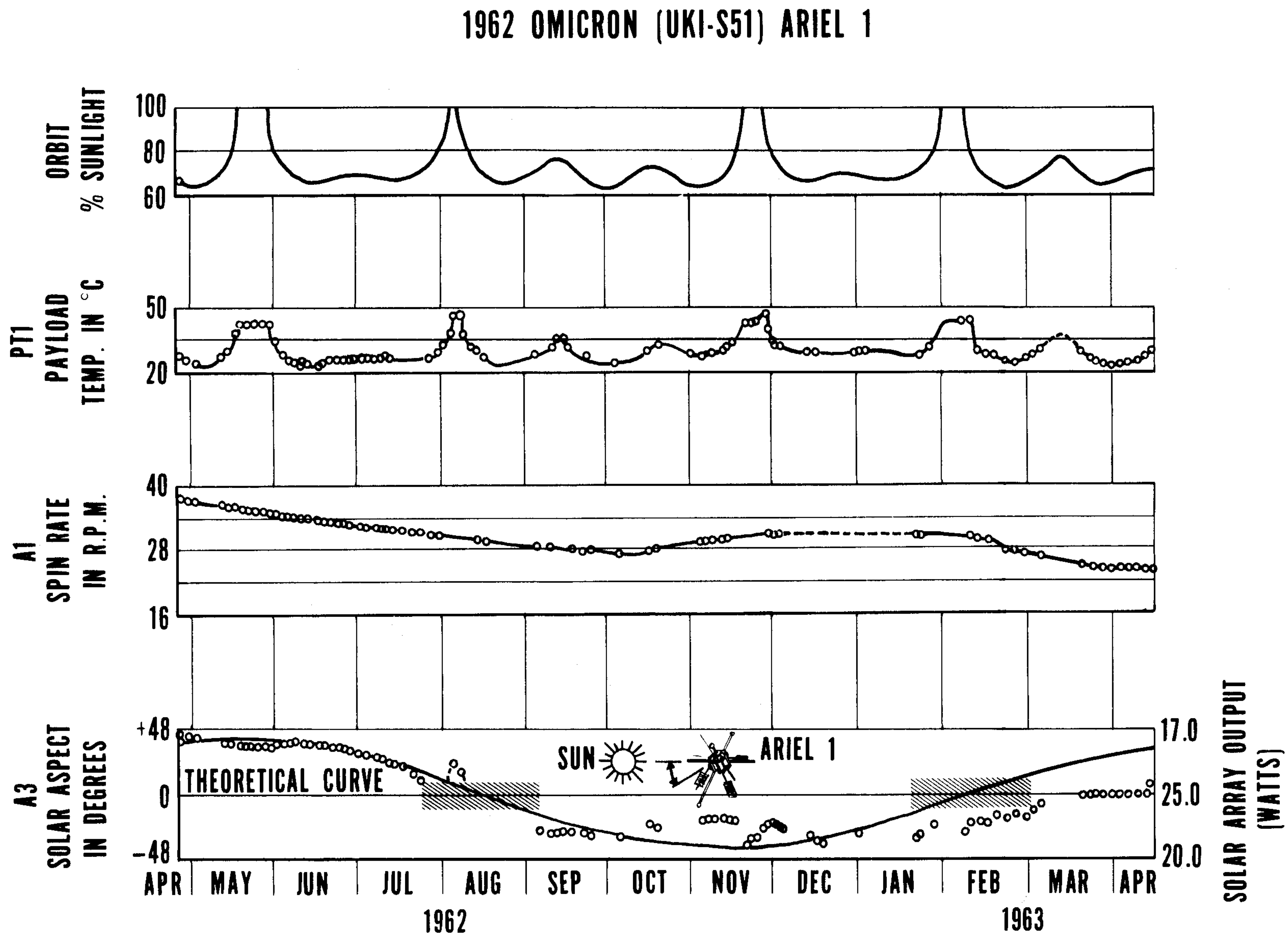

1962 OMICRON (UKI-S51) ARIEL 1
ORBIT
% SUNLIGHT
100
80
60
PT1
PAYLOAD
TEMP. IN °C
50
20
A1
SPIN RATE
IN R.P.M.
40
28
16
A3
SOLAR ASPECT
IN DEGREES
+48
0
-48
THEORETICAL CURVE
SUN
ARIEL 1
17.0
25.0
20.0
SOLAR ARRAY OUTPUT
(WATTS)
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
1962
1963

FIGURE 9

ARIEL 1 EXPERIMENT LIFETIME

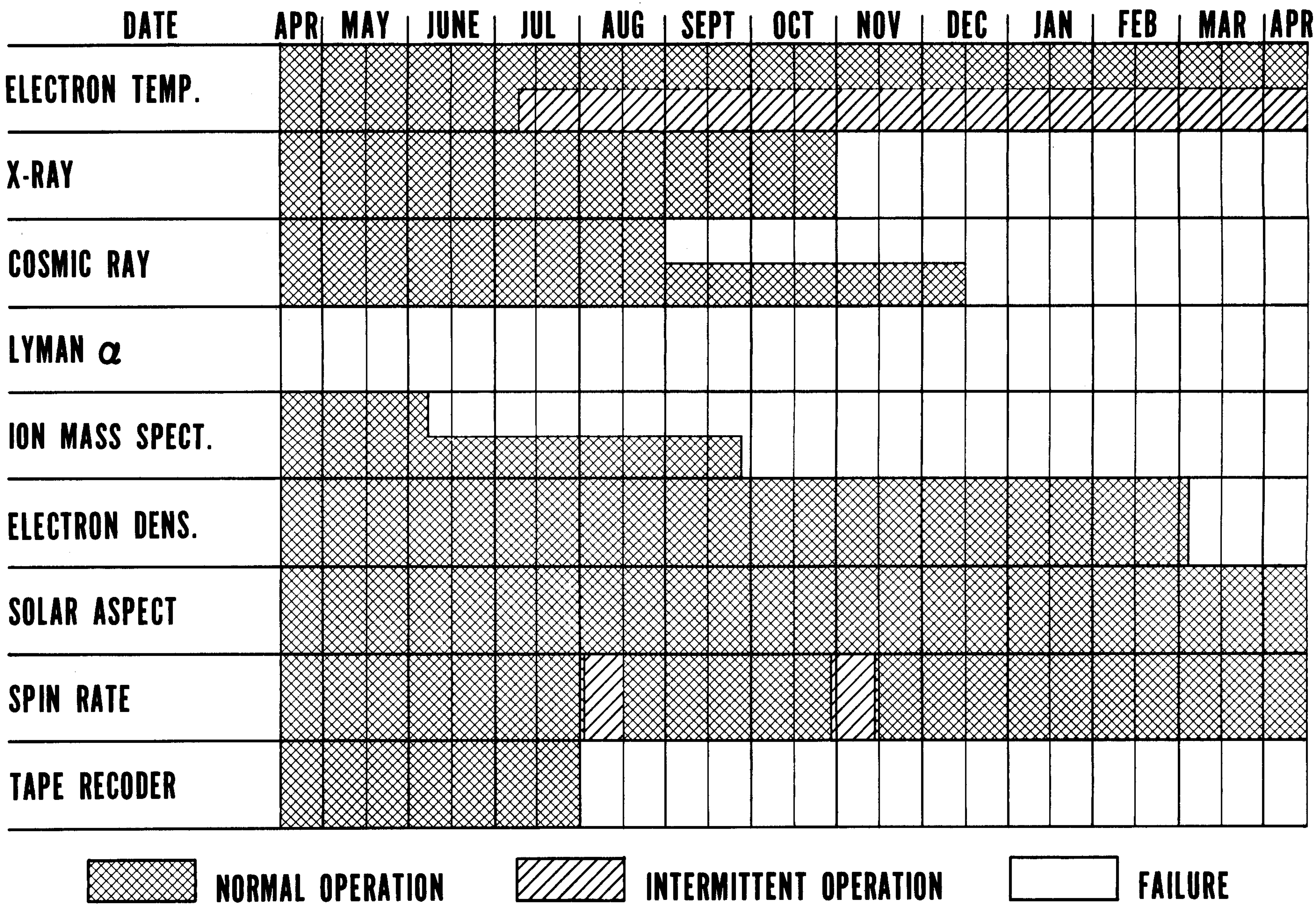
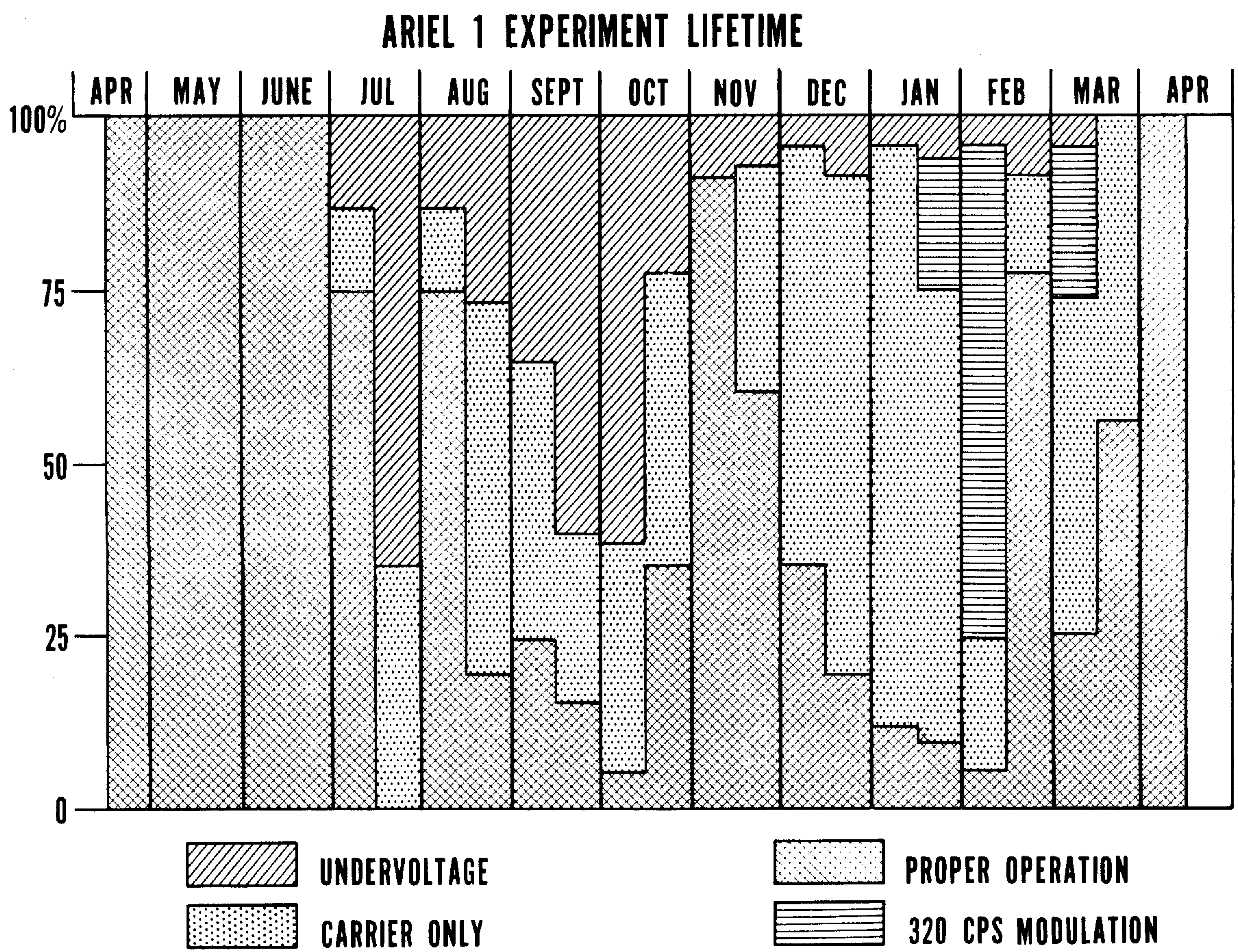


FIGURE 10



ARIEL 1 EXPERIMENT LIFETIME
APR
MAY
JUNE
JUL
AUG
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
100%
75
50
25
0
UNDERVOLTAGE
CARRIER ONLY
PROPER OPERATION
320 CPS MODULATION

FIGURE 11