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SANDIA CORPORATION EXPEDITION FOR AIRBORNE SCIENTIFIC OBSERVATION OF THE QUIET SUN OF MAY 30, 1965

N. C. Anderholm, 9232

September 1965

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SANDIA CORPORATION EXPEDITION FOR AIRBORNE SCIENTIFIC OBSERVATION OF THE ECLIPSE OF THE QUIET SUN OF MAY 30, 1965

N. C. Anderholm - 9232

September 1965

Approved by: H. H. Patterson, 9230

ABSTRACT

This report describes the preparations for and operations of the Sandia Corporation sponsored expedition to observe the total solar eclipse of May 30, 1965. Of the other observations made on the expedition, brief summaries are given on the measurements of the cosmic ray induced neutron flux and the twinkle experiment. This report is also intended to serve as a reference for future airborne scientific expeditions. Brief statements of expected results are included. Detailed reports by the individual project leaders are to follow this preliminary summary of results.

III

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Introduction

Sandia Corporation's expedition to observe the solar eclipse of May 30, 1965, over the South Pacific Ocean was a success from the logistic and scientific points of view. To document this expedition and to serve as a reference for future expeditions, this paper presents the necessary planning, the procurement and installation of test equipment, an account of the mission itself, the problems encountered, and the data gathered as seen by the experimenters themselves. The many organizations that contributed to the success are enumerated also. The report covers a time span from December 1964, when formal planning began, to June 6, 1965, when the expedition returned. The Appendices include copies of pertinent documents.

Preparation
(See Also Table I)

On December 1, 1964, a meeting was held to discuss the possibility of Sandia Corporation's organizing a field expedition to make scientific observations of the total solar eclipse of May 30, 1965. This organizational meeting was the result of the reactions to two earlier meetings: a similar meeting at LASL a month before at which Sandia had been represented but had made no commitments; the other, a meeting attended by two Sandians, M. M. Robertson and D. Parsons, at Douglas Aircraft Company, Santa Monica, at which members of the expedition for Airborne Photography of the Eclipse of the Quiet Sun (APEQS), 1963, had given initial reports on the results of that effort.[1]

After the participants in a second organizational meeting a week after the first decided that enough worthwhile experiments could be put on board the Sandia diagnostic aircraft to make the effort profitable, the proposal* was assembled and circulated among Sandia Management. Included in the proposal were experiments from the U.S. Naval Ordnance Test Station (NOTS), Edgerton, Germeshausen & Grier, Inc. (EG&G) of Boston, and the University of Chicago, as well as Sandia Corporation. By December 24 the proposal and covering letter were sent to Washington via AEC-ALO for consideration by DMA.

*"Proposed Airborne Scientific Experiments for the May 30, 1965, Eclipse."

TABLE I

Calendar of Events

December 1963	M. M. Robertson and D. Parsons to Douglas Aircraft (Santa Monica) for results of APEQS expedition
November 1964	Meeting at LASL (Sandia represented)
December 1, 1964	Discussion of possibility of expedition to make scientific observations of eclipse
One Week Later	Discussion of proposed experiments
Following Recent Discussion	Proposal circulated among Sandia Management
December 24, 1964	Proposal and covering letter to Washington (via AEC-ALO) for consideration by DMA
January - May 1965	Planning of experiments, discussion of flight plans, etc.
Early January 1965	Experimenters and technical crew first assembled
Following Above	Fitting of equipment for the experiments into aircraft
February 1965	Draftsmen helping experimenters put requirements on paper
Mid-February 1965	N. C. Anderholm, W. B. Pafford (plus Wells and Notman of KAFB) attended meeting of NASA experimenters at Douglas--along with LASL and Air Force Cambridge Research Lab people, the experimenters insured against conflicting flight plans, etc.
March 1965	Orders placed; machine shops began fabricating equipment
March 1965	Trip (Pafford, Wells of KAFB, Lyon of LASL) to Samoa to make arrangements
End of March 1965	J. E. Keith proposed extension of flight to Australia to measure cosmic ray induced neutron flux
March 1965	Some participants to Ft. Worth for Air Force physiological training
March 1965	Travel desk began processing forms and securing passports and visas
April 1965	Equipment taking shape in labs of Division 7224
April 1965	Division 7255 acting as liaison between builders at Sandia and NOTS and those responsible for plane at KAFB and Gen Dynamics (at least one man from Division 7255 assigned to each experiment; others planned means to record data and store film)
May 3, 1965	Plane modification begun
May 10, 1965	Installation of instruments
May 17, 1965	First shakedown flight
May 19, 1965	Flight to calibrate counters (see Appendix A)
May 21, 1965	Mission began

The next few months were filled with planning of experiments, discussion of various flight plans, trips to Sacramento Peak Observatory, and the many other tasks required to insure a successful trip. The multitude of tasks required an organization which consisted of people ranging from machinists at Sandia to Air Force personnel in Washington, D.C. Early in January the experimenters and others who were to make up the technical crew were assembled for the first time. Each experimenter briefly described his plans so that the work of fitting these diverse experiments into the aircraft could begin. By February draftsmen were getting the experimenters' ideas down on paper. In mid-February N. C. Anderholm and W. B. Pafford (Sandia Corporation project leaders), together with Major Wells and Captain Notman of KAFB, attended the meeting of NASA experimenters held at Douglas Aircraft Corporation in Santa Monica, California. Also present were representatives of LASL and Air Force Cambridge Research Laboratory. On the second day of the meeting the managers, pilots, and navigators of the various expeditions discussed common problems and insured against conflicting flight plans.

In March the orders for equipment and filters were placed; the machine shops started making the instruments that were to prove the foundation of a successful expedition. The organization that proved crucial now started work. When American Samoa was chosen for the base of operations, W. B. Pafford, Major Wells of KAFB, and B. C. Lyon of LASL made a hurried trip to Samoa to make preliminary arrangements, check on facilities, and in general obtain the necessary information. Near the end of March, J. E. Keith requested that the aircraft continue on to Australia after the eclipse to make further measurements of the cosmic ray induced neutron flux. Other experimenters concurred in the usefulness of such an extension, and plans were revised to include it. At Fort Worth, Texas, participants new to airborne expeditions attended the physiological training session required by the Air Force. The travel desk started processing all the necessary forms and requested passports and visas where required. During April the equipment started to take shape in the laboratories of Division 7224. Division 7255 personnel were acting as liaison between those who were building equipment at Sandia and NOTS and those people at KAFB and General Dynamics who were responsible for structural integrity of the KC135A aircraft. At least one man from Division 7255 was assigned to each experiment; others from this division were assigned responsibilities for recording data and storing film.

On May 3, 1965, the changes in the aircraft were initiated. Some equipment came out; new windows and cabling went in, and on May 10 the installation of the instruments began. The first shakedown flight took place on May 17. The flight was satisfactory, but much work remained for the final 2 weeks. On May 19 (and later on June 11) the plane flew a course designated by the cosmic ray experimenters to calibrate their counters (see Appendix A). Others participated to make preliminary or continued airborne observations of atmospheric phenomena. On Friday afternoon, May 21, at 5:10 p.m., aircraft 370 took off from KAFB bound for American Samoa and Australia (see Table II).

TABLE II

Mission

		Local Time	
Friday	May 21, 1965	5:10 p.m.	Leave Albuquerque
Friday	May 21, 1965	Evening	Arrive Travis AFB, California
Friday	May 21, 1965	Evening	Leave Travis AFB, California
Saturday	May 22, 1965	4:00 a.m.	Arrive Hawaii
Monday	May 24, 1965	2:10 a.m.	Leave Hawaii
Tuesday	May 25, 1965	9:00 a.m.	Arrive Fiji
Wednesday	May 26, 1965	6:00 a.m.	Leave Fiji
Tuesday	May 25, 1965	Noon	Arrive Samoa
Wednesday	May 26, 1965	6:15 a.m.	First practice flight
Thursday	May 27, 1965	12:30 p.m.	Second practice flight
Friday	May 28, 1965		Rest and recuperation
Saturday	May 29, 1965		Final details
Saturday	May 29, 1965	Evening	Crew briefings
Sunday	May 30, 1965	6:15 a.m.	Actual mission began
Sunday	May 30, 1965	8:10 a.m.	Aircraft rose above clouds
		8:15 a.m.	Arrive at Point "A" (see Figure 1)
		8:15 a.m.	Window icing appeared
		8:34 a.m.	Entered flight pattern (i.e., Point "B")
		$9^h\ 11^m\ 50^s$ a.m.	Second contact (predicted contact time $9^h\ 11^m\ 48^s$)
		$9^h\ 16^m\ 17^s$	End of total eclipse
Following eclipse			Landed at Samoa
Remainder of Sunday			Packing
Monday	May 31, 1965	6:00 a.m.	Leave Samoa
Tuesday	June 1, 1965	2:30 p.m.	Arrive Avalon Airdrome (40 miles outside Melbourne)
Wednesday	June 2, 1965	10:00 p.m.	Leave hotel for Avalon and flight to south magnetic pole
Thursday	June 3, 1965	4:15 a.m.	Turn-around point
Thursday	June 3, 1965	7:10 a.m.	Arrive RAAF Base at East Sale
Friday	June 4, 1965	Afternoon	Leave Avalon
Friday	June 4, 1965	Evening	Arrive Darwin
Saturday	June 5, 1965	Morning	Leave Darwin
Saturday	June 5, 1965	Afternoon	Arrive Guam
Saturday	June 5, 1965	Evening	Leave Guam
Saturday	June 5, 1965	Morning	Arrive Honolulu
Sunday	June 6, 1965	8:00 a.m.	Leave Honolulu
Sunday	June 6, 1965	5:15 p.m.	Arrive KAFB

Mission
(See Also Appendix B)

The first stop was Travis AFB in California. After a delay, the expedition left for Hawaii and landed at 4:00 a.m. local time. The estimated take off was 1:00 a.m. on May 23. However, there was an unavoidable delay of 24 hours. 2:10 a.m. on May 24 was departure time for Samoa. However, heavy cloud cover at Samoa forced both the Sandia plane (No. 370) and the LASL plane (No. 369) to fly on to Fiji. The next morning the group flew to Samoa and began final preparations. The 2-day delay made the situation very pressing for some of the experiments.

The first practice flight,with take-off and flight plan identical to those on the day of the eclipse, took place the following morning. This was the first chance for the navigators to use Billingshausen Island to "fix" flight position prior to entering the final flight pattern. The general route is shown in Figure 1. The flight was generally successful although some work still remained.

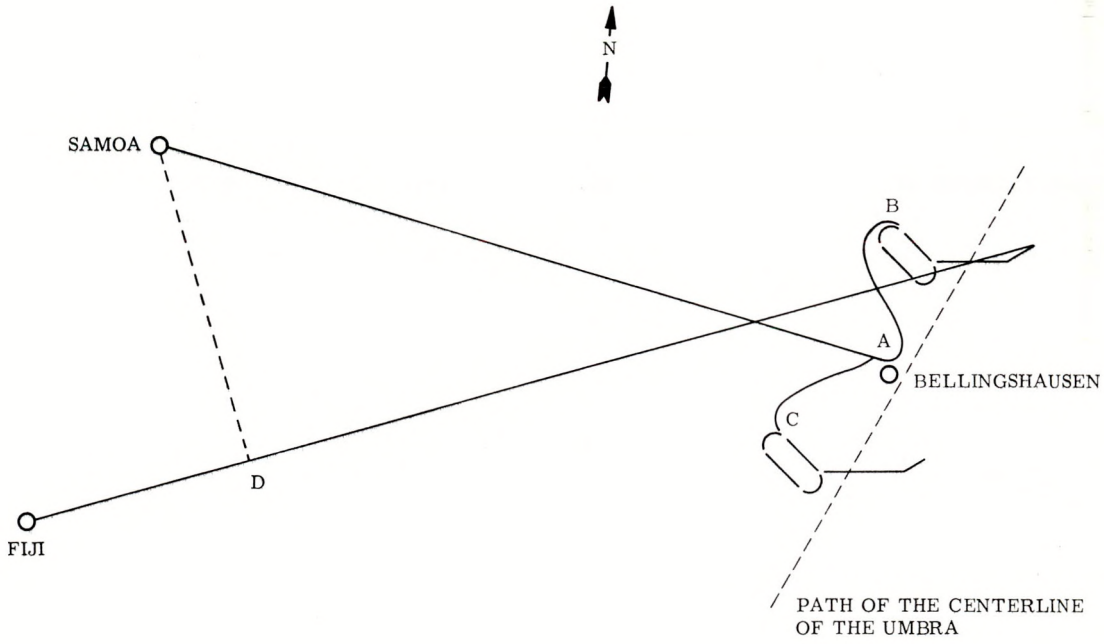


Figure 1. Schematic Representation of the Flight Plan and Programmed Alternates

The above flight, the second practice flight, and the actual eclipse observation flight all followed the same flight plan. It had two programmed, i.e., preplanned, alternatives in addition to the original. Take off was set for 6:15 a.m. Flying at 33,000 feet pressure altitude, the aircraft was scheduled to arrive at point "A" (see Figure 1) at 8:15 a.m. Samoan time (add 11 hours to obtain Universal Time).

At this time a decision would be made to fly to either point "B" (the original plan) or point "C" (the first alternative). In either case the same general "race track" pattern would be flown. If the first alternative was chosen, there were no programmed alternatives. If the original plan was chosen, a second alternative remained open until the flight pattern at point "B" was entered. This second alternative was: after arriving at point "B" the expedition could either continue the original plan or turn and fly to point "C" and make the observation of the eclipse without any race track orbits. The orbits consisted of 5-minute legs and 3-minute turns. The first leg in an easterly direction from B was called the "East Leg" and numbered I, II, or III. The return leg was called "West Leg" and numbered I or II. After traversing "East Leg III" the heading of the aircraft was set so that at mid-totality the relative bearing of the sun was 90 degrees. The aircraft crossed the centerline of the umbra at a time chosen to coincide with the time midway between second contact (when the photosphere of the sun disappears behind the moon) and the third contact (when the photosphere of the sun first appears). This heading change was made 1 minute before the estimated time of second contact. This estimate was made from data supplied by the U.S. Naval Observatory; the results of their calculations are reproduced in Appendix C. The actual times for the morning of the eclipse are given in the outline of the sequence of events also reproduced in Appendix D. One minute after third contact, a change was made in the aircraft heading so that 2 minutes later the relative bearing of the sun would again be 90 degrees. Second contact and third contact were noted by the appearance of Bailey's Beads.*

The second practice flight occurred the following afternoon southeast of Samoa. The race track pattern was flown, using procedures decided on after the first practice mission. Friday and Saturday were days of final planning, as well as much needed rest. On Saturday evening, crew briefings were held, film was loaded, and final details were attended to. Although the evening sky had been clear, Sunday morning the sky was clouded over. Within 1/2 hour after take off the course had been changed twice to avoid thunderstorms. The planned altitude for the observations was 33,000 feet pressure altitude. However, on May 30 the aircraft continued climbing to a pressure altitude of 40,000 feet; the actual altitude during the eclipse was 41,720 feet.

It was not until 5 minutes before the aircraft reached point "A" that it rose above the clouds. After this no clouds were seen above but always just below. The pilot turned the aircraft to follow the original plan. However, a new problem now appeared--window icing. Emergency measures were taken, and it appears that ice affected only the cameras used for "visible region" photometry (see experimenter's report). The flight pattern, i.e., point B, was entered at 8:34 a.m., on time.** The plan called for the aircraft to maintain a constant ground speed of

*This phenomenon is caused by light coming through the valleys of the moon after the edge of the photosphere is below the tops of the mountains of the moon but above the valley floors. Needless to say, the duration of this phenomenon is very short.

**Appendix D gives the precise eclipse time tables.

440 knots. Because the plane was at a maximum altitude, it was not possible to adjust the velocity; also, headings were specified so that a drift occurred as a result of the inability to "crab" the aircraft to compensate for the winds. Second contact occurred at $9^h\ 11^m\ 50^s$ a.m. ($20^h\ 11^m\ 50^s$ UT) instead of $9^h\ 11^m\ 48^s$ as had been predicted.* The observed duration was $4^m\ 27^s$. During totality all systems functioned as planned (in the following section the appraisals of the experiments by the experimenters are given). The aircraft turned on the leg for Fiji, but when point D was approached, it was decided a safe landing could be made at Samoa so the pilot turned the plane toward the Tafuna airport.

The remainder of Sunday was spent packing, removing cameras to be shipped back to Sandia, and installing the apparatus for the experiments that were to be conducted on the flight to Australia, Guam, and Albuquerque. At 6:00 a.m. the aircraft took off from Samoa, stopped in Fiji for refueling, and arrived at Avalon Airdrome, 40 miles outside of Melbourne, Australia, at 2:30 p.m. local time. The next evening at 10:00 p.m. buses were loaded at the hotel to take the crew back to Avalon for the flight toward the south magnetic pole. Both the cosmic ray experiment and the twinkle experiment were carried out. Take-off time had been chosen so that the turn-around point would be reached at twilight, i.e., 18 degrees solar depression. On the return flight, airglow studies were made, and observations on the atmosphere were continued. The aircraft landed at the RAAF Base at East Sale at 7:10 a.m. to load both fuel and lox (liquid oxygen).** On the flight back to Avalon, an additional 300-mile southerly leg was taken on longitude 145°E. This was the longitude to be followed on the flight from Melbourne to Guam, and this additional leg allowed a complete measurement of the latitude effect on cosmic ray intensity to be made from the "Knee," where the intensity stops increasing, northward past the magnetic equator where the intensity stops decreasing.

The next afternoon the plane took off from Avalon, flew north on longitude 145°E to the northern coast of Australia, flew west, and landed at Darwin. The next morning it flew east to 145°E, north to a point north of Guam, and returned for refueling at Guam. Two hours later the expedition took off for Honolulu, arriving in Hawaii Saturday morning, June 5. The plane took off for Albuquerque at 8:00 a.m. the next morning and landed at KAFB at 5:15 p.m., June 6, 1965.

*See also Appendix C, "Local Circumstances of the Total Solar Eclipse," as compiled by the U.S. Naval Observatory.

**The lox was unavailable at Avalon.

Cosmic Ray Latitude Survey - J. E. Keith, Sandia Corporation, and J. A. Simpson, University of Chicago

A latitude survey of the nucleonic component of cosmic rays was made in conjunction with the solar eclipse expedition. The detector used in these experiments was a four-tube Simpson neutron pile, the standard instrument for such measurements for the International Geophysical Year. The pile (see Figure 2) was operated with two separate counter systems to furnish a continual check of counter performance.

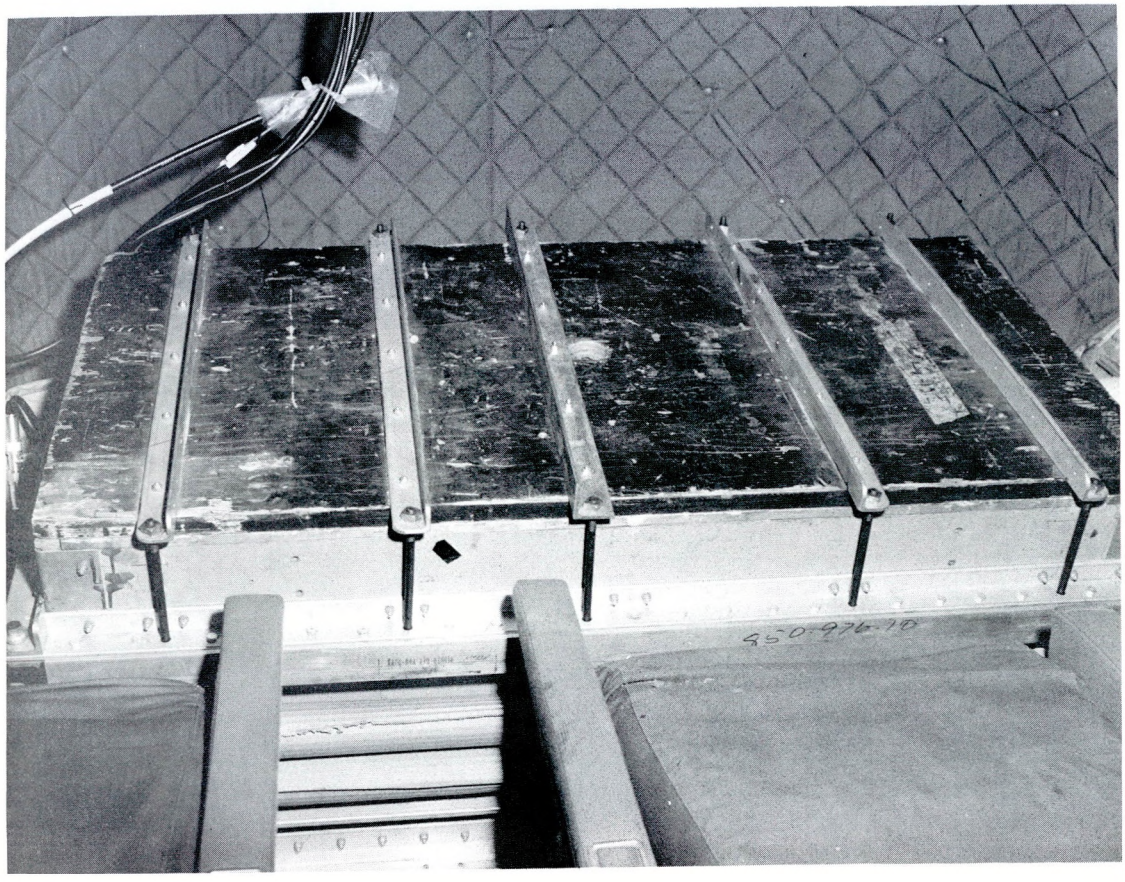


Figure 2. Four-Tube Simpson Neutron Pile as Installed in the Aircraft

Between May 19 and June 11 a series of cosmic ray measurements were made during flights of the Sandia KC135A aircraft. On these 2 days northern latitude surveys were made along a standard path from New Orleans to a point somewhat north of Sioux Lookout, Ontario. This path has been used for more than a decade by the Simpson group at the University of Chicago, so these measurements served to calibrate the instruments as well as to measure the current rigidity spectrum of the

cosmic rays. Between the two northern latitude surveys, two equatorial crossings (at 170°W and 145°E) and a southern latitude survey (along 145°E latitude from 60°S to 17°N) were made in conjunction with the solar eclipse expedition. The resulting data (more than 500 data points) are being examined for internal consistency and are being reduced. Unfortunately, this must be done by hand. These data should furnish at the very least the rigidity spectrum at the end of solar minimum, the position of the cosmic ray equator at two latitudes, and an interesting direct comparison of the latitude effect in northern and southern hemispheres (Appendix A).

Twinkle Experiment - C. C. Hudson, Sandia Corporation

Disturbances in the atmosphere are thought to cause the scintillations of starlight commonly called twinkling. Careful studies show that most of the twinkling is of too high a frequency to be observed by eye, so sensitive instruments are required. Recent experiments using a fast response photometer in conjunction with rocket-borne beacons indicated that most of the twinkling occurred because of a peculiar layer of air at about 30,000 to 35,000 feet altitude. The eclipse flight offered an opportunity to explore this layer over a far wider range of conditions than was formerly possible.

Two experiments were devised. The first, an inter-aircraft experiment, consisted of a photometer on one aircraft and a light beacon on the other. When the planes were flying in consort through both altitude and horizontal range, a variety of conditions could be studied. The second, for use when only one aircraft was available, consisted of a photometer which could be trained on a star. Thus, as the aircraft maneuvered in altitude, the twinkling could be measured.

Although the star twinkle experiment could not be used because of limitations in aircraft maneuverability, the inter-aircraft experiment operated successfully and gave the expected result at about 30,000 feet. Both techniques appear to be usable, and a more thorough study of the twinkle layer may be possible in the future.

Photographic and Photometric Photometry - M. M. Robertson, Sandia Corporation

R-θ Photometer Experiment* -- This was a joint experiment in cooperation with LASL. The purpose was to measure the intensity of the radiation from the corona as a function of the position (R,θ). This experiment utilized a photoelectric tracker designed at LASL and other instrumentation designed by the Sandia Corporation. These data are promising, and the absolute intensity measurements should be published in the future.

Spectrometry and Photometry of the Visible Region of the Spectrum -- This experiment consisted of three units (see Figure 3). The first was of a documentary nature and suffered exposure loss due to frost, and, for the longer exposures, a smearing of images due to aircraft motion. However, some of the exposures may be

*This experiment was installed on board the LASL aircraft and was conducted by Sandia Corporation personnel.

usable for studies of the inner corona. (See Figure 4 of a partial phase under good conditions and Figure 5 of the diamond ring effect with window frost.) The second unit was to take pictures through various filters--neutral density, narrow bandpass, and polarizing. However, data suffered from window frost and aircraft motion on longer exposures. Data have been only censorially reviewed but indicate that the exposures taken early in totality suffered less from frost than the later exposures. Hence these earlier data should be valuable. The visible region spectrograph, the third unit, was to determine spectral lines present during flash at second and third contact and to relate these to elemental abundances, distribution, etc. First indications are that frost smeared the images but that some usable information may be present. The value of these data will be determined after detailed investigation.

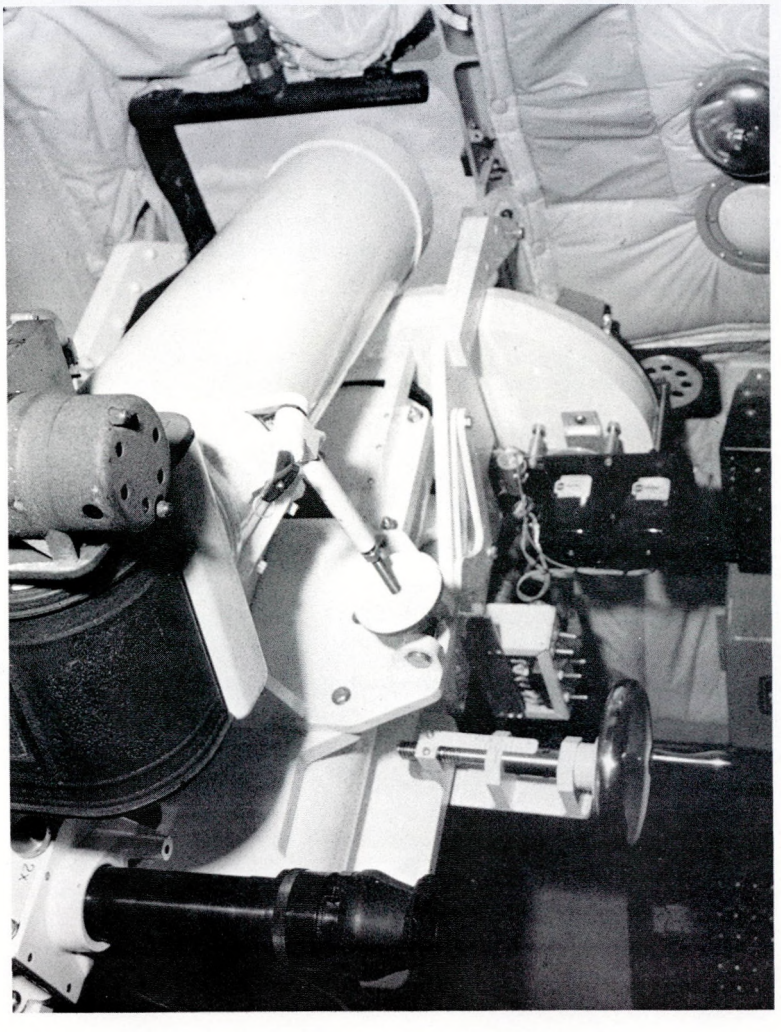


Figure 3. Visible Region Photometer Installed in Aircraft

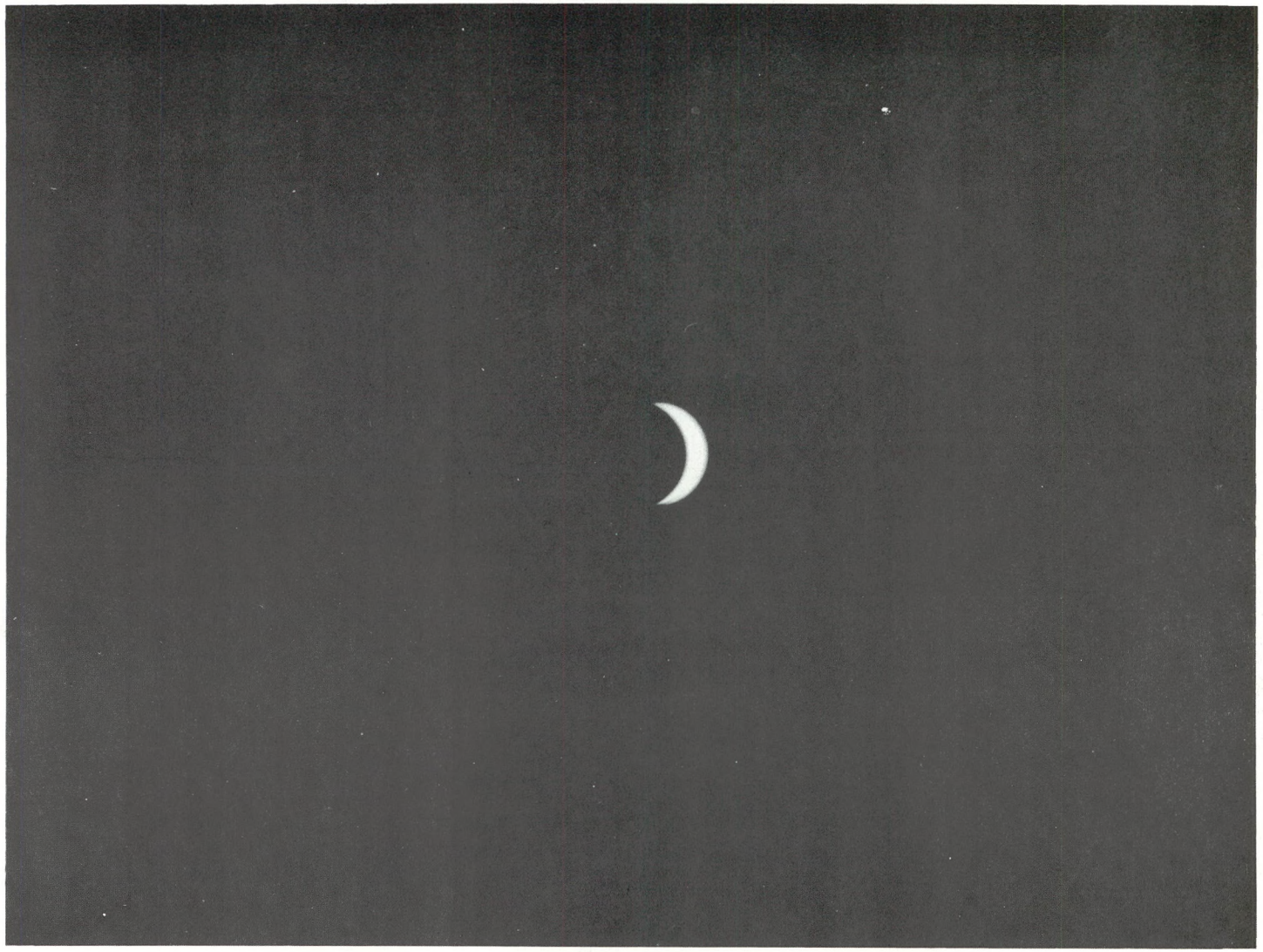


Figure 4. Partial Phase Photograph Taken During No-Frost Condition

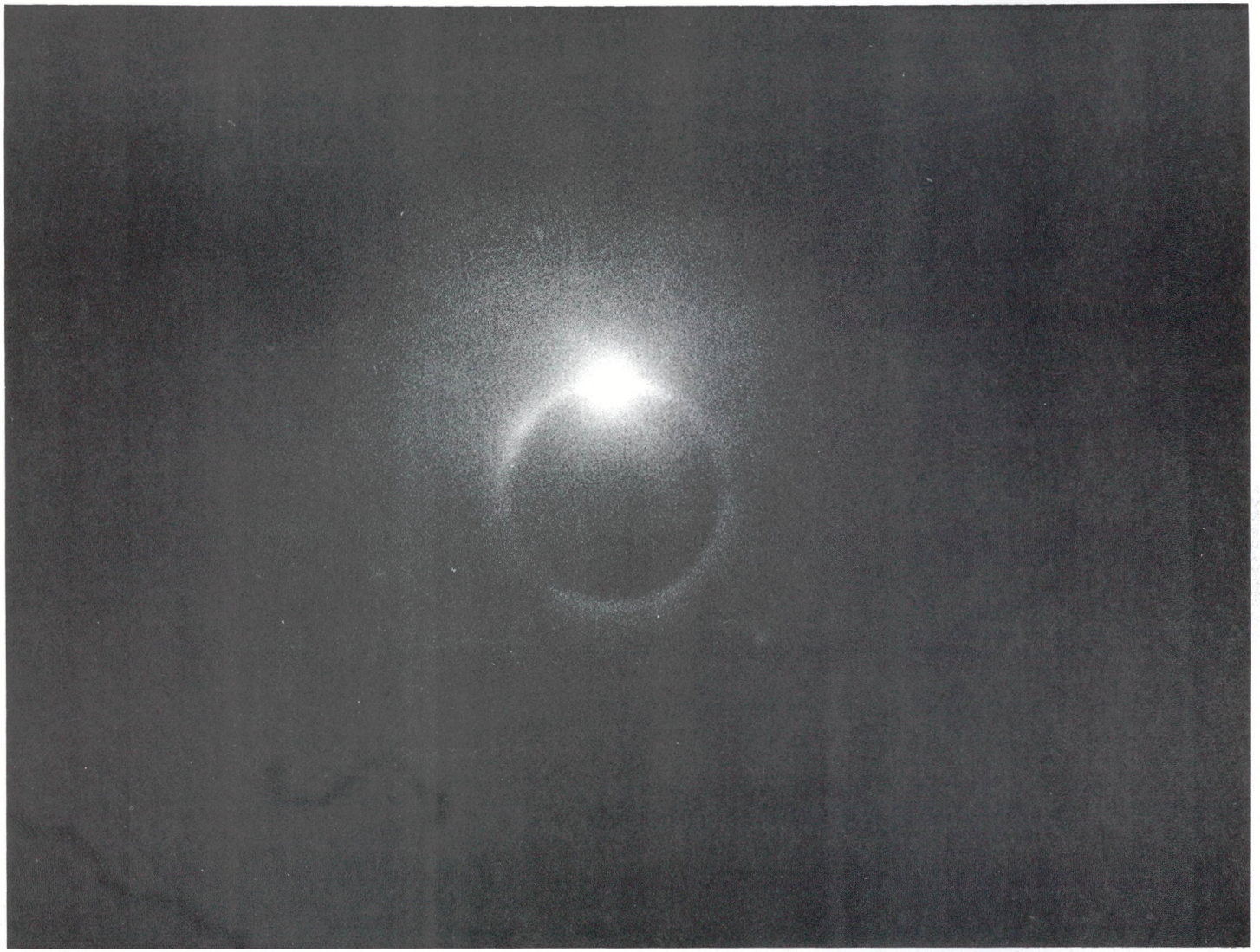
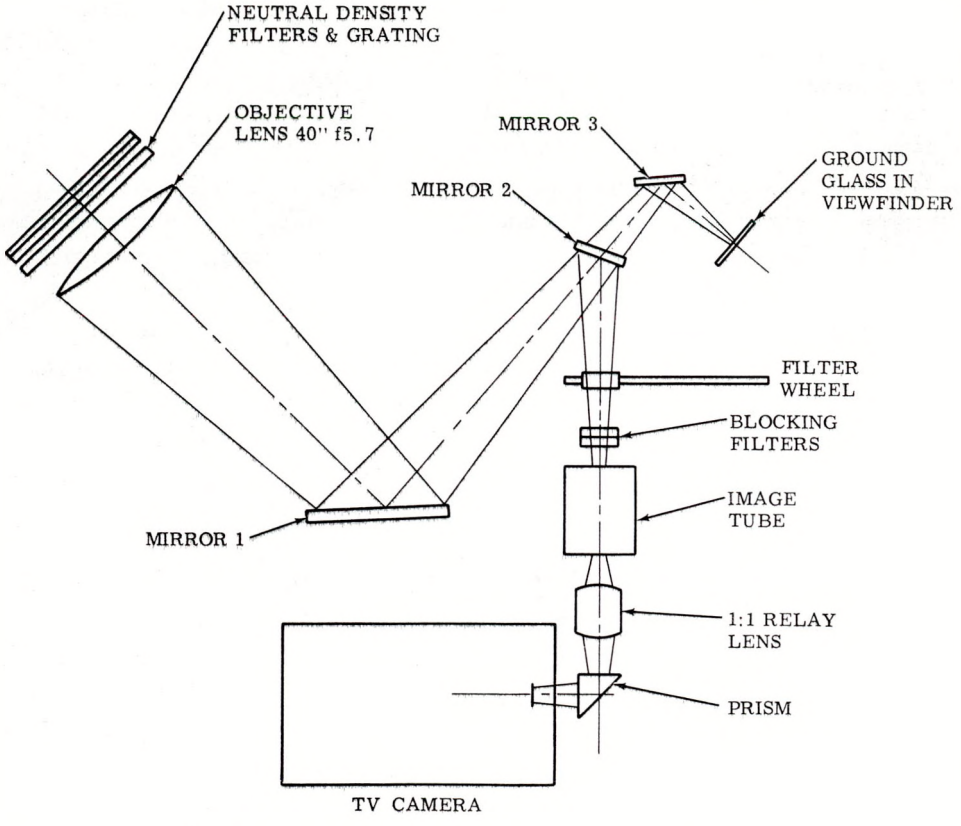


Figure 5. Diamond Ring Effect Taken (with a 0.6-second exposure and an ND-1 filter) Showing the Effect of Frost

TV-Spectrograph[2] -- The purpose of this experiment was to obtain spectra during flash and narrow band pictures during totality in the infrared region near 1 μ. A schematic of the experiment is shown in Figure 6 and photographs of the instrumentation in Figures 7 and 8. The spectra were quite good during flash, and some of the narrow band pictures during totality show spectral line presence in two flares on the sun. No frost trouble was experienced, but aircraft motion hurt the integrated time displays.

Spectrometry and Photometry of the Ultraviolet Region of the Spectrum -- The objectives here were to obtain the spectra during flash and totality, and photographs using neutral density, polarizing, and narrow band filters. The instrumentation is shown in Figure 9. The spectra were hurt some by frost and by aircraft motion, but early results look good. In regard to the photographs, the short exposures were good, but the long exposures were hurt by aircraft motion. Examples are shown in Figures 10 and 11.



MIRROR 1 ~ GOLD COATED
MIRROR 2 ~ DICHROIC REFLECTS 95% BETWEEN 7500 & 11000 A°
TRANSMITS 80% BETWEEN 4500 & 6500 A°
MIRROR 3 ~ ALUMINIZED

Figure 6. A Schematic Representation of the TV Spectrograph Experiment

Figure 7. Tracking Portion of the TV Spectrograph Experiment

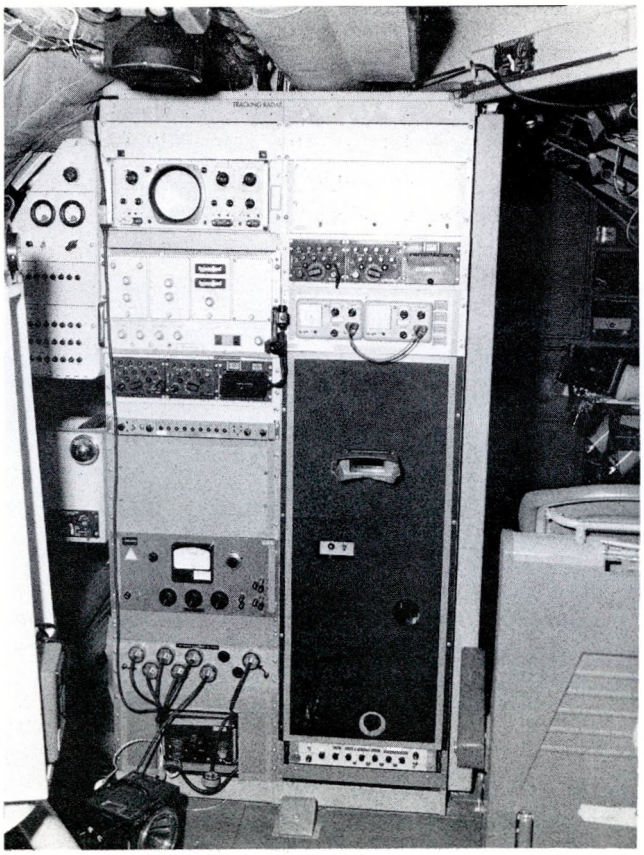


Figure 8. Electronics of the TV Spectrograph Experiment Showing the Viewer for the Monitor Station Which was Manned During the Eclipse

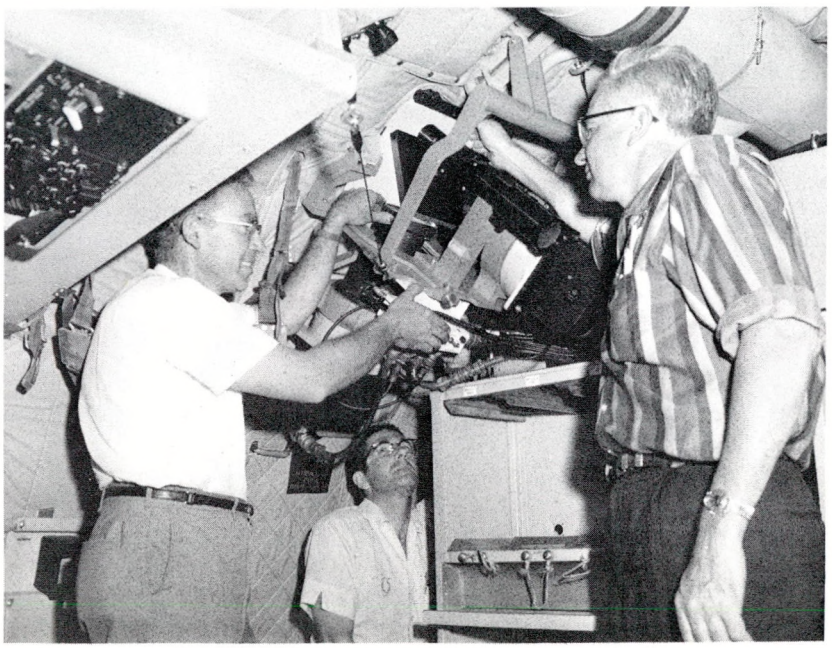


Figure 9.

Instrumentation for the Ultraviolet Region Experiments as it was Installed in the Aircraft

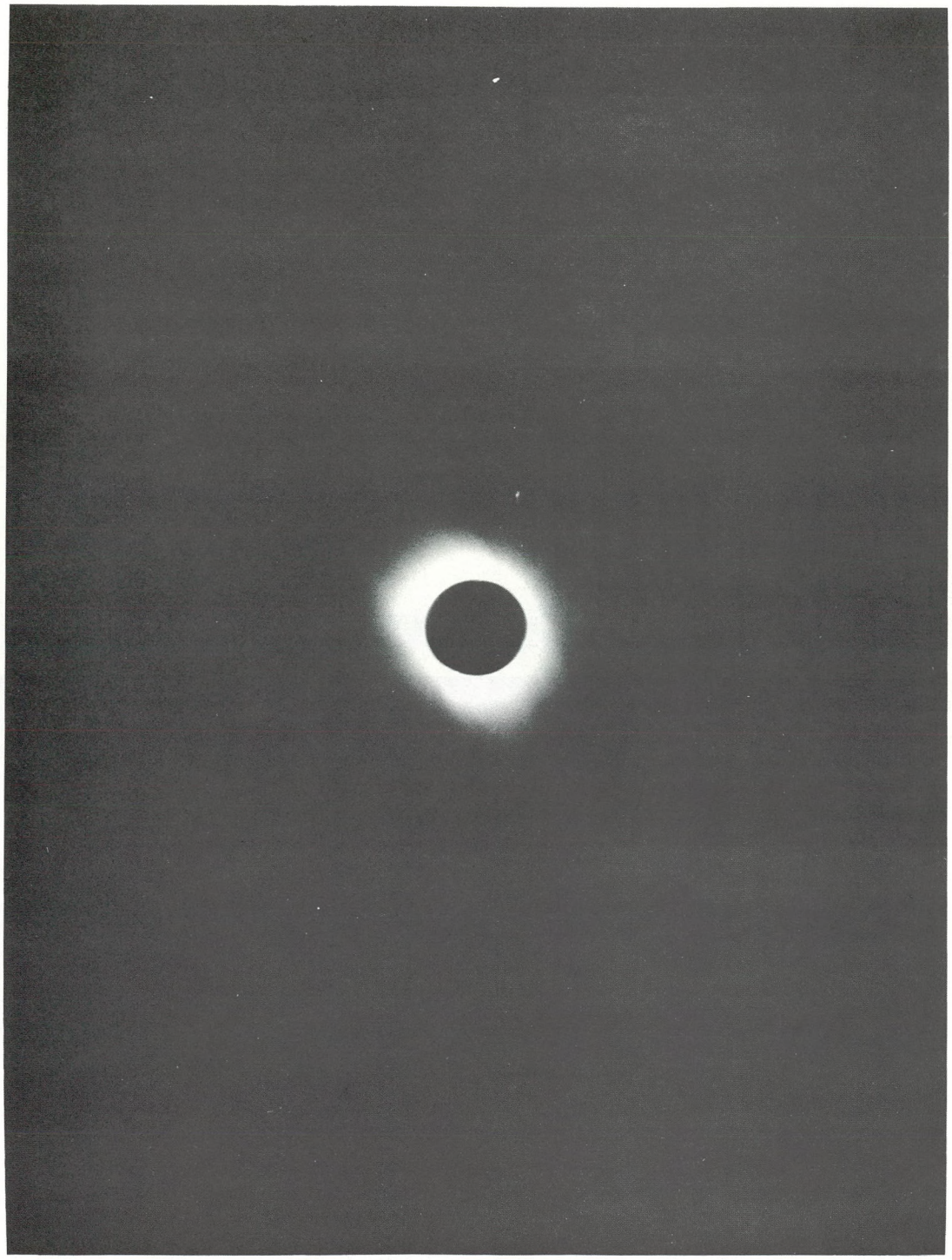


Figure 10. Eclipsed Sun Photographed with no Filter at f/16 for 0.4 Second. (Courtesy of M. M. Robertson.)

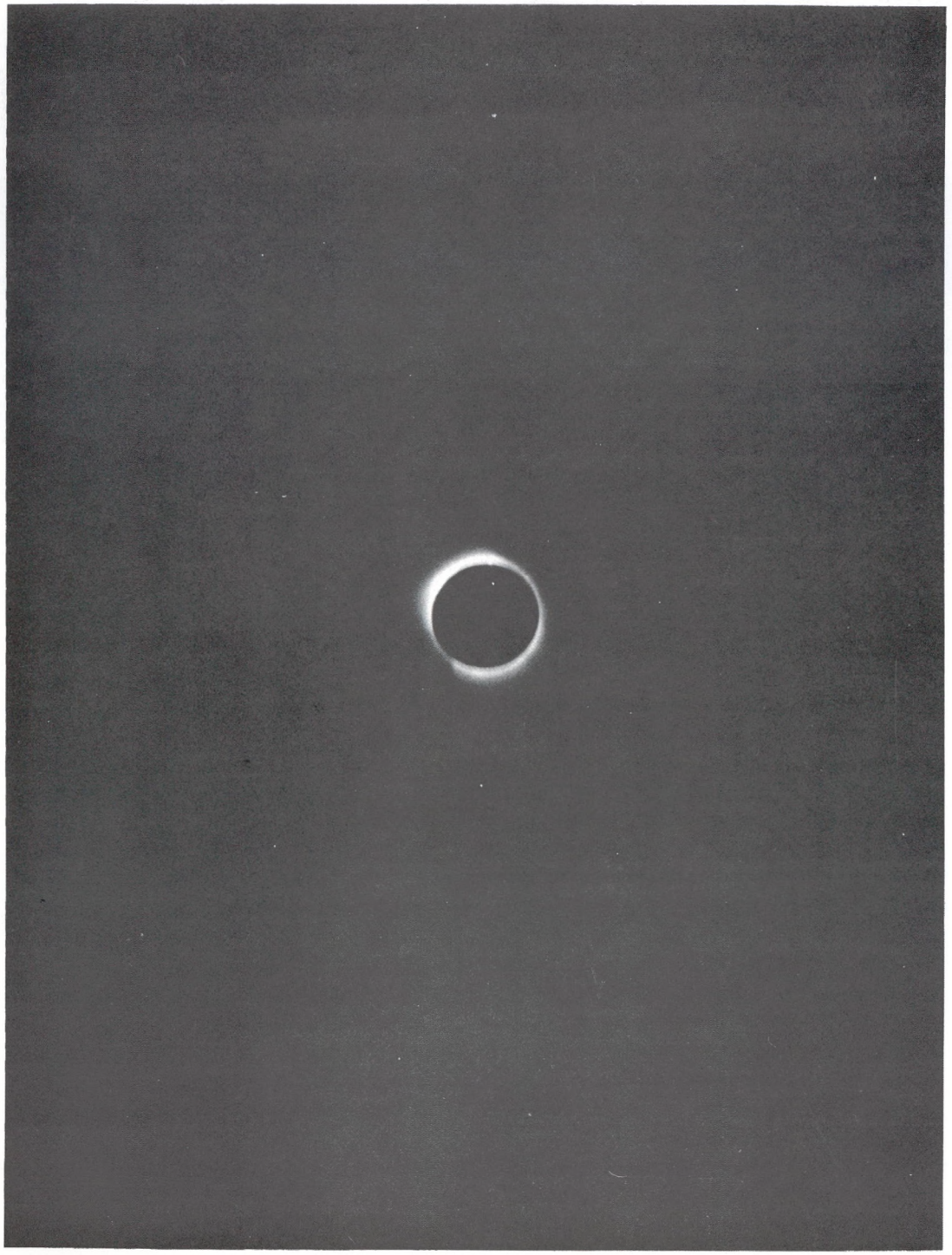


Figure 11. Eclipsed Sun Photographed with a Filter Centered λ 3550 Å. The Exposure was 0.1 Second at f/4. (Courtesy of M. M. Robertson.)

Aurora Spectrograph -- There was not enough intensity in the observed aurora to record even on 1/2-hour exposures; hence, no data. A photograph of the camera is shown (Figure 12).

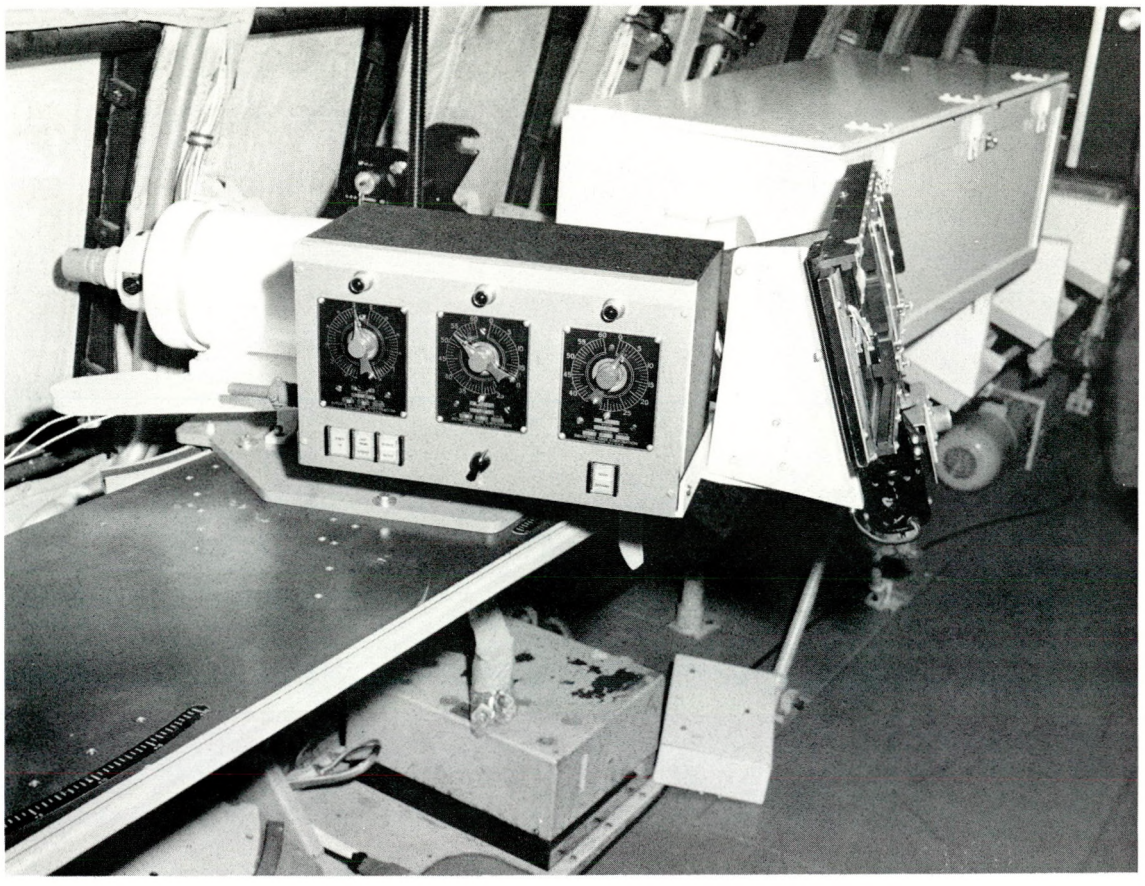


Figure 12. Aurora Camera as it Appeared on the Flight from Melbourne, Australia

Valuable support and cooperation were provided by Sandia personnel of Department 7220, Division 7255 and by the Air Force.

Sky Brightness and Day Airglow - James G. Moore, U.S. Naval Ordnance Test Station, China Lake, California

Observations to verify the existence, spectral composition, intensities, and heights of day airglow are needed to explain the interactions between the incident solar energy and the earth's atmosphere. An all-sky scanning multicolor photometer installed in one of the 15-inch hemispherical domes measured brightness of a small region of the sky (a circular field of 4 degrees) along four vertical circles to zenith distances of approximately 75 degrees. Figure 13 shows the equipment installed in the dome. The vertical circles were spaced 45 degrees apart to allow complete sky coverage. During totality the eclipsed sun appeared 90 degrees from the direction of flight so one of the scans was oriented in this direction. In

this way, brightness measurements of the corona were obtained, as well as sky brightness measurements. Each of the four vertical circles was scanned ten times during totality to provide simultaneous measurements in six discrete wavelength intervals. These wavelength intervals were centered on line and band emissions, as well as on nearby continuum. These included line emission due to forbidden atomic oxygen transitions at 5577 Å and at 6300 Å, as well as band emission from ionized molecular oxygen at 3914 Å and continuum radiation centered at 4000 Å, 5600 Å, and 6200 Å. The data were recorded simultaneously on a strip chart recorder and a tape recorder. Additional measurements of the zenith twilight sky at an altitude of 30,000 feet as the solar depression angle varied from 0 to 8 degrees were recorded on two separate occasions during the expedition. Zenith sky brightness measurement during a display of an aurora australis were also obtained while flying at 30,000 feet and at 147°30'E longitude and 60°S latitude. The aurora was detected on the 3914 Å and 5577 Å photometers only.

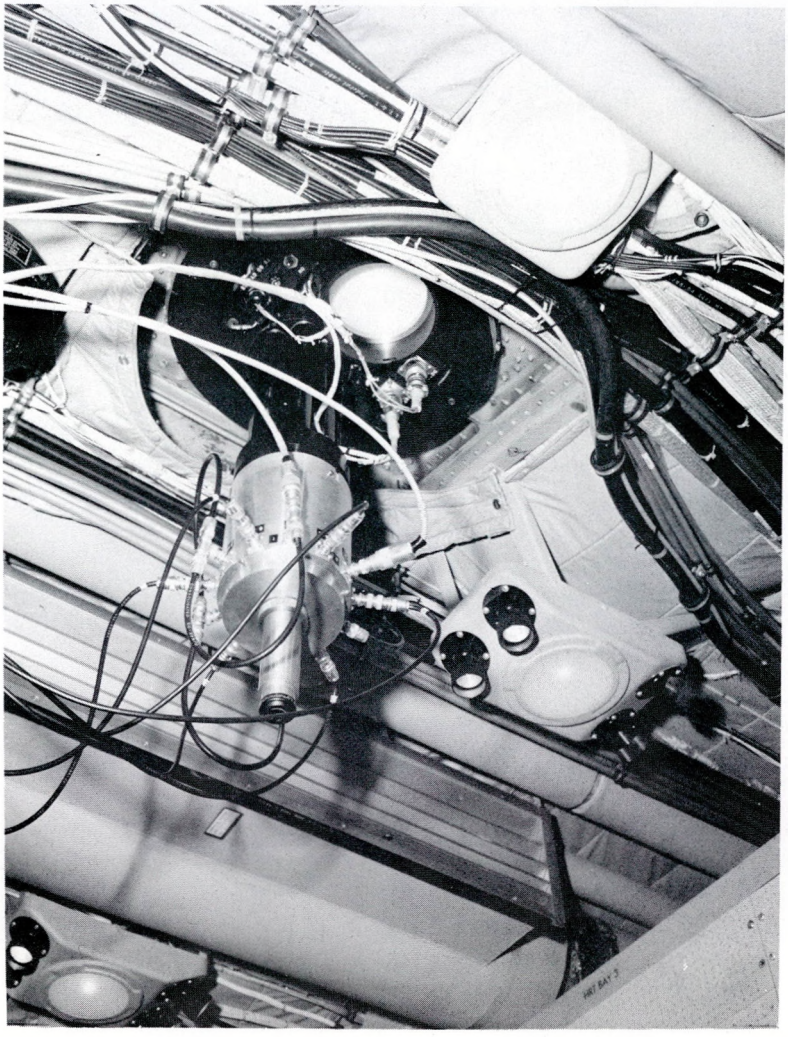


Figure 13. All-Sky Scanning Photometer Installed in a 15-Inch Dome in the Aircraft

All of the data are being reduced, and the results will be published in the open literature in the future. It is planned to obtain ratios of line emission to nearby continuum emission as a function of photometer look angle to discover the effects of day airglow emission or possible dust layers in the atmosphere.

Measurements of the Relative Contributions of Primary and Higher Order Scattering (of sunlight) to the Illumination of the Daytime Sky - James G. Moore, U.S. Naval Ordnance Test Station, China Lake, California

The illumination of the daytime sky results from repeated scattering of the incoming natural sunlight by constituents of the atmosphere. Because of Rayleigh scattering, diffuse skylight is partially, linearly polarized. The departure from complete polarization is caused primarily by light which has been scattered more than once. Knowledge of the degree of polarization of skylight in selected spectral regions can be employed to evaluate the relative contributions of primary and higher order scattering to the illumination of the daytime sky. During totality, the illumination of the sky is mainly due to light which has undergone multiple scattering and hence depolarization.

The degree of polarization before, during, and after totality was measured by two polarimeters (see Figure 14) whose spectral regions were defined by narrow band interference filters centered at 4750 Å and 6010 Å. The polarimeters consisted of two optical telescopes, filters, rotating polaroid disks, and photomultiplier tubes. The polarimeters were aimed at the point lying 90 degrees from the sun in the sun's vertical, since that portion of the sky is in the region of maximum polarization. Measurements of the polarization were obtained before, during, and after totality as well as during simulated eclipse runs with the uneclipsed sun as a source. These data are being evaluated to determine the influence of multiple scattering in the daytime sky; the results will be published elsewhere in the near future.

The cooperation and assistance of personnel of the Sandia Corporation; the Nevada Operations Office of the AEC; Edgerton, Germeshausen & Grier, Inc.; General Dynamics; U.S. Air Force; and the Naval Ordnance Test Station and financial assistance from the Office of Naval Research made these observations possible. Messrs. B. R. Stanton and C. A. Nelson of Sandia Corporation and Messrs. Philip Morin and Fred C. Davis of NOTS were especially helpful.

Photography of the Outer Corona - William C. White, U.S. Naval Ordnance Test Station, China Lake, California

A basic description of the experiment was published in ISA Transactions.[3] Briefly, the camera used in the experiment was designed to take four simultaneous photographs in four different wavelength regions. Three polaroid filters were mounted with their polarization vectors oriented 45 degrees apart. The lens assembly could be rotated with respect to the photographic plate and the polaroid filters. One exposure, then, resulted in exposures in four wavelengths, one photograph without, the other three with polaroid filters. The lens assembly was

rotated 90 degrees to obtain exposures through the polaroid filters at a different wavelength. The four wavelengths were isolated by interference filters at λ 4010, 5303, 5694, and 6050 Å. The field was approximately 20 solar radii for each photograph.

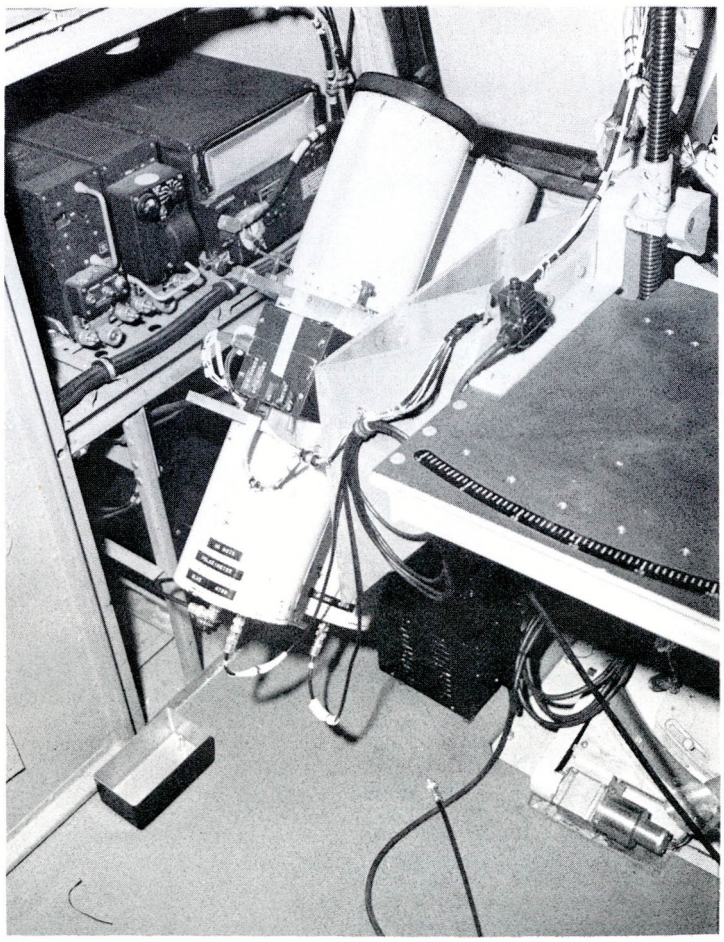


Figure 14. Polarimeters Used to Measure the Degree of Polarization Before, During, and After Totality in Two Spectral Regions

The purpose of the experiment was to obtain data on coronal intensity with wavelength, polarization, and surface brightness of the corona. From the measurements, the electron density and temperature of the corona can be deduced.

The primary calibration of the plates will be photographs of the sun taken with the camera through pinhole apertures and ND filters. These photographs were obtained on a test prior to the eclipse flight. A secondary calibration is yet to be performed by photographing a tungsten lamp behind diffusing screens and a set of ND filters. The secondary calibration insures that brightness of any portion of the photograph can be determined in terms of solar intensity.

Unfortunately, the eclipse film has not been developed at this time. The secondary calibration could not be obtained in Samoa because of a breakdown in the lamp power supply the night before the eclipse flight. As soon as the author receives this equipment, now being shipped to NOTS, the calibration photographs will be obtained and the film will be developed. It is necessary to develop coronal, solar, and calibration film at the same time to insure that the calibration is valid.

Until further assessment can be made, the author feels that the experiment was at least a partial success. In all, four 1-second, four 5-second, and two 30-second exposures were attempted.

Photographic Photometry - John Champeny, Edgerton, Germeshausen & Grier, Inc.[4]

Description of Experiments -- During the eclipse of May 30, 1965, three experiments were conducted aboard aircraft 370 by EG&G personnel. These experiments were designed (1) to obtain information on the orientation of the aircraft with respect to the sun, (2) to obtain precise three-color and infrared photometry of the outer corona, and (3) to record coronal spectra in the visible range and in the ultraviolet range to 3000 Å. The camera used for orientation purposes was a Northridge RZ-12 loaded with 35-mm Tri-X film and operated at 2 frames per second. The equipment used to photograph the phenomena included two framing cameras and an optically fast spectrograph containing only reflecting and quartz optics.

A Beattie-Coleman equipped with a lens suitable for providing a 30 x 30-degree field of view was used for the photometric photography. The camera was fixed-aimed, and the frame size of its 70-mm film was approximately 58 x 58 mm. During the first half of the eclipse, Ektachrome Type ER film was utilized. A filter wheel was employed so that the camera could be operated either (1) without a filter in the optical path (open position on wheel) or (2) with any one of three Polaroid HN-22 filters in the optical path and positioned at 45-degree relative orientation. Sixteen frames were exposed, with exposure times ranging from 0.1 to 20 seconds. After mid-totality, the Ektachrome magazine was replaced by one containing 70-mm Kodak Type 1N film. This film was selected because of its infrared sensitivity (to approximately 9000 Å). The film was exposed in the manner explained above, both with and without filters in the optical path. Three nonpolarizing filters were used. These were designed to pass thousand-angstrom bands in the blue, orange, and far red regions. The exposure times ranged from 0.1 to 30 seconds. Shutter openings and closures were recorded on an oscillograph to enable exposure-time determination to an accuracy of ±5 milliseconds.

The spectrograph employed was a Regulus Model 1 (see Figure 15) operated with 16-mm Kodak spectroscopic 103F film. The recorded spectrum extended from approximately 3000 to 7000 Å. The spectrograph was operated at f/0.8 through a quartz aircraft window. The image was then reflected using a hand-guided plane mirror and passed into a 5-inch Newtonian telescope.

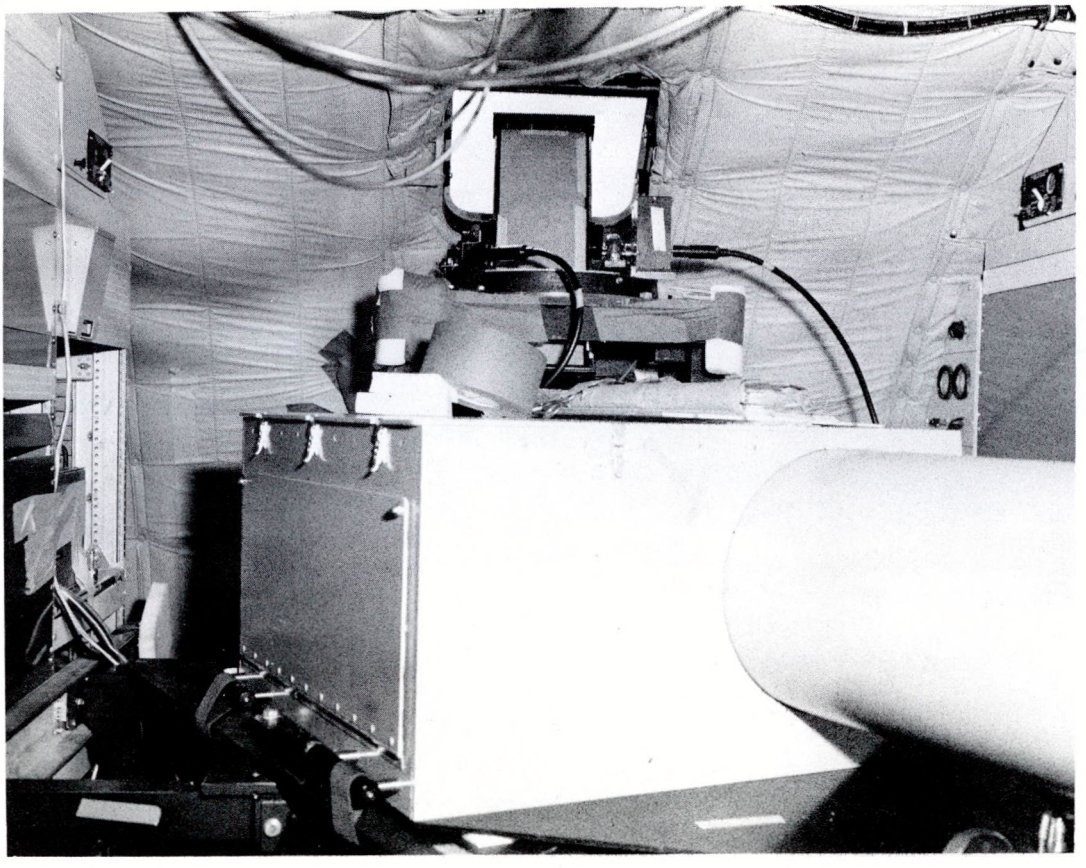


Figure 15. Regulus Model 1 Spectrograph Used by EG&G

Results -- The orientation camera jammed before second contact, so no photographs were taken. Even if the camera had functioned, it is doubtful that useful records would have been obtained, because the viewing window was heavily frosted. Frosting also occurred at the spectrograph window; however, it is believed that this was not so serious.

The spectrograph and coronal camera films are now in storage awaiting calibration and processing. The Ektachrome photographs should contain information on the coronal polarization and radiance in the three spectral regions of the film. The infrared film, because it was exposed to widely separated spectral bands, should yield information relating to scattering caused by dust and by electrons. If the window frosting problem was not serious, the spectrograph records should provide low-resolution, high-speed spectral data related to the outer corona.

Conclusion

The flow of scientific results will begin at a symposium to be held at the NASA Ames Research Center on December 16 and 17, 1965. These proceedings will be but a token indication of the value to the scientific community of the observations made during this expedition. The success of the expedition depended on the efforts of many people and organizations, and although some of them have been mentioned throughout the report, others have not been. The contributions of all of these cannot be overemphasized.

APPENDIX A -- FLIGHT FROM ALBUQUERQUE TO BARKSDALE TO 55° LAT N TO ALBUQUERQUE

APPENDIX B -- FLIGHT FROM TRAVIS TO HICKAM (TO Travis 0641)

APPENDIX C -- ECLIPSE TIME TABLE

APPENDIX D -- LETTER, DUNCOMBE TO MOFFAT IN RE: LOCAL CIRCUMSTANCES OF THE TOTAL SOLAR ECLIPSE

Many of the documents included in the appendices will be of little interest to the casual reader. They are included here so that an official permanent record will be available to assist in the planning and execution of any future expeditions.

APPENDIX A

May 19, 1965

Flight from Albuquerque to Barksdale to 55° Lat N to Albuquerque

Approximate Location	Fixed Position	Time (Zulu)	Calculated Ground Speed (average between the two fixed positions)
New Orleans	30°01'N 90°10'W	1736	
			415
McComb	31°28'N 90°15'W	1747	
			438
Jackson	32°30'N 90°10'W	1757	
			435
Greenwood	33°28'N 90°16'W	1805	
			475
Memphis	35°01'N 89°53'W	1817	
			430
Dyersburg	36°01'N 89°18'W	1826.5	
			430
Paducah	37°03'N 88°43'W	1835.5	
			429
Effington	39°12'N 88°30'W	1853	
			437
--------	40°23'N 88°08'W	1903	
			437
South Chicago	41°31'N 87°34'W	1913	
			438
Janesville	42°36'N 89°03'W	1926	
			420
Madison	43°05'N 89°25'W	1931	

Approximate Location	Fixed Position	Time (Zulu)	Calculated Ground Speed (average between the two fixed positions)
--------	43°31'N 89°28'W	1935.5	
			345
--------	44°16'N 89°31'W	1943.5	
			365
--------	45°24'N 90°08'W	1955	
			360
Duluth	46°52'N 92°07'W	2015	
			395
--------	48°31'N 91°58'W	2030	
			445
Sioux Lookout	50°00'N 91°56'W	2042	
			447
--------	51°14'N 92°13'W	2052	
			350
--------	52°00'N 92°20'W	2100	
			398
--------	52°54'N 92°11'W	2108	
			425
--------	53°47'N 92°10'W	2115.5	
			415
--------	54°39'N 92°08'W	2123	

June 11, 1965

Flight from Albuquerque to Barksdale to New Orleans to 53° N Lat to Albuquerque

New Orleans	30°08'N 90°05'W	1843	
			470 KTS
McComb	31°04'N 90°05'W	1850	
			456
Jackson	32°21'N 90°12'W	1900	
			410

Approximate Location	Fixed Position	Time (Zulu)	Calculated Ground Speed (average between the two fixed positions)
--------	34°36'N 89°59'W	1920	
			424
Everett-Stewart	36°15'N 89°12'W	1935	
			396
--------	37°19'N 88°45'W	1945	
			403
--------	39°00'N 88°37'W	2000	
			520
Kaukakee	41°02'N 87°41'W	2015	
			354
Chicago Heights	41°30'N 87°38'W	2020	
			440
Chicago O'Hare	42°04'N 88°13'W	2026	
			420
Madison	42°55'N 89°15'W	2036	
			338
Watoma	44°12'N 89°31'W	2050	
			515
--------	45°30'N 90°16'W	2100	
			402
Duluth	46°48'N 92°17'W	2117	
			380
--------	48°54'N 92°07'W	2137	

--------	49°04'N 92°06'W	2140	
			430
Sioux Lookout	50°06'N 91°58'W	2148.5	
			402

Approximate Location	Fixed Position	Time (Zulu)	Calculated Ground Speed (average between the two fixed positions)
--------	51°22'N 92°00'W	2200	
			330
	53°00'N 92°00'W	2217	

APPENDIX B

May 21, 1965

Flight from Travis to Hickam (TO Travis 0641)

Approximate Location	Fixed Position	Time (Zulu)	Calculated Ground Speed (average between the two fixed positions)
--------	37°22'N 124°13'W	0702	380 KTS
			345
--------	36°13'N 127°15'W	0730	
			445
--------	34°52'N 131°28'W	0800	
			450
--------	33°52'N 134°39'W	0823	
			408
--------	31°43'N 140°24'W	0910	
			388
--------	28°37'N 146°43'W	1000	
			410 KTS
--------	26°21'N 151°05'W	1040	
			360
--------	25°22'N 152°48'W	1058	
			400
--------	23°37'N 155°25'W	1125	
			395
--------	22°21'N 156°18'W	1139	

May 24, 1965 (crossed international date line)

Flight from Hickam to Fiji (overflew Samoa because of bad weather)

Hickam	------	1142 TO	
--------	20°56'N 159°25'W	1201	

Approximate Location	Fixed Position	Time (Zulu)	Calculated Ground Speed (average between the two fixed positions)
--------	20°33'N 164°50'W	1250	
			435 KTS
--------	16°58'N 165°52'W	1321	
			415
--------	12°50'N 166°56'W	1358	
			410
--------	9°50'N 167°42'W	1425	
			412
--------	6°00'N 168°48'W	1500	
			435
--------	2°05'N 169°56'W	1534	
			430
Canton Island	2°49'S 171°03'W	1616	
			400
--------	7°05'S 171°41'W	1655	
			545
--------	8°47'S 171°37'W	1706	
			445
--------	12°30'S 170°57'W	1737	
			400
Over Pago Pago and on to Fiji			
	15°34'S 173°30'W	1822	
			345
--------	16°42'S 178°12'W	1911	
			265
--------	17°48'S 177°25'E	2010 (TA Nandi)	

Approximate Location	Fixed Position	Time (Zulu)	Calculated Ground Speed (average between the two fixed positions)
May 30, 1965			
Eclipse Mission Flight			
--------	14°44'S 167°41'W	1740	
			435 KTS
--------	15°10'S 165°15'W	1800	
			47°
--------	15°37'S 161°15'W	1830	
			460
--------	16°12'S 157°20'W	1900	
			450
--------	16°19'S 155°50'W	1912	
			450
--------	16°25'S 155°8'W	1917 (turned NE)	

--------	15°05'S(Control 154°00'W Ref.)	1938) 1954) 16 min orbits 2010)	
			430
--------	15°22'S 153°37'W	2014 (heading Chg at ~ 2011)	
			435
Atoll Motu-Iti	16°10'S 152°17'W	2026 (turned to westerly heading)	

--------	16°21'S 153°58'W	2043	
			395
--------	16°30'S 157°30'W	2115	
			395
--------	16°40'S 160°55'W	2145	
			395
--------	16°45'S 167°11'W	2240	

Approximate Location	Fixed Position	Time (Zulu)	Calculated Ground Speed (average between the two fixed positions)
May 31 - June 2, 1965			
Samoa - Fiji - Avalon (TO Samoa 1700)			
--------	14°00'S 173°32'W	1732	
			280 KTS
Niuatoputapu	16°05'S 174°13'W	1800	
			415
--------	17°19'S 177°48'W	1832	

(TA Nandi 1920) (TO Nandi 2225)			
--------	18°18'S 176°58'E	2234	
			400
--------	22°05'S 171°28'E	2333	
			390
	24°52'S 167°53'E	0013	
			355
--------	30°05'S 161°27'E	0132	
			345
Lord Howe Island	31°31'S 159°05'E	0158	
			365
--------	33°23'S 152°30'E	0256	

(TO Avalon 0435)			
June 3, 1965			
Mission South from Melbourne (TO Avalon 1520)			
--------	40°00'S 145°30'E	1547	
			515 KTS
Hobart	42°53'S 147°33'E	1610	
			535

Approximate Location	Fixed Position	Time (Zulu)	Calculated Ground Speed (average between the two fixed positions)
--------	43°50'S 147°32'E	1616.5	
			545
--------	45°00'S 147°30'E	1625	
			490
--------	47°45'S 147°30'E	1645	
			505
--------	50°00'S 147°30'E	1701	
			495
--------	51°55'S 147°30'E	1715	
			495
--------	56°06'S 147°30'E	1745	
			470
--------	60°00'S 147°38'E	1815 (turned back North)	

June 4, 1965			
Avalon to Darwin (TO Avalon 0535)			
Bendigo	36°46'S 144°12'E	0550	

Denliquin	35°25'S 144°58'E	0600	
			415
--------	31°25'S 144°56'E	0635	
			440
--------	26°38'S 144°55'E	0714	
			425
--------	24°25'S 144°52'E	0733	
			480
--------	21°35'S 144°57'E	0754	
			440
--------	17°27'S 145°08'E	0828	
			460

Approximate Location	Fixed Position	Time (Zulu)	Calculated Ground Speed (average between the two fixed positions)
--------	12°40'S 144°55'E	0906 (turned West)	
			415
--------	12°29'S 141°53'E	0932	
			425
--------	12°29'S 138°00'E	1004	
			450
--------	12°30'S 133°46'E	1037	

(TA Darwin 1110)

June 5, 1965

Darwin to Guam to Hickam (TO Darwin 0705)

--------	12°27'S 132°53'E	0227	
			450 KTS
--------	12°28'S 134°37'E	0241	
			450
--------	12°28'S 136°09'E	0253	
			475
--------	12°37'S 139°37'E	0319	
			480
--------	12°37'S 141°40'E	0334	
			470
--------	12°37'S 143°32'E	0348.5	
			470
--------	12°35'S 144°55'E	0359	

--------	12°27'S 145°00'E	0401	
			450
--------	11°58'S 145°00'E	0405	
			460

Approximate Location	Fixed Position	Time (Zulu)	Calculated Ground Speed (average between the two fixed positions)
--------	10°10'S 145°00'E	0419	
			460
--------	08°38'S 145°00'E	0431	
			430
--------	07°38'S 145°00'E	0439.5	
			435
--------	05°35'S 145°00'E	0456	
			445
Manam	04°05'S 145°00'E	0508.5	
			440
--------	02°41'S 145°00'E	0520	
			445
--------	00°26'S 145°00'E	0538	
			430
--------	00°25'N 145°00'E	0545	
			430
--------	02°48'N 145°00'E	0605	
			485
--------	04°33'N 145°00'E	0618	
			455
--------	08°20'N 145°05'E	0648	
			430
--------	10°00'N 145°02'E	0702	
			425
--------	12°33'N 145°00'E	0723.5	
			400
--------	13°56'N 145°30'E	0737	
			450
--------	15°00'N 145°07'E	0746	
			435

Approximate Location	Fixed Position	Time (Zulu)	Calculated Ground Speed (average between the two fixed positions)
--------	17°20'N 145°00'E	0805 (turn around for Guam)	

(TO Guam 1310)			
--------	13°56'N 146°27'E	1329	
			420
--------	14°48'N 150°03'E	1400	
			440
--------	15°41'N 153°43'E	1430	
			440
--------	16°30'N 157°28'E	1500	
			445
--------	17°37'N 161°09'E	1530	
			450
--------	18°13'N 163°24'E	1548	
			455
Wake	19°16'N 166°37'E	1614	
			420
--------	19°40'N 173°00'E	1706	
			435
--------	19°45'N 175°00'E	1722	
			410
--------	19°57'N 180°00'E/W	1803.5	
			430
--------	20°13'N 175°00'W	1843	
			430
--------	20°20'N 172°12'W	1905	
			405
--------	20°24'N 170°00'W	1923.5	
			440

Approximate Location	Fixed Position	Time (Zulu)	Calculated Ground Speed (average between the two fixed positions)
--------	20°33'N 167°25'W	1944	---

(TA Hickam 2115)

APPENDIX C

ECLIPSE TIME TABLE

Samoa Time	(U.T.)
$8^h\ 33^m\ 48^s$	($19^h\ 33^m\ 48^s.2$)
Nav:	East Leg I
N.C.A.:	38 min to estimated 2nd contact (ELI)
$8^h\ 38^m\ 48^s$	($19^h\ 38^m\ 48^s.2$) enter turn
$8^h\ 41^m\ 48^s$	($19^h\ 41^m\ 48^s.2$)
Nav:	West Leg I
N.C.A.:	30 min to estimated 2nd contact (WLI)
$8^h\ 46^m\ 48^s$	($19^h\ 46^m\ 48^s$) enter turn
$8^h\ 49^m\ 48^s$	($19^h\ 49^m\ 48^s.2$)
Nav:	East Leg II
N.C.A.:	22 min to estimated 2nd contact (ELII)
$8^h\ 54^m\ 48^s$	($19^h\ 54^m\ 48^s.2$) enter turn
$8^h\ 57^m\ 48^s$	($19^h\ 57^m\ 48^s.2$)
Nav.:	West Leg II
N.C.A.:	14 min to estimated 2nd contact (WLII)
$9^h\ 2^m\ 48^s$	($20^h\ 02^m\ 48^s.2$) enter turn
$9^h\ 5^m\ 48^s$	($20^h\ 05^m\ 48^s.2$)
Nav:	East Leg III
N.C.A.	6 min to estimated 2nd contact (ELIII)
$9^h\ 6^m\ 48^s$	($20^h\ 06^m\ 48^s.2$)
Garcia:	5 min to estimated 2nd contact now.
$9^h\ 7^m\ 48^s$	($20^h\ 07^m\ 48^s.2$)
Garcia:	4 min to estimated 2nd contact now.
$9^h\ 8^m\ 48^s$	($20^h\ 08^m\ 48^s.2$)
Garcia:	3 min to estimated 2nd contact now.
$9^h\ 9^m\ 48^s$	($20^h\ 09^m\ 48^s.2$)
Garcia:	2 min to estimated 2nd contact now.

$9^h\ 10^m\ 48^s$ ($20^h\ 10^m\ 48^s.2$) (turn)

Garcia: 1 min to estimated 2nd contact now.

$9^h\ 11^m\ 03^s$ ($20^h\ 11^m\ 03^s.2$)

Garcia: 45 sec to estimated 2nd contact now.

$9^h\ 11^m\ 18^s$ ($20^h\ 11^m\ 18^s.2$)

Garcia: 30 sec to estimated 2nd contact now.

$9^h\ 11^m\ 28^s$ ($20^h\ 11^m\ 28^s.2$)

Garcia: 20 sec to estimated 2nd contact now.

N.C.A.: The horns are closing fast.

MARK Bailey's Beads 2nd contact.

Garcia: Time_____.*

N.C.A.: Duration_____.

Garcia: 4 min to estimated 3rd contact.

3 min 30 sec to estimated 3rd contact.

3 min -- to estimated 3rd contact.

2 min 30 sec to estimated 3rd contact.

2 min -- to estimated 3rd contact.

1 min 30 sec to estimated 3rd contact.

1 min -- to estimated 3rd contact.

-- 30 sec to estimated 3rd contact.

Garcia: -- 20 sec to estimated 3rd contact.

N.C.A.: MARK Bailey's Beads 3rd contact.

Garcia: Time_____.

+1 min (turn)

Nav: Final Leg - duration 4 min.

*The times and duration indicated here by blanks were those observed during the eclipse and are noted in the text.

APPENDIX D

NAVY DEPARTMENT
U. S. NAVAL OBSERVATORY
WASHINGTON, D.C. 20390

12 April 1965

AIR MAIL
SPECIAL DELIVERY

Dear Mr. Moffat:

In reply to your letter and subsequent phone call, attached are the local circumstances of the total solar eclipse of 30 May 1965.

1. Sheets A, A' give the local circumstances on the central line at 33,000 feet for each minute of U.T. from $20^h\ 00^m$ to $20^h\ 30^m$.

2. Sheets B, B' give pairs of local circumstances associated with times of the phenomena on the central line from $20^h\ 09^m$ to $20^h\ 21^m$. The locations are those the aircraft should occupy at second contact and third contact respectively if the aircraft flies at right angles to the direction to the sun and at a speed of 440 knots. This assumes crossing the central line of the eclipse at mid totality and at the time and position indicated in sheets A, A'. The duration of totality, as seen from the aircraft, is third contact from second phenomena of each pair minus second contact from first phenomena of each pair.

Example: Assume intercept of center line of eclipse to be made at $20^h\ 14^m$ at latitude -15° 26.1 and longitude, +153° 36.6. See sheets A, A' for local circumstances at this instant. For an aircraft travelling at 440 knots and heading shown on sheets B, B' (orthogonal to direction to sun), observer should be at latitude -15° 16.1 and longitude +153° 49.5 at instant of second contact ($20^h\ 11^m\ 48^s.2$) and at latitude -15° 36.1 and longitude +153° 23.7 at instant of third contact ($20^h\ 16^m\ 12^s.2$) See sheets B, B'. The duration of totality for this intercept is $4^m\ 24^s.0$.

The velocity of the shadow is approximately 34.5 nautical miles per minute at $20^h\ 09^m$, 30.8 n.m. at $20^h\ 15^m$, and 28.0 n.m. at $20^h\ 21^m$. From this you can compute the change in time argument for a desired distance displacement of intercept along the path.

Please let us know if you require any further information.

Sincerely yours,

R. L. DUNCOMBE
Director
Nautical Almanac Office

Mr. W. T. Moffat, Manager
Test Range Department
Sandia Corporation
Sandia Base, Albuquerque, New Mexico

Encl: Listings

NAUTICAL ALMANAC OFFICE
U.S. NAVAL OBSERVATORY
WASHINGTON, D.C. 20390

LOCAL CIRCUMSTANCES OF THE TOTAL SOLAR ECLIPSE OF 30 MAY 1965
ALTITUDE 33,000 FEET DELTA T 35 SECONDS
FOR SANDIA CORPORATION

A

CENTRAL LINE AT 33,000 FT			FIRST CONTACT			SECOND CONTACT		
U.T.	LATITUDE	LONGITUDE	U.T.	P	V	U.T.	P	V
20h00m	-20°35.3	+160°44.3	18h48m04.5	242°	4°	19h58m12.1	61°	195°
20 01	-20 09.7	+160 07.6	18 48 36.1	242	4	19 59 10.7	61	196
20 02	-19 44.7	+159 32.2	18 49 08.2	242	4	20 00 09.5	61	196
20 03	-19 20.4	+158 57.9	18 49 40.8	241	4	20 01 08.3	61	196
20 04	-18 56.7	+158 24.6	18 50 13.9	241	4	20 02 07.2	61	196
20 05	-18 33.5	+157 52.4	18 50 47.3	241	4	20 03 05.9	61	197
20 06	-18 10.9	+157 21.0	18 51 21.1	241	4	20 04 04.8	61	197
20 07	-17 48.8	+156 50.5	18 51 55.3	241	4	20 05 03.7	61	197
20 08	-17 27.2	+156 20.8	18 52 29.7	241	4	20 06 02.5	61	197
20 09	-17 06.0	+155 51.9	18 53 04.5	241	4	20 07 01.3	61	198
20 10	-16 45.2	+155 23.6	18 53 39.6	241	4	20 08 00.2	61	198
20 11	-16 24.9	+154 56.0	18 54 14.9	241	4	20 08 59.0	61	199
20 12	-16 04.9	+154 28.9	18 54 50.6	241	4	20 09 58.1	61	199
20 13	-15 45.3	+154 02.5	18 55 26.6	241	4	20 10 57.0	61	199
20 14	-15 26.1	+153 36.6	18 56 02.7	241	4	20 11 55.9	61	200
20 15	-15 07.2	+153 11.2	18 56 39.2	241	4	20 12 54.9	61	200
20 16	-14 48.6	+152 46.2	18 57 16.0	241	4	20 13 54.1	61	200
20 17	-14 30.4	+152 21.8	18 57 52.7	241	4	20 14 53.0	60	201
20 18	-14 12.5	+151 57.7	18 58 29.9	240	4	20 15 52.0	61	201
20 19	-13 54.8	+151 34.1	18 59 07.3	240	4	20 16 51.1	60	202
20 20	-13 37.5	+151 10.8	18 59 44.9	240	5	20 17 50.2	61	202
20 21	-13 20.4	+150 47.9	19 00 22.7	240	5	20 18 49.3	61	203
20 22	-13 03.6	+150 25.4	19 01 00.7	240	5	20 19 48.3	61	203
20 23	-12 47.1	+150 03.2	19 01 38.8	240	5	20 20 47.3	61	204
20 24	-12 30.8	+149 41.3	19 02 17.2	240	5	20 21 46.4	61	204
20 25	-12 14.7	+149 19.7	19 02 55.9	240	5	20 22 45.7	61	205
20 26	-11 58.9	+148 58.4	19 03 34.6	240	5	20 23 44.8	61	205
20 27	-11 43.4	+148 37.3	19 04 13.6	240	5	20 24 44.0	61	206
20 28	-11 28.0	+148 16.6	19 04 52.6	240	5	20 25 43.0	61	207
20 29	-11 12.9	+147 56.0	19 05 32.0	240	6	20 26 42.4	61	207
20 30	-10 58.0	+147 35.7	19 06 11.6	240	6	20 27 41.5	61	208

V_o is always measured CCW from the vertical.

P_o is measured eastward from the north point.

LOCAL CIRCUMSTANCES OF THE TOTAL SOLAR ECLIPSE OF 30 MAY 1965
ALTITUDE 33,000 FEET DELTA T 35 SECONDS
FOR SANDIA CORPORATION

NAUTICAL ALMANAC OFFICE
U.S. NAVAL OBSERVATORY
WASHINGTON, D.C. 20390

A'

MAXIMUM ECLIPSE U.T.	MAG	ALT	AZ	THIRD CONTACT U.T.	P	V	FOURTH CONTACT U.T.	P	V	DURATION	WIDTH OF PATH	LATITUDE	LONGITUDE
20h00m00s.0	1.048	32°	45°	20h01m47s.9	241°	16°	21h22m06s.3	61°	215°	3m35s.8	102mi	-20°35'.3	+160°44'.3
20 00 59.9	1.048	33	45	20 02 49.1	241	16	21 23 41.3	61	216	3 38.4	102	-20 09.7	+160 07.6
20 01 59.9	1.048	34	44	20 03 50.3	241	16	21 25 15.3	61	217	3 40.8	102	-19 44.7	+159 32.2
20 02 59.9	1.049	35	44	20 04 51.6	241	17	21 26 48.5	61	218	3 43.3	103	-19 20.4	+158 57.9
20 04 00.1	1.049	36	43	20 05 52.9	241	17	21 28 21.1	61	219	3 45.7	104	-18 56.7	+158 24.6
20 05 00.0	1.049	37	43	20 06 54.1	241	17	21 29 52.7	61	220	3 48.2	104	-18 33.5	+157 52.4
20 06 00.1	1.049	37	42	20 07 55.3	241	18	21 31 23.8	61	221	3 50.5	105	-18 10.9	+157 21.0
20 07 00.1	1.049	38	42	20 08 56.5	241	18	21 32 53.9	61	222	3 52.8	105	-17 48.8	+156 50.5
20 08 00.1	1.050	39	41	20 09 57.6	241	18	21 34 23.3	61	223	3 55.1	106	-17 27.2	+156 20.8
20 08 59.9	1.050	40	41	20 10 58.6	241	19	21 35 52.0	61	224	3 57.3	106	-17 06.0	+155 51.9
20 10 00.0	1.050	40	40	20 11 59.8	241	19	21 37 20.1	61	225	3 59.6	106	-16 45.2	+155 23.6
20 10 59.9	1.050	41	40	20 13 00.7	241	19	21 38 47.4	61	227	4 01.7	107	-16 24.9	+154 56.0
20 12 00.1	1.050	42	39	20 14 02.0	241	20	21 40 14.5	61	228	4 03.9	107	-16 04.9	+154 28.9
20 12 59.9	1.051	42	39	20 15 02.9	241	20	21 41 40.6	61	229	4 05.9	108	-15 45.3	+154 02.5
20 13 59.9	1.051	43	39	20 16 03.8	241	21	21 43 06.0	61	230	4 07.9	108	-15 26.1	+153 36.6
20 14 59.9	1.051	44	38	20 17 04.9	241	21	21 44 31.0	62	231	4 10.0	109	-15 07.2	+153 11.2
20 16 00.1	1.051	44	38	20 18 06.1	241	22	21 45 55.6	62	232	4 12.0	109	-14 48.6	+152 46.2
20 16 59.9	1.051	45	37	20 19 06.9	241	22	21 47 19.1	62	234	4 13.9	109	-14 30.4	+152 21.8
20 18 00.0	1.051	46	37	20 20 08.0	240	22	21 48 42.4	62	235	4 16.0	110	-14 12.5	+151 57.7
20 19 00.0	1.051	46	36	20 21 08.9	241	23	21 50 04.9	62	236	4 17.8	110	-13 54.8	+151 34.1
20 20 00.0	1.052	47	36	20 22 09.8	240	23	21 51 27.1	62	237	4 19.6	110	-13 37.5	+151 10.8
20 21 00.1	1.052	47	35	20 23 10.9	240	24	21 52 48.5	62	239	4 21.6	110	-13 20.4	+150 47.9
20 22 00.0	1.052	48	35	20 24 11.7	241	25	21 54 09.4	62	240	4 23.4	111	-13 03.6	+150 25.4
20 22 59.9	1.052	48	34	20 25 12.5	241	25	21 55 29.6	62	241	4 25.2	111	-12 47.1	+150 03.2
20 23 59.9	1.052	49	34	20 26 13.4	241	26	21 56 49.3	62	242	4 27.0	112	-12 30.8	+149 41.3
20 25 00.0	1.052	50	33	20 27 14.3	241	26	21 58 08.6	62	244	4 28.6	112	-12 14.7	+149 19.7
20 26 00.0	1.052	50	32	20 28 15.2	241	27	21 59 27.3	62	245	4 30.4	112	-11 58.9	+148 58.4
20 27 00.1	1.052	51	32	20 29 16.1	241	27	22 00 45.4	62	246	4 32.1	113	-11 43.4	+148 37.3
20 27 59.9	1.053	51	31	20 30 16.9	241	28	22 02 02.8	63	248	4 33.9	113	-11 28.0	+148 16.6
20 29 00.1	1.053	52	31	20 31 17.8	241	29	22 03 19.9	63	249	4 35.4	114	-11 12.9	+147 56.0
20 30 00.0	1.053	52	30	20 32 18.5	241	29	22 04 36.4	63	250	4 37.0	114	-10 58.0	+147 35.7

B

LOCAL CIRCUMSTANCES OF THE TOTAL SOLAR ECLIPSE OF 30 MAY 1965
ALTITUDE 33,000 FEET DELTA T 35 SECONDS
FOR SANDIA CORPORATION

NAUTICAL ALMANAC OFFICE
U.S. NAVAL OBSERVATORY
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HEADING OF AIRCRAFT	U.T. OF CENTRAL LINE	LOCATION OF SECOND CON. AND THIRD CON. LATITUDE	LONGITUDE	FIRST CONTACT U.T.	P	V	SECOND CONTACT U.T.	P	V
130°.8	20 09°	-16° 56'.0	+156° 03'.9	18h 52m 58s.6	241°	3°	20h 06m 55s.3	42°	179°
	20 09	-17 16.0	+155 39.9	18 53 10.7	241	5	20 07 20.2	80	217
130.4	20 10	-16 35.2	+155 35.8	18 53 33.5	240	3	20 07 53.9	42	179
	20 10	-16 55.2	+155 11.4	18 53 46.1	241	5	20 08 19.8	80	218
129.9	20 11	-16 14.9	+155 08.4	18 54 08.5	240	3	20 08 52.3	41	179
	20 11	-16 34.9	+154 43.7	18 54 21.6	241	5	20 09 19.0	80	218
129.5	20 12	-15 54.9	+154 41.5	18 54 44.0	240	3	20 09 51.1	41	179
	20 12	-16 14.9	+154 16.4	18 54 57.7	241	5	20 10 18.8	80	218
129.0	20 13	-15 35.3	+154 15.2	18 55 19.7	240	3	20 10 49.7	41	180
	20 13	-15 55.3	+153 49.8	18 55 33.9	241	5	20 11 18.2	80	219
128.5	20 14	-15 16.1	+153 49.5	18 55 55.5	240	3	20 11 48.2	41	180
	20 14	-15 36.1	+153 23.7	18 56 10.3	241	5	20 12 17.8	80	219
128.1	20 15	-14 57.2	+153 24.3	18 56 31.7	240	3	20 12 46.8	41	180
	20 15	-15 17.2	+152 58.1	18 56 47.1	241	5	20 13 17.5	80	220
127.6	20 16	-14 38.6	+152 59.6	18 57 08.0	240	3	20 13 45.4	41	180
	20 16	-14 58.6	+152 32.8	18 57 24.3	241	5	20 14 17.5	80	220
127.1	20 17	-14 20.4	+152 35.3	18 57 44.6	240	3	20 14 44.0	41	181
	20 17	-14 40.4	+152 08.2	18 58 01.5	241	5	20 15 17.0	80	221
126.6	20 18	-14 02.5	+152 11.4	18 58 21.4	240	3	20 15 42.5	41	181
	20 18	-14 22.5	+151 43.8	18 58 39.1	241	5	20 16 17.2	80	222
126.1	20 19	-13 44.8	+151 48.1	18 58 58.3	240	4	20 16 41.2	41	181
	20 19	-14 04.8	+151 20.0	18 59 16.9	241	5	20 17 16.7	80	222
125.6	20 20	-13 27.5	+151 25.0	18 59 35.6	240	4	20 17 39.7	41	182
	20 20	-13 47.5	+150 56.6	18 59 54.7	241	5	20 18 16.4	80	223
125.1	20 21	-13 10.4	+151 02.4	19 00 12.9	240	4	20 18 38.2	40	182
	20 21	-13 30.4	+150 33.4	19 00 33.1	241	5	20 19 16.5	81	223

LOCAL CIRCUMSTANCES OF THE TOTAL SOLAR ECLIPSE OF 30 MAY 1965
ALTITUDE 33,000 FEET — DELTA T 35 SECONDS
FOR SANDIA CORPORATION

NAUTICAL ALMANAC OFFICE
U.S. NAVAL OBSERVATORY
WASHINGTON, D.C. 20390

B'

MAXIMUM ECLIPSE U.T.	MAG	ALT	AZ	THIRD CONTACT U.T.	P	V	FOURTH CONTACT U.T.	P	V	DURATION	WIDTH OF PATH	LATITUDE	LONGITUDE
20h08m47s3	1.050	40°	41°	20h10m39s4	260°	37°	21h35m32s9	62°	224°	3m44s1	106mi	-16°56.0	+156°03.9
20 09 12.7	1.050	40	41	20 11 05.1	222	0	21 36 10.7	61	224	3 44.9	106	-17 16.0	+155 39.9
20 09 46.9	1.050	40	41	20 11 40.0	260	38	21 37 00.5	62	225	3 46.1	106	-16 35.2	+155 35.8
20 10 13.2	1.050	40	40	20 12 06.6	222	0	21 37 39.5	61	226	3 46.8	106	-16 55.2	+155 11.4
20 10 46.3	1.050	41	40	20 12 40.3	260	38	21 38 27.2	62	227	3 48.0	106	-16 14.9	+155 08.4
20 11 13.4	1.050	41	40	20 13 07.9	222	1	21 39 07.3	61	227	3 48.9	107	-16 34.9	+154 43.7
20 11 46.0	1.050	42	40	20 13 41.0	260	39	21 39 53.6	62	228	3 49.9	107	-15 54.9	+154 41.5
20 12 14.1	1.050	42	39	20 14 09.4	221	1	21 40 34.9	61	228	3 50.6	107	-16 14.9	+154 16.4
20 12 45.5	1.051	42	39	20 14 41.4	260	39	21 41 19.1	62	229	3 51.7	107	-15 35.3	+154 15.2
20 13 14.5	1.051	42	39	20 15 10.9	221	1	21 42 01.6	61	229	3 52.7	108	-15 55.3	+153 49.8
20 13 45.0	1.051	43	39	20 15 41.8	260	40	21 42 44.0	62	230	3 53.6	108	-15 16.1	+153 49.5
20 14 15.0	1.051	43	38	20 16 12.2	221	2	21 43 27.8	61	230	3 54.4	108	-15 36.1	+153 23.7
20 14 44.5	1.051	44	38	20 16 42.1	260	40	21 44 08.3	62	231	3 55.3	108	-14 57.2	+153 24.3
20 15 15.5	1.051	44	38	20 17 13.6	221	2	21 44 53.5	61	231	3 56.1	109	-15 17.2	+152 58.1
20 15 43.9	1.051	44	38	20 17 42.4	260	41	21 45 32.0	62	232	3 57.0	109	-14 38.6	+152 59.6
20 16 16.4	1.051	44	37	20 18 15.4	221	2	21 46 19.0	61	232	3 57.9	109	-14 58.6	+152 32.8
20 16 43.4	1.051	45	37	20 18 42.8	260	41	21 46 55.1	62	233	3 58.8	109	-14 20.4	+152 35.3
20 17 16.9	1.051	45	37	20 19 16.7	221	3	21 47 43.1	61	234	3 59.7	110	-14 40.4	+152 08.2
20 17 42.8	1.051	45	37	20 19 43.1	260	42	21 48 17.6	62	235	4 00.6	110	-14 02.5	+152 11.4
20 18 17.7	1.051	46	36	20 20 18.2	221	3	21 49 07.4	61	235	4 01.0	110	-14 22.5	+151 43.8
20 18 42.1	1.051	46	37	20 20 43.1	260	42	21 49 39.3	62	236	4 01.9	110	-13 44.8	+151 48.1
20 19 18.2	1.051	46	36	20 21 19.7	221	4	21 50 30.7	61	236	4 03.0	110	-14 04.8	+151 20.0
20 19 41.5	1.052	47	36	20 21 43.4	260	43	21 51 00.7	62	237	4 03.7	110	-13 27.5	+151 25.0
20 20 18.7	1.052	47	35	20 22 21.0	221	4	21 51 53.1	61	237	4 04.6	110	-13 47.5	+150 56.6
20 20 40.7	1.052	47	36	20 22 43.3	261	43	21 52 21.2	62	238	4 05.1	110	-13 10.4	+151 02.4
20 21 19.6	1.052	47	35	20 23 22.6	220	4	21 53 15.7	61	239	4 06.1	110	-13 30.4	+150 33.4

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3. "A Description of Multilens Cameras for the APEQS Expedition," ISA Transactions, Vol. 3, No. 4, October 1964.

4. Champeny, John C., Measurement of Typical NC-135 Aircraft Stability, Edgerton, Germeshausen & Grier, Inc., Technical Memorandum No. B-462 (EGG 1183-185), April 9, 1965

The following internal communications:*

Topic	Sender	Date
Proposed Airborne Scientific Experiments for the May 30, 1965, Eclipse		December 1964
Eclipse Instrumentation	D. B. Shuster, 9200	February 1, 1965
Eclipse Expedition	N. C. Anderholm, 9232	March 19, 1965
Trip to American Samoa, March 6-12	W. B. Pafford, 7255	April 8, 1965
Information for Employees Traveling to Pago Pago, Samoa, and Australia	L. E. Hollingsworth, 7200	April 26, 1965
Flight Pay and Insurance Associated with C-135 Flights	R. E. Hooker, 2551	April 29, 1965
Use of Interphone Facilities on A/C 370 During the Eclipse Mission of 5/30/65	W. B. Pafford, 7255	May 12, 1965

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