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MARCH 1977

GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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March 1977

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GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

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ABSTRACT

Total solar irradiance was observed simultaneously outside the Earth's atmosphere by three types of absolute cavity radiometers and duplicates of four of the Nimbus 6 Earth Radiation Budget (ERB) solar channels in a June 1976 Sounding Rocket Experiment. The preliminary average solar "constant" result from the cavity radiometers is 1367 Wm^{-2} with an uncertainty of less than $\pm 0.5\%$ in S. I. units. The duplicate ERB channel 3 on the rocket gave a value of 1389 Wm^{-2} which agreed exactly with the Nimbus 6 ERB channel 3 measurement made simultaneously with the rocket flight. Therefore, Nimbus 6 ERB solar constant values should be reduced approximately 1.6% in order to convert the values to S. I. units.

3 March 1977

Rocket Calibration of the Nimbus 6 Solar Constant Measurements

INTRODUCTION

The NASA Office of Applications (OA) activated a project in late January 1976 to obtain independent calibrations of the solar constant measurement instrumentation aboard Nimbus 6. This instrumentation is known as the Earth Radiation Budget (ERB) experiment[1] and was built by Gulton Data Systems Division of Albuquerque, NM and the Eppley Laboratory of Newport, RI.

This project was initiated because the values which were being obtained for the solar constant from Nimbus 6 ERB were approximately 1½% higher than had been anticipated. An Ad Hoc Science Review Committee was convened by OA to consider the merits, probability of success of such a project, and the selection of the experiment payload. The committee personnel were:

Dr. Guenter Brueckner, Naval Research Laboratory, Washington, D.C.

Dr. Louis Drummeter, Naval Research Laboratory, Washington, D.C.

Dr. John Gille, National Center for Atmospheric Research, Boulder, CO

Dr. Verner Suomi, U. of Wisconsin, Madison, WI

Dr. Robert Madden, National Bureau of Standards, Washington, D.C.

Mr. Jon Geist, National Bureau of Standards, Washington, D.C.

Observers from the Office of Applications, Office of Space Science, Meteorology Program Office, and Nimbus 6 Project were also present at the meeting.

The Science Review Committee recommended that a rocket calibration of the Nimbus 6 ERB solar detectors should be implemented using a recoverable rocket platform. A further recommendation was that extensive ground intercomparisons under ambient and vacuum conditions be performed prior to the flight to determine any effects of packaging in the rocket configuration and the ability of the instruments to track each other under varying environmental conditions. Also recommended was the presence of an absolute radiometer other than one of the rocket instruments during the intercomparisons and that the calibration flight be launched while the Nimbus 6 ERB was still operational.

The experiments and principal investigators recommended for flight by the Science Committee and approved by NASA Headquarters management were:

	Experiments	Principal Investigators
1.	ERB duplicate solar detectors and Eclectic Satellite Pyrheliometer (ESP) prototype	John Hickey - Eppley Laboratory
2.	Primary Absolute Cavity Radiometer (PACRAD)	James M. Kendall, Sr. & Royal G. Harrison, - Jet Propulsion Laboratory
3.	Two Active Cavity Radiometers, Type IV (ACR IV)	Dr. Richard C. Willson - Jet Propulsion Laboratory

Personnel from Goddard Space Flight Center were assigned to the project as follows:

Project Manager - Charles H. Duncan, Earth Observation Systems Division

Project Scientist - Dr. Matthew P. Thekaekara, Atmospheric & Hydrospheric Applications Division

Vehicle Manager - W. Frank Lau, Sounding Rocket Division

*SPARCS Manager - R. Morgan Windsor, Sounding Rocket Division

*Solar Pointing Aerobee Rocket Control System (SPARCS)

The experiment instruments, upon delivery to GSFC, were integrated into the rocket canister (Figure 1). The canister with the instruments was integrated to the SPARCS and telemetry systems, shock, vibration, bend, balance and mass properties tests were performed on the package in order to qualify the payload for flight. The instrument canister was then subjected to various pressure and temperature variations to determine the effects upon the payload. These tests were performed at pressure levels varying from ambient to 10^{-6} torr using a solar simulator as the source of irradiance. Upon completion of these tests the instrument canister and support equipment were taken to the Joint Observatory for Cometary Research on South Baldy Peak, (Elev. 3.2 Km), near Socorro, NM. Dr. Elliott Moore of the New Mexico Institute for Mining & Technology is co-director of this observatory. Extensive intercomparisons both at ambient and at reduced pressure levels (Figs. 2 & 3) were performed over the Memorial Day weekend at this site. These intercomparisons of the rocket instruments were performed using the sun as source together with two absolute radiometers developed by Fröhlich and Brusa of the Physikalisch-Meteorologisches Observatorium, Davos, Switzerland.[2] The instruments used were designated as PMO2 and PMO5 and were operated by Mr. Brusa during the intercomparisons. The goal of the intercomparisons was to verify agreement of all the rocket instruments to within ± 0.5% for pressures between ambient and 10^{-4} torr.

The rocket instruments were subjected to the lower pressures since the payload was planned to be launched at reduced pressure to minimize thermal gradients between the instruments and the outer skin of the rocket. Due to the extremely tight launch schedule, these intercomparisons were not continued for a sufficient period of time to definitively characterize the relative performance of the instruments to within their bounds of uncertainty but were terminated when sufficient data were obtained to verify agreement of the instruments to within ± 0.5%.

A final Science Review was held at NASA Headquarters on June 3, 1976 to consider the results of the intercomparisons and to give final approval for flight. Since all the instruments had agreed to within ± 0.5% during the intercomparisons at South Baldy Peak and had performed satisfactorily during the pressure-temperature tests at GSFC the project was approved for flight.

An Aerobee 170 sounding rocket designated as 13.130 GS was the vehicle used for the flight of the experiment instruments and was launched at

12:20:08 PM MDT on June 29, 1976 at White Sands, NM (Figure 4). The launch coincided with a Nimbus 6 ERB measurement interval. The SPARCS pointing system operated nominally throughout the flight. The sun was acquired within 1' of the center of the sun at plus 93 seconds and continued to hold until plus 428 seconds. The rocket reached a peak altitude of 140 statue miles at plus 247 seconds. The recovery system performed normally and the payload was recovered intact, however, some sand and dirt entered the instrument cavities upon impact negating the possibility of post flight intercomparisons (Figures 5, 6, & 7).

All of the radiometers performed normally during the flight and sufficient data were obtained to define a value for the solar constant for each instrument of the payload.

Experiment Description and Results

1. Active Cavity Radiometer Type IV

The JPL ACR IV (S/N 402) is a two channel instrument containing two independent dual cavity detectors, each equivalent to that shown in Figure 8, sharing a common heat sink. The ACR 402 cavities are operated automatically in the active mode by a high gain, digital servosystem. Differential measurements are made using servo controlled shutters, facilitating reference (electrical calibration) observations during the flight by alternately admitting solar radiation to and blocking it from the detectors. The active cavity, differential mode of operation contributes substantially to the accuracy of ACR flight observations by providing in-flight electrical calibration, which obviates measurement dependence on the absolute temperature of the instrument and the atmospheric pressure.

A theoretical analysis of the physics of ACR 402 has been performed using the approach described in reference 3 for the ACR III. The actual flight measurement uncertainty will depend on the results of ACR IV cavity absorptance characterization tests to be performed by J. Geist at the National Bureau of Standards. At present it is known that the uncertainty for the ACR 402 solar constant results is substantially less than ± 0.5%. When the results of the NBS cavity characterization are available, and postflight testing has been completed at JPL, a more specific uncertainty bound will be known. What follows is a preliminary report of ACR IV results.

ACR 402 data was sampled 14 times a second for both cavities, producing over 4000 individual cavity power and temperature observations for each detector. Of these a representative sample of 556 shutter open-solar observations have been selected to characterize the range of ACR 402 measurements observed. Each ACR 402 detector (ACR 402 A and B) is independently shuttered. The shutters change state every 64 seconds, with a 90° phase overlap, providing simultaneous reference and observation measurements, and guaranteeing that at least one detector is observing the sun at all times. ACR 402 A experienced three 64 second shutter open periods, and 402 B two, during the flight. A total of 396 402 A and 160 402 B observations have been analyzed. The results are summarized in Table I. Weighting factors equal to the inverse square of the standard error for each period were used to determine mean results for each detector for all observations.

The observed irradiance was corrected to one astronomical unit to yield the "solar constant". The Earth was near aphelion at the time of the experiment, at a radius of 1.016698 A. U.

Table 1

Summary of Solar Constant Results by Measurement Period

ACR 402	Channel A			Channel B	
Measurement Period	A1	A2	A3	B1	B2
Mean Solar Constant (W/M^2)	1367.6	1368.1	1367.8	1367.6	1367.9
Standard Deviation[1] $\pm(W/M^2)$	1.2	0.3	0.8	0.3	0.6
Standard Error[2] $\pm(W/M^2)$	0.11	0.02	0.07	0.03	0.07
Mean Solar Constant	1368.1 ± 0.1			1367.6 ± .10	
Mean Solar Constant (Both channels) (W/M^2)	1367.9 ± .3				

[1]For single observation

[2]Standard deviation of mean

The solar constant result for the 1976 rocket ACR IV experiment is, to four significant digits: $H_o = 1368\ W/M^2$ with an uncertainty of less than $\pm 7\ W/M^2$ in S. I. units. The weighted mean solar constant results in Table 1 are shown with their statistical uncertainties. In theory pyrheliometers such as the ACR IV, with specular black cavities and the active, differential mode of operation, are capable of solar "constant" observations with SI uncertainties near ± 0.1%. The remaining analysis and instrument checkout presently being carried out at JPL, TRW and NBS is to determine how closely the ACR 402 adhered to its theoretical performance during the 1976 rocket flight. When this work is concluded, final publication of the results will be made with the actual flight uncertainty as nearly as it can be determined.

2. PACRAD

The PACRAD[4] used on the Aerobee has a massive copper heat sink (7 lbs.) which encloses the cavity assembly. The cavity assembly consists of a symmetrical arrangement of two cavities. The irradiated cavity becomes warmed (about 1°C above the heat sink) for one solar constant. The compensation cavity serves as a temperature reference for the cold junctions of the thermopile, and provides compensation for time rate of change of the radiometer heat sink. A heater winding is located on the cone in the irradiated cavity to provide electrical heating, accurately equivalent to irradiance heating, for an electrical calibration capability. A resistance thermometer on the heat sink provided a continuous and accurate measurement of the heat sink temperature.

The electronics contained in the flight configuration of the PACRAD amplified the thermopile output and converted it to a frequency, and amplified the output of the resistance thermometer circuit to provide an analog output of the heat sink temperature. All calibrating functions such as the electrical calibration and amplifier gain calibration, were performed by the ground support instrumentation through the umbilical connection. The geometry of the view limiting aperture provided a 25° viewing angle (12.5° on either side of the center line). This viewing angle produces a pointing tolerance of 1.38°.

The radiometer was calibrated repeatedly, at atmospheric pressure and at high vacuum, and at various temperatures. The calibrated values repeated to within ±0.03% over a period of three months up to the time of launch. The tests and calibrations, made at JPL, GSFC, South Baldy Mountain, and White Sands indicated that the PACRAD would make absolute solar irradiance measurements with an accuracy of better than 0.2%.

The two data channels recorded during the flight were the thermopile output frequency and the heat sink thermometer analog output. The frequency was counted during periods of 10 seconds each, and recorded along with the heat sink temperature on the ground support instrumentation. The two data channels were recorded on the telemetry receiving stations tape recorders as continuous signals. These tapes were played back to the ground support instrumentation after the flight and produced an exact duplicate of the real time flight data. At 130 seconds after launch the radiometer achieved equilibrium at the value recorded for the solar constant. This value remained constant (within 0.03%) for 200 seconds. The heat sink temperature increased 0.21° C during the 200 second measurement period. There was no indication of aerodynamic heating, as the rate of temperature increase was essentially the same as the rate of increase for several hours before the flight. The radiometer was recovered intact and operational, except for sand in the cavity. A sample of the data was reduced immediately after the flight which gave a value of 1363 W/M^2 for the solar constant. Subsequent data reduction and a scientific investigation of the absorptivity of the PACRAD cavity indicated a solar constant value of 1364 W/M^2 with an uncertainty of $\pm$ 4 W/M^2.

3. ESP & ERB

The ERB/ESP Rocket Radiometer consists of two flight packages. The sensor package includes five detector channels and the primary electronic components. The PCM telemetry package contains the data processing elements and the power supply. These two packages are shown in Fig. 9. The five sensors include four which match channels 2, 3, 4 and 5 of the ERB solar array and one ESP pre-prototype sensor. The ESP sensor and ERB Channel 3 have no filters or windows and respond to radiant energy over the total wavelength range from < 0.2 to $> 50\mu m$. Channel 2 responds in the region 0.18 to 3.8μm and Channels 4 and 5 have common longwave cutoffs at 2.8μm with shortwave limits of 0.526 and 0.698μm respectively. The ERB channels which are described elsewhere[1] have wire-wound plated thermopile elements with flat plate receivers. The ESP sensor is less well known and requires a short explanation here. The device consists of dual cavity receivers on opposing sides of a true double thermopile of the Hickey-Frieden (H-F) type. This torroidal thermopile has properties such that a plated set of hot junctions and cold junctions are separately deposited on either side of the circular body. The two sets of hot junctions are at the bases of the two cavity receiver units and the two sets of cold junctions are heat sunk to the body. Each silver cavity receiver is of the type which has an inverted cone within a cylinder. The electrical heater is wound on the cavity elements. The interior of the cavity is painted with specularly reflecting black paint.

The double balanced thermopile and cavity configuration allows for operation in a mode which we have called the "Angstrom-mode" because of its similarity to the method of operation of an Angstrom Pyrheliometer. In this mode the rearward facing cavity is electrically heated while the forward cavity is irradiated. This mode of operation was chosen for the rocket experiment, but was limited to the passive state (no servo) because of the electronics of the rocket package not having the capability of the true ESP electronics. For the flight the rear heater power was set to a level very close to that needed to balance the expected solar irradiance, so that the device was in very good balance near thermopile null over the duration of the on-sun period. The field of view of the ESP channel was constructed to match that of the ERB channels of NIMBUS 6 viz.: 10° unencumbered, 18° central and 26° maximum. These are full field angles such that the 10° unencumbered field is equivalent to a slope angle of 5°. During ground calibrations and intercomparisons the rocket instrument package is fitted with a field of view adapter which causes the channel fields to be equal to those of standard absolute radiometers, i.e.: 5° central angle and 0.8° slope angle.

The ERB/ESP rocket electronics is comprised of two units, the sensor subassembly containing both the prime and secondary sensors and their signal conditioners and the PCM containing the data processing elements and power supplies for the sensor subassembly. Signals from: thermopiles, cavity thermopile, and rear cavity heater voltage and current, were conditioned with ERB type differential instrumentation amplifiers. The salient difference was their employment in a dc as opposed to ac (carrier) amplification system. To eliminate amplifier offset, the amplifier's differential input signal was reversed during alternate data frames and the difference of the resultant responses averaged. The secondary temperature sensors are thermistors deployed in precision voltage divider circuits. Both excitation and divider output are measured and used in the computation of temperature eliminating the effect of excitation variation in temperature determination. The resultant high level, essentially dc signals, are applied to a standard PCM data processing system consisting of: a single ended analog multiplexer, allowing for time sharing of subsequent elements, and a 12 bit successive approximation type ADC preceded by an absolute amplifier, the latter employed to both utilize the 12 bit resolution available and eliminate possible ADC non-linearity as an error source in the offset cancelling scheme employed in the conditioning of the primary sensors. The digitized data is inserted in a format which includes frame identification and a two word sync code. The serial data stream is then buffered by an isolated premodulation filter prior to being sent to the rocket's telemetry system consisting of a voltage controlled subcarrier oscillator feeding an RF link. The PCM processing system is controlled by a program stored in an internal Programmed Read Only Memory (PROM). By quantizing the sensor data prior to insertion in the rocket's telemetry system, the calibration of the rocket/ground support system in no way enters into the determination of the measured parameters. The ERB/ESP experiment control unit is shown in Fig. 10.

The performance of the ERB Channel 3 and ESP channel during the period from launch through full solar registration is shown in Fig. 11. The output signal counts for the cavity channel is given in the left hand margin and that for Channel 3 on the right. The plot is essentially vs. time as expressed in data frames. It can be seen from the cavity channel output signal that the ambient pressure increased inside the payload compartment shortly after launch. Channel 3 does not respond to this pressure change since it has no radiative or electronic stimulus and retains its zero level. When the payload is opened up to space at data frame 25, both channels show a response to cold space by a negative going signal. This signal does not constitute the full possible negative signal which would be approximately -3132 counts for the ESP channel and -33 counts for Channel 3, because the field is partially filled with solar radiation as was indicated by a positive going signal on Channel 2 which does not respond to cold space because of its quartz windows. This effect further demonstrates the high speed of the wirewound thermopiles coupled with the state-of-the-art electronics, and also exhibits the necessity for applying a true space reference offset to measured values. As the sun enters the field of view when the SPARCS produces solar alignment the channels reach full response. In Fig. 12 the time period beyond solar acquisition is shown on an expanded scale. Channel 3 appears to increase over the time period, reaching equilibrium within one count signal output at about 280 seconds after launch. The same is true of the cavity channel. However, the nature of the slope of the curve is different. While Channel 3 is increasing the cavity channel is decreasing. This would infer dynamical heating within the instrument or a reduction in pressure or a combination of both at a very low level. However, the plot of Channel 2 shows a much stronger increase a a function of time which would indicate that the pressure change solution is more plausible. Channel 2 did not reach equilibrium until the very end of the on-sun period. Over the entire measuring period the cavity channel's peak-to-peak deviation was 0.21% while the ERB Channel 3 was 0.19%. The resolution each instrument is approximately one part in three thousand or .03%. Based on the foregoing the ability of Channel 3 and the cavity channel to operate on the rocket to a high accuracy level is confirmed. However, for the other three ERB channels which evacuate more slowly because of the windows mounted in them, the best possible operation cannot be achieved unless the payload vacuum can be retained during launch. For these channels we can only accept the latest values during the on-sun time as being representative.

The results from the rocket experiment and the NIMBUS 6 ERB channels are summarized in Table II. The values listed for Channel 2 and Channel 3 of the NIMBUS satellite are values taken on the day of the flight with the distinction that the Channel 2 value was measured by matching Channel 1. This value of 1369 has been stable within 0.2% since NIMBUS launch in July of 1975. Channels 2 and 4 of the ERB Experiment have degraded over the period. The values for Channels 4 and 5 are those from the earliest orbits corrected for earth-sun distance. It should be noted that the values for Channel 2 are 2% lower from the rocket flight than for NIMBUS as are the values for Channel 4. Channel 5 is in good agreement (0.14% higher for the rocket). While these three channels 2, 4 and 5 of the rocket are in question because of the pressure effects previously mentioned these effects should have been smaller than the differences between the ERB values and the rocket values for Channels 2 and 4.

The main channels of this experiment were Channel 3 and the cavity channel. Channel 3 on the rocket agreed with the concurrent Channel 3 of NIMBUS 6 to better than 0.1%. This give confidence that the consistency in the calibration method has been retained to a very high degree over a period of more than three years. However, the cavity value of 1369 W/M^2 is approximately 1.5% lower than the Channel 3 value. Since the cavity is in good agreement with the other absolute radiometers on the rocket flight, and since the ground intercomparison of Channel 3 and the cavity showed no deviations of this magnitude it must be assumed that the calibration of Channel 3 which is accurate for ground measurements cannot be assigned to space measurements. Despite numerous tests to discover the reason for this inability to retain calibration traceability for space measurements with Channel 3 no suitable explanation has been found.

In calculating the irradiance value obtained by the cavity channel a number of instrument factors are included. These are normally called correction factors and include such items as the absorptivity of the cavity, the non-equivalence of the device for electrical and radiant heating, the percentage of scattered light in the baffle assembly, the area of the precision aperture, and the accuracy of the measurements of heater current and heater voltage. The values for some of these correction terms, notably the absorptivity of the cavity, have not been measured to the extent necessary to assign an uncertainty of $<0.5\%$ even though this type of device is capable of achieving uncertainties of the level of 0.1% when all of these correction terms are assessed in a more comprehensive program.

Table 2

Summary of Results From the ESP-ERB Instrumentation

Channel	Wavelength Limits	Rocket	Nimbus 6
2	0.18-3.8μm	1342 Wm^{-2}	1369 Wm^{-2}
3	< 0.2->50μm	1389 Wm^{-2}	1389 Wm^{-2}
4	0.526-2.8μm	950 Wm^{-2}	970 Wm^{-2}
5	0.695-2.8μm	679 Wm^{-2}	678 Wm^{-2}
ESP	<0.2->50μm	1369 Wm^{-2}	--

CONCLUSIONS

The values obtained for tho solar total irradiance or solar constant from each of the rocket instruments as well as the value obtained simultaneously from Nimbus 6 ERB are summarized in Table 3.

Table 3

Preliminary Results of Solar Constant Measurements

Experiment	Solar Constant Value
ACR IV, Channel A	1368 WM^{-2}
ACR IV, Channel B	1368 WM^{-2}
PACRAD	1364 WM^{-2}
ESP	1369 WM^{-2}
Unweighted Average for Absolute Detectors	1367 WM^{-2}
ERB Rocket Channel 3	1389 WM^{-2}
ERB Nimbus Channel 3	1389 WM^{-2}
Average ERB Rocket and Satellite Values	1389 WM^{-2}
Difference between ERB channel 3 and absolute detector results	1.6%

The measurements of the solar constant obtained by the ERB sensors exceeded those obtained by the absolute radiometers by 1.6%. The uncertainty in the average of the absolute radiometers result is probably less than ±0.5%. This rocket experiment indicates that the values being obtained by the Nimbus 6 ERB instrument are higher than the true values of the solar constant in SI units by approximately 1.6%. The values obtained by ERB channel 3, ESP, and the ACR's during the intercomparisons at Mt. South Baldy agreed closely with each other but were consistently higher than the values obtained by the PACRAD and the PMO instruments.

The behavior of the absolute radiometers was consistent during the rocket flight as compared to the Mt. Baldy intercomparisons whereas the ERB channel 3 yielded significantly higher values in comparison to the absolute radiometers during the rocket flight. This result indicates that ground based calibrations of detectors such as ERB are not directly transferable to space operations.

The cause for this behavior is still not identified although extensive studies and testing of possible sources for this anomalous behavior have been performed.

The measurements of the solar total irradiance or solar constant by the absolute radiometers in this rocket experiment are the most accurate which have been made to date. While the preliminary S. I. uncertainties for these instruments is stated conservatively to be less than ± 0.5%, their actual uncertainties may be much less. The theoretical uncertainty of measurements by the instruments is ±0.1 to ±0.2%. The definite flight results from each experiment will be published by the appropriate investigator at a later date. Until these results are published, the value of 1367 WM^{-2} should be used for the solar constant in SI units. This is the unweighted average of the values obtained by the absolute radiometers during the rocket flight. The values for the solar constant being obtained from the Nimbus 6 ERB experiment should therefore be reduced by approximately 1.6% in order to convert the values to S.I. units.

ACKNOWLEDGEMENTS

A project of this magnitude would not have been possible without the knowledge, skills, and cooperation of many persons in several laboratories and locations. The authors wish to acknowledge their appreciation to all of those who contributed toward making this flight successful.

We especially wish to acknowledge the contribution of Frank Griffin and Roger Frieden of the Eppley Laboratory, Arthur Cone, John Gniady, Robert Maschhoff and Zeke Hercey of Gulton Industries, Inc. for their contribution to the ESP and ERB experiment. To Mac Chapman, Dr. Ralph Schilling, and Randy Martin of TRW for their contribution to the ACR IV experiment. To Gordon Wiker, Dick Rice, and Russ Whitman of JPL for their contribution to the PACRAD experiment. To Harvey Rice of General Electric for instrument integration into the rocket payload, to William Boyer of Goddard Space Flight Center for data acquisition support during inter-comparisons and flight, to Thomas Laughlin and Harold Zimmer of Lockheed Missiles and Space Company for telemetry and SPARCS support, to Dr. Elliot Moore of the New Mexico Institute of Mining and Technology for making the Joint

Observatory for Cometary Research available for pre-flight intercomparisons of the instruments, and to Frank Lau, Morgan Windsor and Lloyd Briggs of the Sounding Rocket Division of GSFC.

We also wish to acknowledge Harry Press, Chief of the Meteorology Program Office, Dr. Adrienne Timothy, Chief of Solar Physics, Dr. Morris Tepper, Director of Meteorology and John Theon, Project Scientist for Nimbus 6 for their vigorous support of this project.

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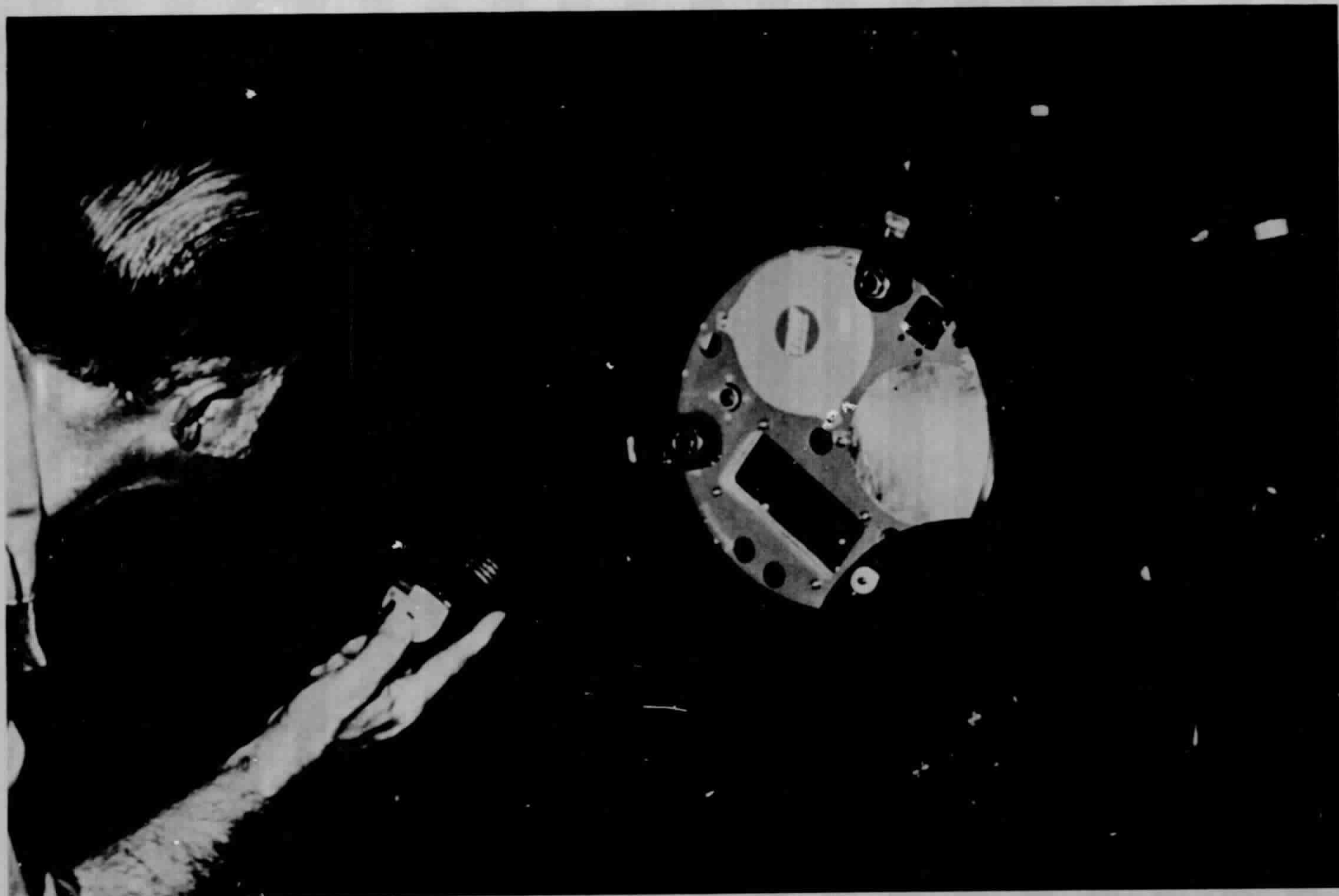

Figure 1. Front view of rocket payload during pre-launch horizontal test.
The instruments are: clockwise from the top: ACRIV, PACRAD, ERB-ESP.

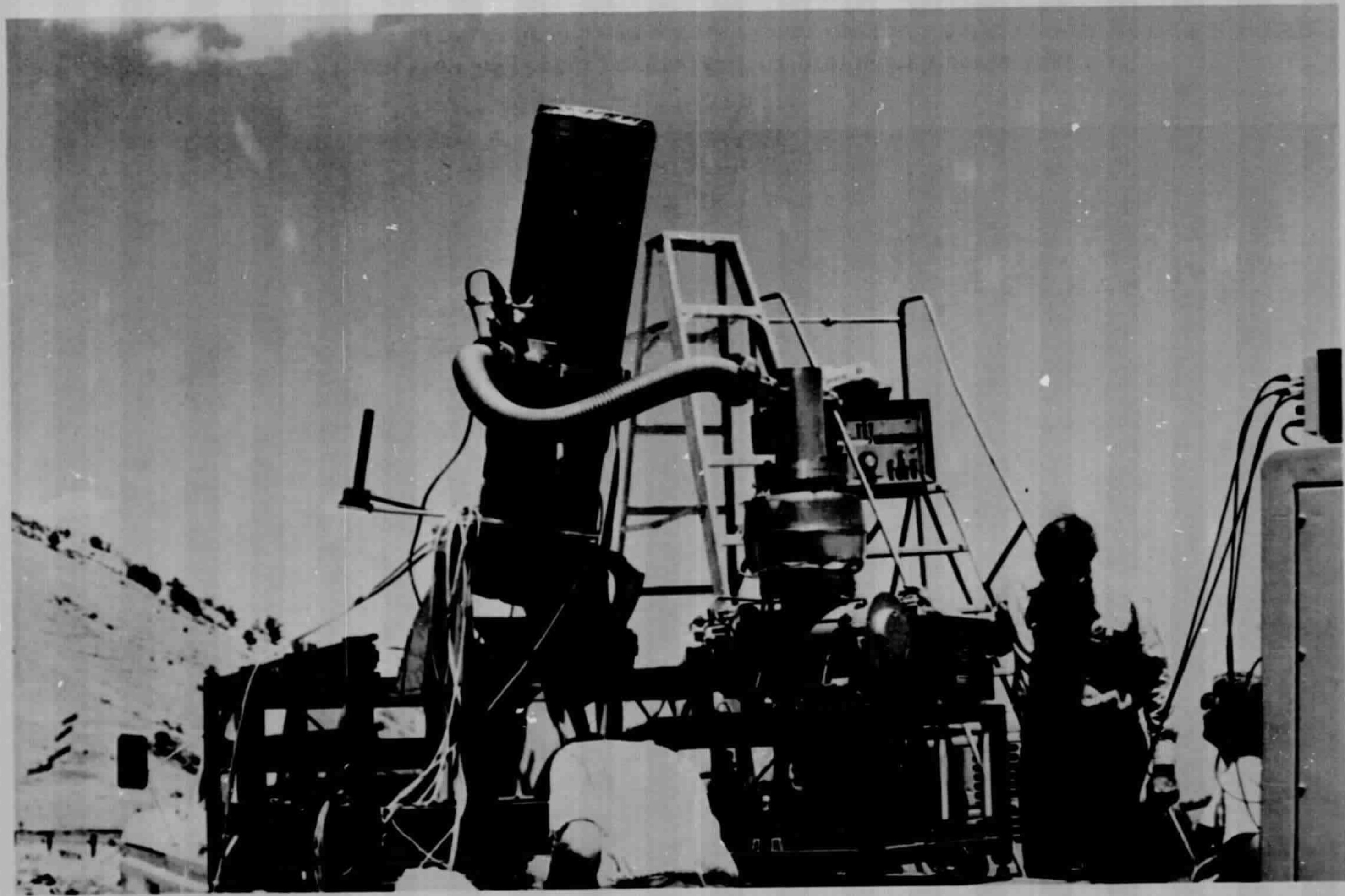

Figure 2. Rocket payload canister with vacuum pump attached during South Baldy intercomparisons.

Figure 3. View of data collection systems at South Baldy.

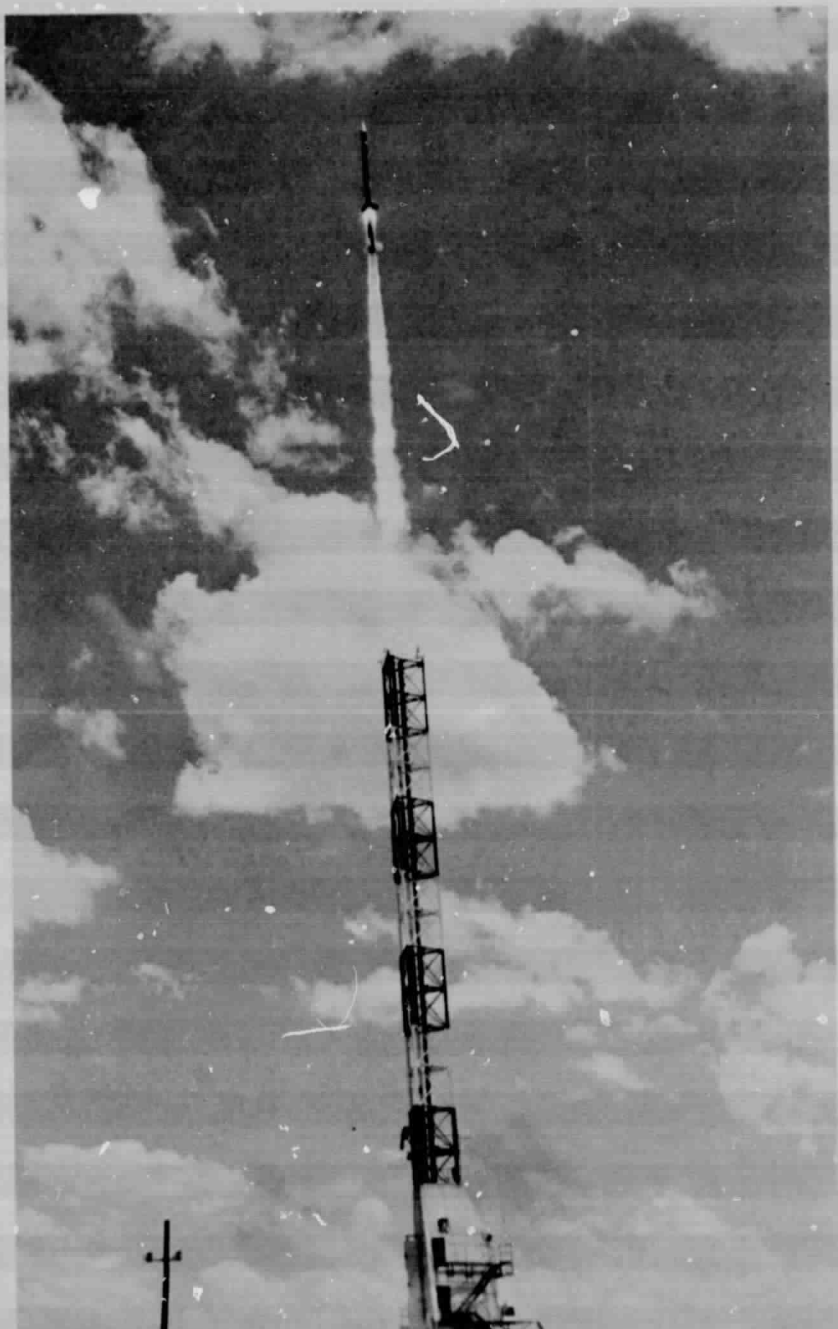

Figure 4. Launch of 13.130 GS rocket

Figure 5. View of recovery area

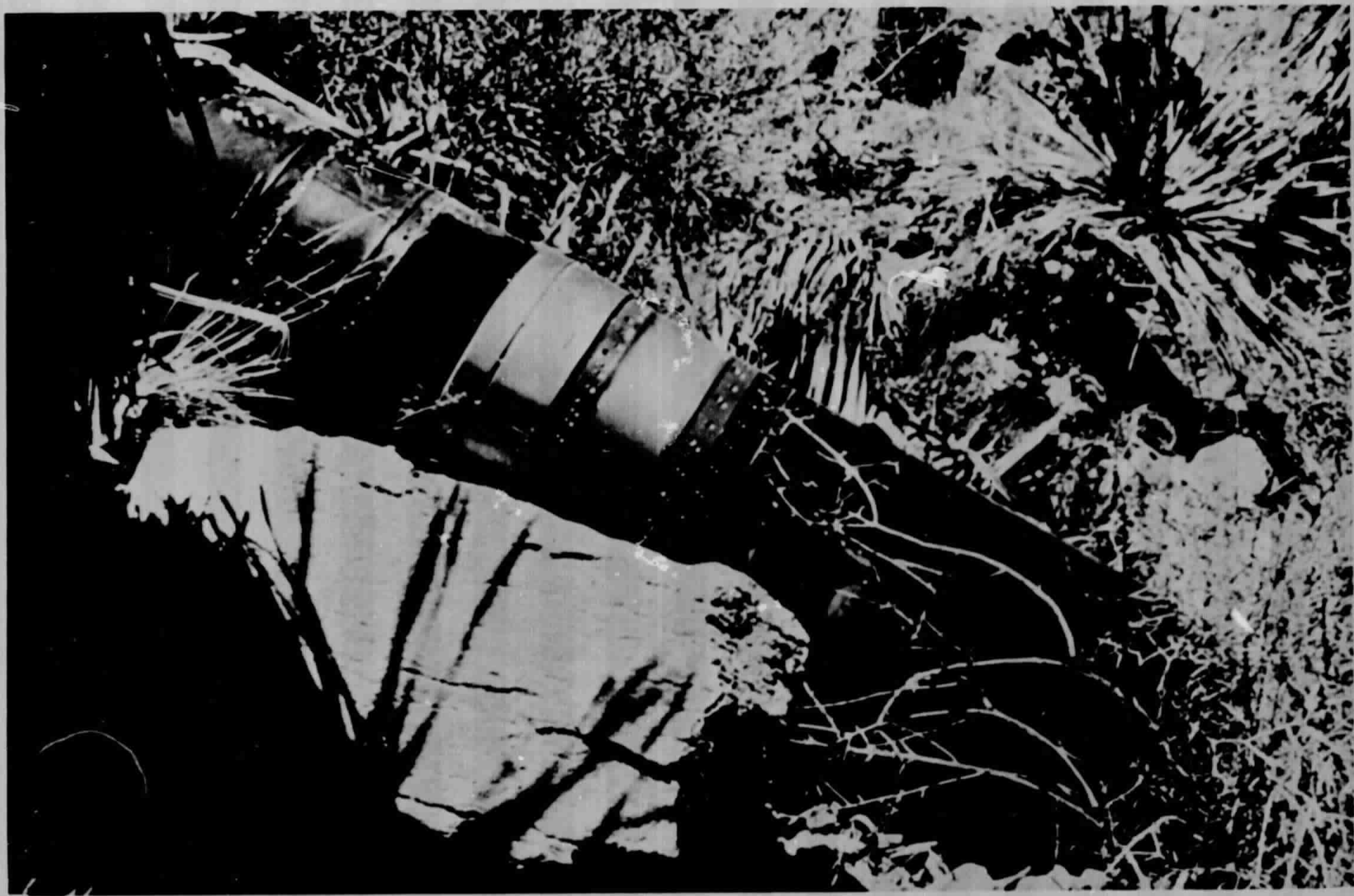

Figure 6. Side view of payload after impact

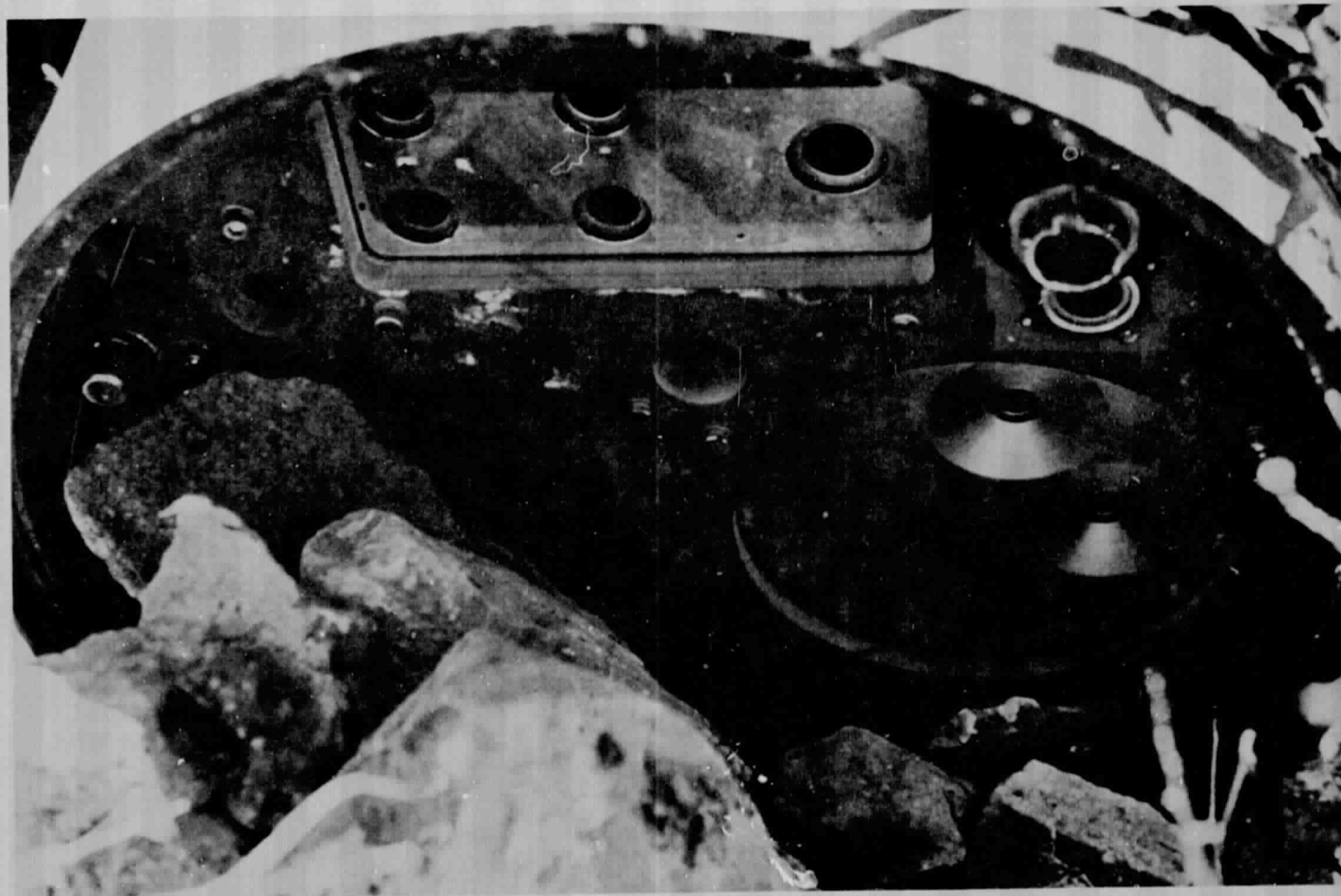

Figure 7. Front view of payload after impact

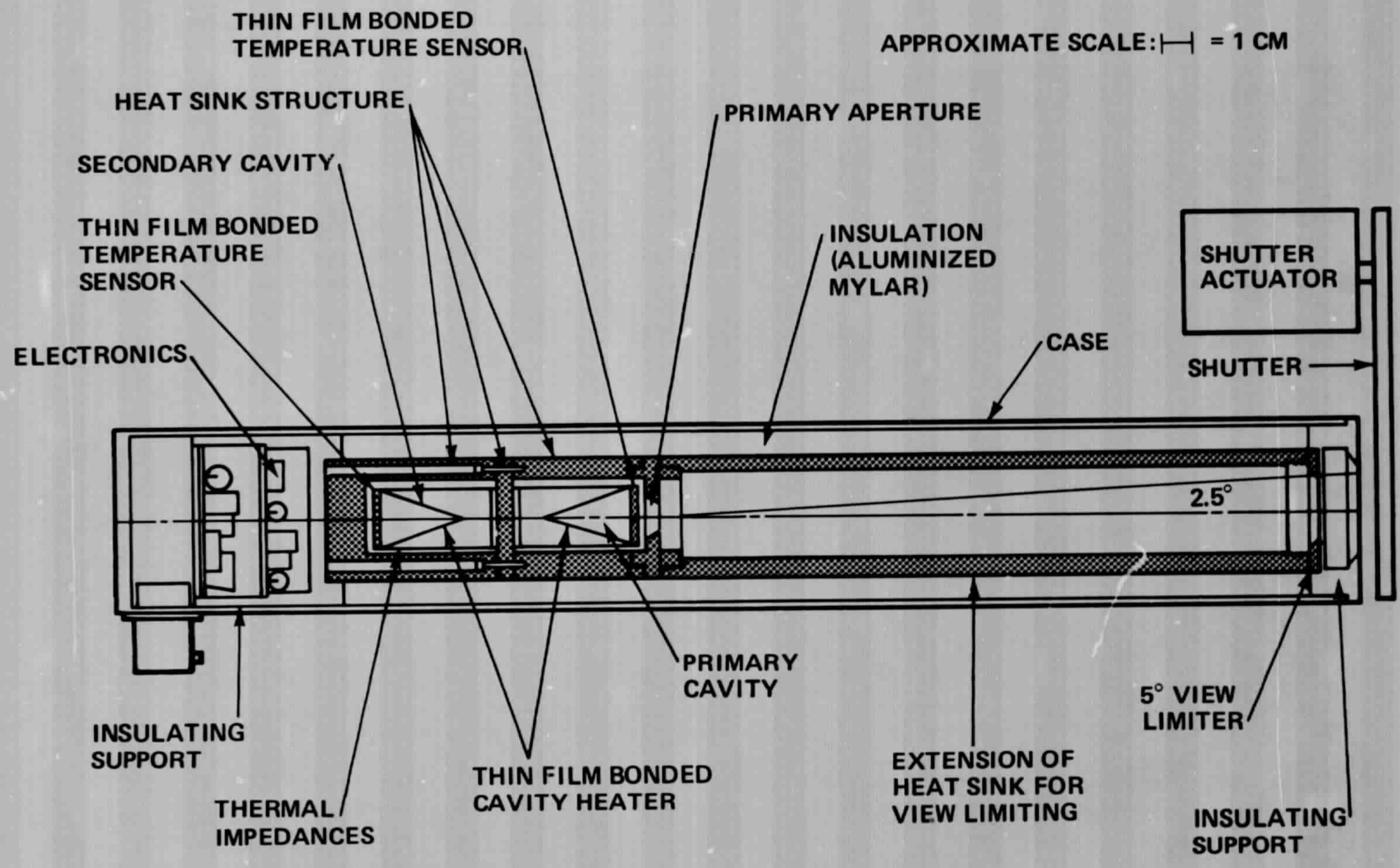

Figure 8. Schematic drawing of JPL-TRW ACR IV

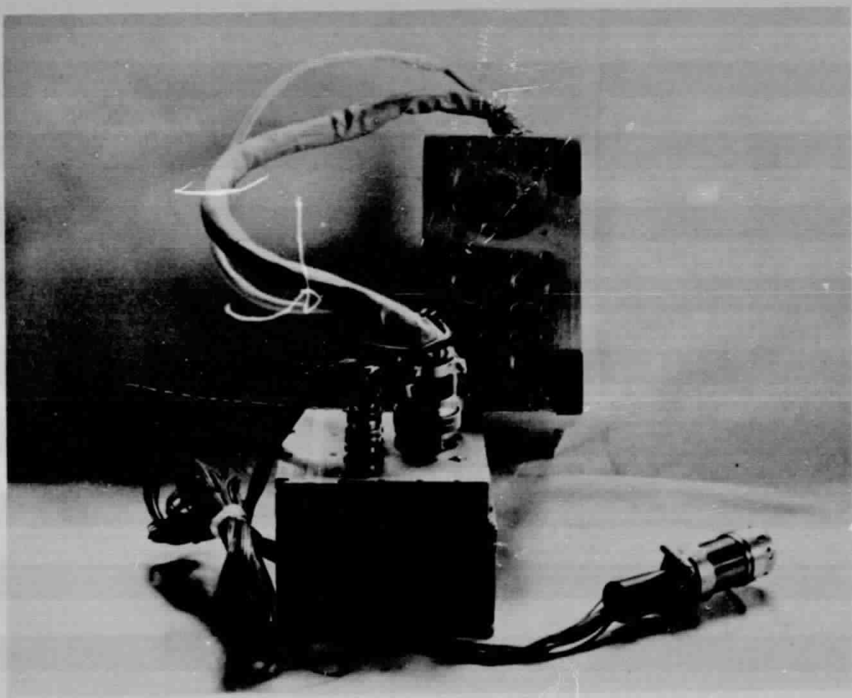

Figure 9. ERB-ESP flight instrument

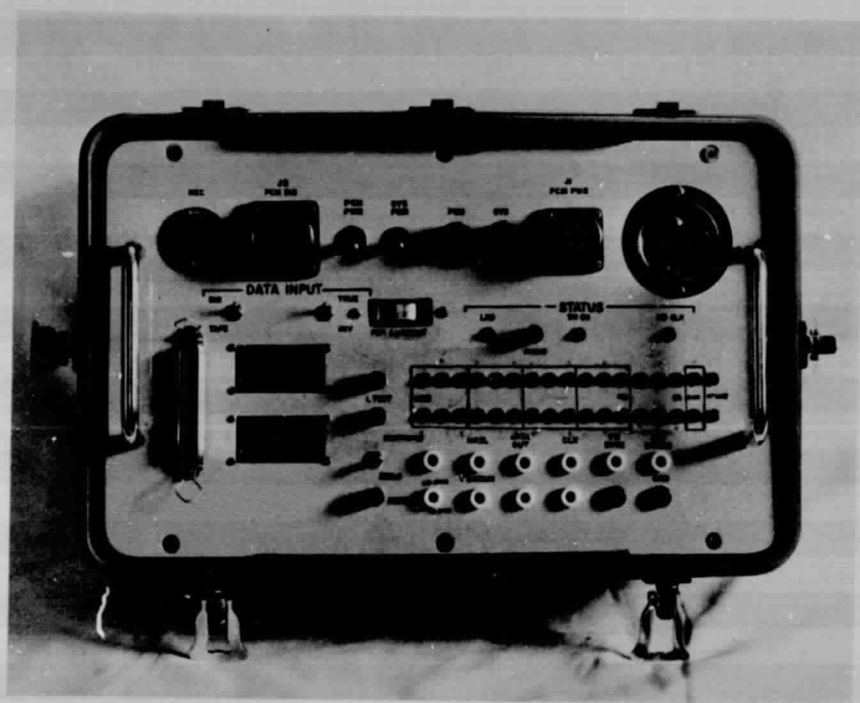

Figure 10. ERB-ESP Experiment Control Unit

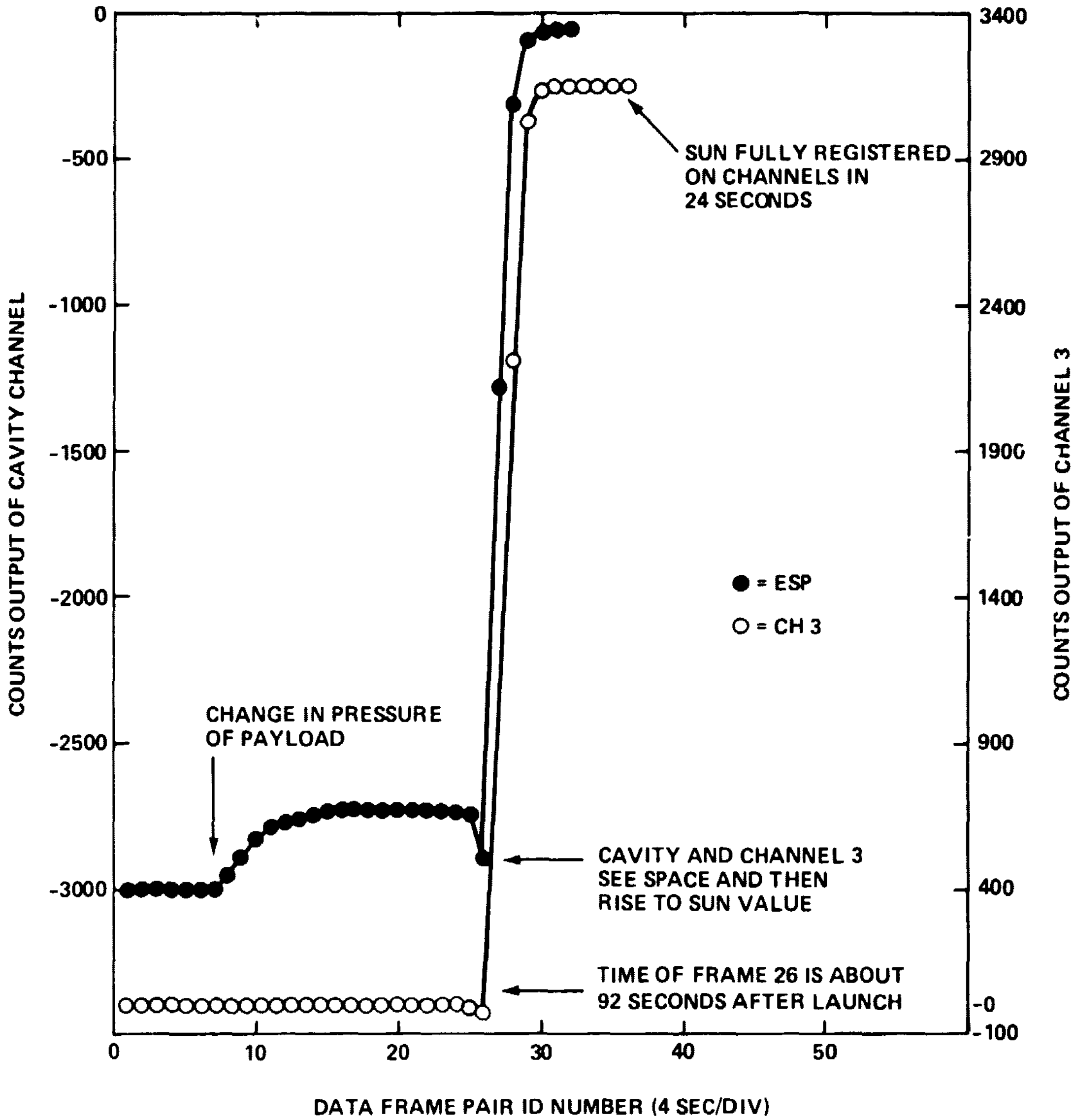

Figure 11. ERB-ESP Rocket Radiometer Plot of Output Counts for Channel 3 and ESP cavity from launch to Solar Acquisition 29 June 1976

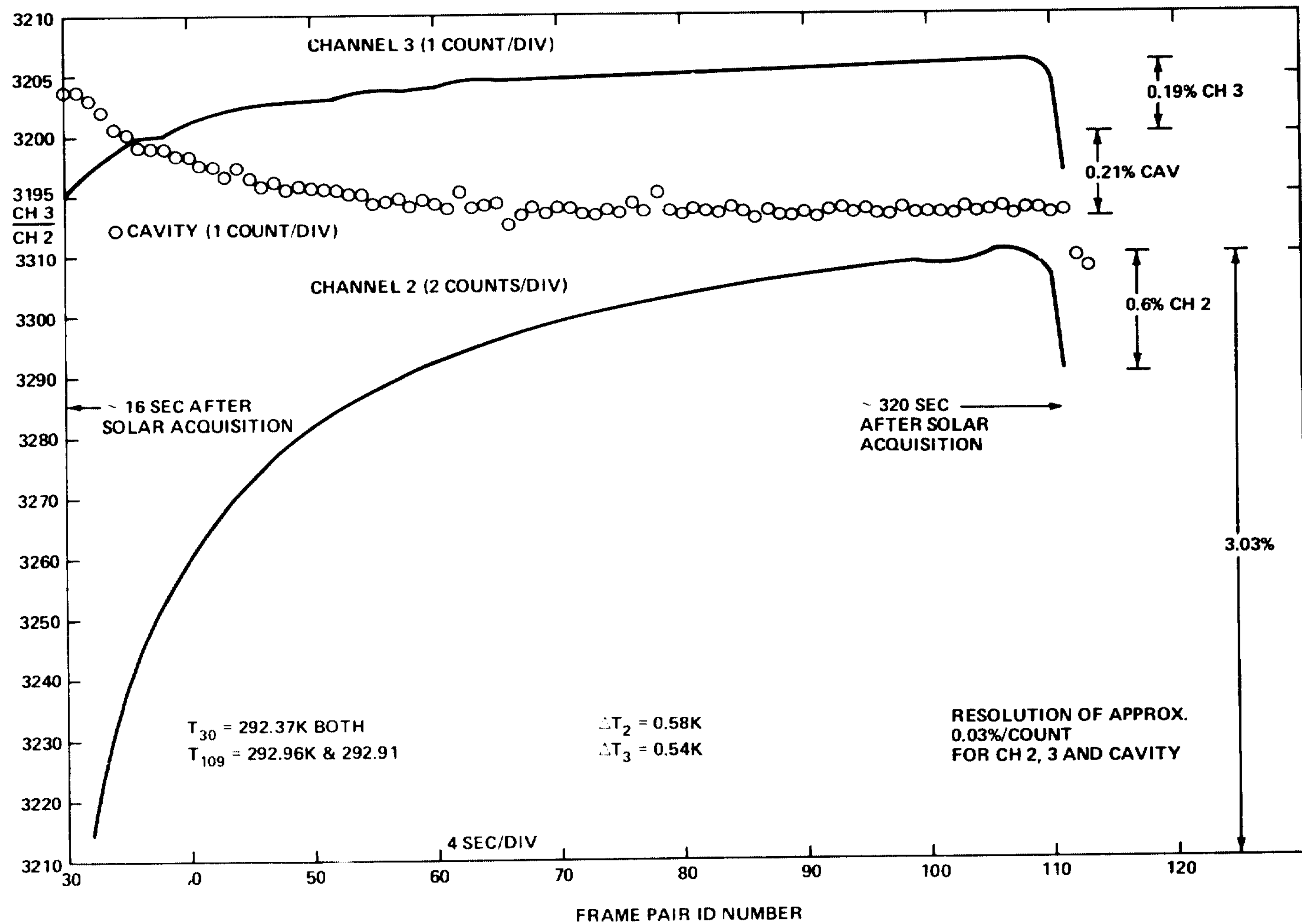

Figure 12. ERB-ESP Rocket Radiometer ON-SUN Plot for channels 2, 3, and cavity 29 June 1976