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VISUAL ACUITY AND ASTRONAUT VISIBILITY

Manned Space Flight Experiment S-8/D-13
Gemini V and Gemini VII Missions

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EXPERIMENT S-8/D-13, VISUAL ACUITY AND ASTRONAUT VISIBILITY

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SUMMARY

Preflight, inflight, and postflight tests of the visual acuity of both members of the Gemini V and Gemini VII crews showed no statistically significant change in their visual capability. Observations of a prepared and monitored pattern of rectangles made at a ground site near Laredo, Texas, confirmed that the visual performance of the astronauts in space was within the statistical range of their respective preflight thresholds, and that laboratory visual acuity data can be combined with environmental optical data to predict correctly man's limiting visual capability to discriminate small objects on the surface of the earth in daytime.

INTRODUCTION

Reports by Mercury astronauts of their sighting small objects on the ground prompted the initiation of a controlled visual acuity experiment which was conducted in both Gemini V and Gemini VII. The first objective of Experiment S-8/D-13 was to measure the visual acuity of the crew members before, during, and after long-duration space flights in order to ascertain the effects of a prolonged spacecraft environment. The second objective was to test the use of basic visual acuity data combined with measured optical properties of ground objects and their natural lighting, as well as of the atmosphere and the spacecraft window, to predict the flight crew's limiting naked-eye visual capability to discriminate small objects on the surface of the earth in daylight.

INFLIGHT VISION TESTS

Inflight Vision Tester

Throughout the flights of Gemini V and Gemini VII the visual performance of the crew members was tested one or more times each day by means of an inflight vision tester. This was a small, self-contained, binocular optical device containing a transilluminated array of 36 high-contrast and low-contrast rectangles. Half of the rectangles were oriented vertically in the field of view and half were oriented horizontally. Rectangle size, contrast, and orientation were randomized; the presentation was sequential; and the sequences were nonrepetitive. Each rectangle was viewed singly at the center of a 30-degree adapting field, the apparent luminance of which was 116 foot-lamberts. Both members of the flight crew made forced-choice judgments of the orientation of each rectangle and indicated their responses by punching holes in a record card. Electrical power for illumination within the instrument was derived from the spacecraft.

The space available between the eyes of the astronaut and the sloping inner surface of the spacecraft window, a matter of 8 or 9 inches, was an important constraint on the physical size of the instrument. The superior visual performance of all crew members, as evidenced by clinical test scores, made it necessary to use great care in alining the instrument with the observer's eyes, since the eyes and not the instrument must set the limit of resolution. In order to achieve this, the permissible tolerance of decentering between a corneal pole and the corresponding optical axis of the eyepiece was less than 0.005 of an inch. This tolerance was met by means of a biteboard equipped with the flight crew member's dental impression to take advantage of the fixed geometrical relation between his upper teeth and his eyes. Figure 1 shows a photograph of the inflight vision tester.

Selection of the Test

The choice of test was made only after protracted study. Many interacting requirements were considered. If, for example, the visual capabilities of the astronauts should change during the long-duration flight, it was of prime importance to measure the change in such a way that man's inflight ability to recognize, classify, and identify landmarks or unknown objects on the ground or in space could be predicted. These higher-order visual discriminations depend upon the quadratic content of the difference images between alternative objects, but virtually all of the conventional patterns used in testing vision yield low-precision information on this important parameter. Thus the prediction requirement tended to eliminate the use of Snellen letters, Landolt rings, checkerboards, and all forms of detection threshold tests.

The readings must not go off-scale if visual changes should occur during flight. This requirement for a broad range of testing was not readily compatible with the desire to have fine steps within the test and yet have sufficient replication to insure statistically significant results.

It was also deemed desirable that the pattern chosen for the inflight vision tester should be compatible with that used on the ground where search contamination of the scores must be carefully avoided; this consideration made any conventional detection threshold test undesirable. The pattern on the ground was within sight for at least 2 minutes during all usable passes, but variations due to atmospheric effects, geometrical foreshortening, directional reflectance characteristics, et cetera, made it necessary to select a test which could be completed in a 20-second period centered about the time of closest approach.

The optimum choice of test proved to be the orientation discrimination of a bar narrow enough to be unresolved in width but long enough to provide for threshold orientation discrimination. The size and apparent contrast of all of the bars used in the test were sufficient to make them readily detectable, but only the larger members of the series were above the threshold of orientation discrimination. These two thresholds are more widely separated for the bar than for any other known test object. The inherent quadratic content of the difference image between orthogonal bars is of greater magnitude than the inherent quadratic content of the bar itself. Interpretation of any changes in the visual performance of the astronauts is, therefore, more generally possible on the basis of orientation discrimination thresholds for the bar than from any other known datum.

Rectangles in the Vision Tester

The rectangles presented for viewing within the inflight vision tester were reproduced photographically on a transparent disc. Two series of rectangles were included, the major series being set at a contrast of -1 and the minor series being set at about one-fourth of this value. The higher contrast series constituted the primary test and was chosen to simulate the expected range of apparent contrast presented by the ground panels to the eyes of the crewmen in orbit. The series consisted of six sizes of rectangles. The sizes covered a sufficient range to guard against virtually any conceivable change in the visual performance of the astronauts during the long-duration flight. The size intervals were small enough, however, to provide a sufficiently sensitive test.

The stringent requirements imposed by conditions of space flight made it impossible to use as many replications of each rectangle as was desirable from statistical considerations. After much study it was decided to display each of the six rectangular sizes four times. This compromise produced a sufficient statistical sample to make the sensitivity of the inflight test comparable to that ordinarily achieved with the most common variety of clinical wall chart. This sensitivity corresponds roughly to the ability to separate performance at 20/15 from performance at 20/20. It was judged that this compromise between the sensitivity of test and the range of the variables tested was the proper one for this exploratory investigation.

A secondary test at lower contrast was included as a safeguard against the possibility that visual performance at low contrast might change in some different way. With only 12 rectangles assignable within the inflight vision tester for the low-contrast array, it was decided to use only three widely different rectangle sizes, presenting each of these sizes four times.

Because of the accelerated launch schedule of Gemini V it was not possible to use the flight instrument for preflight experiments. These data were, therefore, obtained with the first of the inflight vision testers (serial no. 1) while the last instrument to be constructed (serial no. 5) was put aboard the spacecraft. The two instruments were optically identical except for their 12 low-contrast rectangles, which measured a contrast of -0.332 and -0.233, respectively. In Gemini VII all of the reported data (preflight, inflight, and postflight) were obtained with serial no. 5 tester.

Analysis of Correct Scores in Gemini V

A comparison of the correct scores made by the Gemini V crew members on the ground (preflight) and in space (inflight) can be used to ascertain whether their observed visual performance differed in the environments or changed during the 7-day mission. The correct scores from the low-contrast and high-contrast series in the vision tester are shown for both crew members in figure 2. The results of standard statistical tests applied to these data are shown in tables I through IV.

Comparisons between preflight and inflight data are given in tables I and II. All Student's t tests show no significant difference in means. All Snedecor's F tests show no significant difference in variances at the 0.05 level, with the exception of Cooper's high-contrast comparison which shows no significant difference at the 0.01 level.

Comparisons between the inflight data at the beginning of the mission with that at the end are made in tables III and IV. All Student's t tests and Snedecor's F tests show no significant difference at 0.05 level with the exception of the F test on Conrad's low-contrast comparison which shows no significant contrast at 0.01 level.

These statistical findings support the null hypothesis advanced by many scientists before the Gemini V mission was flown.

TABLE I .- VISION TESTER (GROUND VERSUS SPACE)

Cooper	C = -1		C = -0.23	
	Ground	Space	Ground	Space
Number	7	9	7	9
Mean	17.6	18.4	8.6	8.3
S.d	2.3	0.96	1.3	1.4
t	0.96		0.31	
$t_{0.05}$	2.14		2.14	
F	6.12		1.02	
$F_{0.05}$	3.58		3.58	
$F_{0.01}$	6.37			

TABLE II .- VISION TESTER (GROUND VERSUS SPACE)

Conrad	C = -1		C = -0.23	
	Ground	Space	Ground	Space
Number	7	9	7	9
Mean	20.7	20.7	9.7	8.6
S.d	2.7	1.7	1.2	2.0
t	0		1.13	
$t_{0.05}$	2.14		2.14	
F	2.79		2.43	
$F_{0.05}$	3.69		4.82	

TABLE III .- VISION TESTER (INFLIGHT TREND)

Cooper	C = -1		C = -0.23	
	First 4	Last 4	First 4	Last 4
Number	4	4	4	4
Mean	18.2	18.8	8.5	8.5
S.d	0.83	1.1	0.87	1.8
t	0.68		0	
$t_{0.05}$	2.45		2.45	
F	1.73		4.33	
$F_{0.05}$	9.28		9.28	

TABLE IV .- VISION TESTER (INFLIGHT TREND)

Conrad	C = -1		C = -0.23	
	First 4	Last 4	First 4	Last 4
Number	4	4	4	4
Mean	21.3	19.5	8.8	8.75
S.d	1.5	1.1	2.8	0.83
t	1.64		0	
$t_{0.05}$	2.45		2.45	
F	1.96		11.19	
$F_{0.05}$	9.28		9.28	
$F_{0.01}$			29.5	

Analysis of Correct Scores in Gemini VII

A comparison of the correct scores made by the Gemini VII crew members on the ground (preflight) and in space (inflight) can be used to ascertain whether their observed visual performance differed in the environments or changed during the 14-day mission. The correct scores from the low-contrast and high-contrast series in the vision tester are shown for both crew members in figure 3. The results of standard statistical tests applied to these data are shown in tables V through VIII .

Comparisons between preflight and inflight data are given in tables V and VI . All Student's t tests show no significant difference in means. All Snedecor's F tests show no significant difference in variances at the 0.05 level, with the exception of Borman's low-contrast comparison which shows a weakly significant difference at the 0.01 level.

Comparisons between the inflight data at the beginning of the mission with that at the end are made in tables VII and VIII . All Student's t tests and Snedecor's F tests show no significant difference at 0.05 level with the exception of the F test on Borman's low-contrast comparison which shows no significant contrast at the 0.01 level.

These statistical findings provide additional support for the null hypothesis advanced by many scientists before the Gemini missions were flown. Examination of the sensitivity of the test must be considered next. This topic is treated in the following paragraphs.

Preflight Physiological Baseline

Design of the inflight vision tester, as well as the ground sighting experiments described in subsequent paragraphs and the interpretation of the results from both experiments, required that a preflight physiological baseline be obtained for both crew members. For this purpose a NASA van was fitted out as a portable vision research laboratory, moved to the Manned Spacecraft Center at Houston, Texas, and operated by Visibility Laboratory personnel. Figure 4 is a cutaway drawing of this research van. The astronauts, seated at the left, viewed rear-screen projections from an automatic projection system located in the opposite end of the van. Each astronaut participated in several sessions in the laboratory van, during which they became experienced in the psychophysical techniques of the rectangle orientation discrimination visual task. A sufficiently large number of presentations was made to secure a properly numerous statistical sample. The astronauts' forced-choice visual thresholds for the discrimination task were measured accurately and their response distributions determined so that the standard deviations and confidence limits of their preflight visual performance were determined.

TABLE V .- VISION TESTER (GROUND VERSUS SPACE)

Borman	C = -1		C = -0.23	
	Ground	Space	Ground	Space
Number	11	14	11	14
Mean	20.0	19.9	8.45	8.4
S.d	1.3	1.6	0.78	1.7
t	0.12		0.017	
$t_{0.05}$	2.07		2.07	
F	1.49		4.74	
$F_{0.05}$	2.89		2.89	
$F_{0.01}$	4.66		4.66	

TABLE VI .- VISION TESTER (GROUND VERSUS SPACE)

Lovell	C = -1		C = -0.23	
	Ground	Space	Ground	Space
Number	9	14	9	14
Mean	20.9	20.0	9.1	9.1
S.d	1.4	1.6	0.74	1.4
t	1.29		0.073	
$t_{0.05}$	2.08		2.08	
F	1.17		3.64	
$F_{0.05}$	3.26		3.26	
$F_{0.01}$	5.62		5.62	

TABLE VII .- VISION TESTER (INFLIGHT TREND)

Borman	C = -1		C = -0.23	
	First 5	Last 5	First 5	Last 5
Number	5	5	5	5
Mean	19.0	20.0	8.0	9.0
S.d	1.4	1.4	1.3	1.8
t	1.00		0.91	
$t_{0.05}$	2.31		2.31	
F	1.00		2.00	
$F_{0.05}$	6.39		6.39	

TABLE VIII .- VISION TESTER (INFLIGHT TREND)

Lovell	C = -1		C = -0.23	
	First 5	Last 5	First 5	Last 5
Number	5	5	5	5
Mean	19.8	20.4	8.8	9.2
S.d	1.3	1.5	1.2	1.6
t	0.60		0.40	
$t_{0.05}$	2.31		2.31	
F	1.27		1.88	
$F_{0.05}$	6.39		6.39	

Figure 5 is a logarithmic plot of the Gemini V pilot's preflight visual thresholds for the rectangle orientation discrimination task. In this figure the solid angular subtense of the rectangles is plotted along the horizontal axis because both the inflight vision tester and the ground observation experiments used angular size as the independent variable. The solid line in this figure represents the forced-choice rectangle orientation threshold of the pilot at the 0.50 probability level. The dashed curves indicate the $-\sigma$, $+\sigma$, and $+2\sigma$ levels in terms of contrast. The six circled points in the upper row indicate the angular sizes of the high-contrast (C = -1) rectangles presented by the inflight vision tester. The three circled points of the middle and lower rows show the angular sizes of the low-contrast rectangles used in the preflight unit (serial no. 1) and the flight unit (serial no. 5), respectively.

The separate discriminations recorded on the record cards in the inflight vision tester can be used to determine a threshold of angular size. These thresholds and corresponding statistical confidence limits derived with the aid of figure 5 are plotted for the high- and low-contrast tests of the Gemini V command pilot in figures 6 and 7 and for the Gemini V pilot in figures 8 and 9. Corresponding thresholds and confidence limits for the vision tester data secured by the Gemini VII command pilot are shown in figures 10 and 11. Similar data secured by the Gemini VII pilot are shown in figures 12 and 13.

These eight figures also support the null hypothesis, and their quantitative aspect constitutes a specification of the sensitivity of the test. Thus, as planned, variations in visual performance comparable with a change of one line on a conventional clinical wall chart would have been detected. Preflight threshold data can, therefore, be used to predict the limiting visual acuity capabilities of astronauts during space flight provided adequate physical information concerning the object and its background, atmospheric effects, and the spacecraft window exists. A test of such predictions was also carried out and is described in the following paragraphs.

GROUND OBSERVATIONS

The crews of both Gemini V and Gemini VII observed prepared and monitored rectangular patterns on the ground in order to test the use of basic visual acuity data combined with measured optical properties of ground objects and their natural lighting, the atmosphere, and the spacecraft window to predict the limiting naked-eye visual capability of astronauts to discriminate small objects on the surface of the earth in daylight.

Equipment

The experimental equipment consists of an inflight photometer to monitor the spacecraft window, test patterns at two ground observation sites, instrumentation for atmospheric, lighting, and pattern measurements at both sites, and a laboratory facility (housed in a trailer van) for training the astronauts to perform visual acuity threshold measurements and for obtaining a preflight physiological baseline descriptive of their visual performance and its statistical fluctuations. These equipments, except the last, are described in the following paragraphs.

Spacecraft window photometer.- A photoelectric inflight photometer was mounted near the lower right corner of the pilot's window of the Gemini V spacecraft, as shown in figure 14 , in order to measure the amount of ambient light scattered by the window into the path of sight at the moment when observations of the ground test patterns were made. The photometer (fig. 15) had a narrow (1.2°) circular field of view, which was directed through the pilot's window and into the opening of a small black cavity a few inches away outside the window. The photometric scale was linear and extended from approximately 12 to 3000 foot-lamberts. Since the apparent luminance of the black cavity was always much less than 12 foot-lamberts, any reading of the inflight photometer was ascribable to ambient light scattered by the window. Typical data during passes of Gemini V over the Laredo site are shown in figure 16. This information combined with data on the beam transmittance of the window and on the apparent luminance of the background squares in the ground pattern array enabled the contrast transmittance of the window at the moment of observation to be calculated. Uniformity of the window could be tested by removing the photometer from its positioning bracket and making a handheld scan of the window, using a black region of space in lieu of the black cavity. A direct-reading meter incorporated in the photometer enabled the command pilot to observe the photometer readings while the pilot scanned his own window for uniformity. A corresponding scan of the command pilot's window could be made in the same way. Data from the photometer were sent to the ground by real-time telemetry. Electrical power for the photometer was provided entirely by batteries within the instrument.

Ground observation sites.- Sites for observations by the crew of Gemini V were provided on the Gates Ranch, 40 miles north of Laredo, Texas (fig. 17), and on the Woodleigh Ranch, 90 miles south of Carnarvon, Australia (figs. 18 and 19). At the Texas site, 12 squares of plowed, graded, and raked soil 2000 feet by 2000 feet were arranged in a 4 by 3 matrix. White rectangles of styrofoam-coated wallboard were laid out in each square. Their length decreased in a uniform logarithmic progression from 610 feet in the northwest corner (square number 1) to 152 feet in the southwest corner (square number 12) of the array. Each of the 12 rectangles was oriented in one of four positions (i.e., north-south, east-west, or diagonal), and the orientations were random within the series of 12. Advance knowledge of the rectangle orientations was withheld from the flight crew since their task was to report the orientations. Provision was made for changing the rectangle orientations between passes and for adjusting their size in accordance with anticipated slant range, solar elevation, and the visual performance of the astronauts on preceding passes. The observation site in Australia was somewhat similar to the Texas site, but, inasmuch as no observations occurred there, the specific details are unnecessary in this report.

The Australian ground observation site was not manned during Gemini VII because the afternoon time of launch caused no usable daytime overpasses to occur there until the last day of the mission. The 82.5° launch azimuth used for Gemini VII prevented the use of an otherwise highly desirable ground site in the California desert near the Mexican border. Weather statistics for December made the use of the Texas site appear dubious but no alternative was available. The afternoon launch made midday passes over this site available on every day of the mission. Experience gained on Gemini V pointed to the need for a more prominent orientation marking. This was provided by placing east-to-west strips of crushed white limestone 26 feet wide and 2000 feet long across the center of each of the four north background squares in the array. Thus, only eight test rectangles were used in a 2 by 4 matrix on the center and south rows of background squares, as shown in figure 20 . The largest and smallest rectangles were of the same size as those used in Gemini V.

Instrumentation.- Instrumentation at both ground sites consisted of a single tripod-mounted, multipurpose, recording photoelectric photometer (figs. 21 and 22) capable of obtaining all the data needed to specify the apparent contrast of the pattern as seen from the spacecraft at the moment of observation. The apparent luminance of the background squares needed for evaluation of the contrast loss due to the spacecraft window was also ascertained by this instrument. A 14-foot high mobile tower, constructed of metal scaffolding and attached to a truck, supported the tripod-mounted photometer high enough above the ground to enable the plowed surface of the background squares to be measured properly. This arrangement is shown in figures 23 and 24 .

Observations in Gemini V

Observation of the Texas ground pattern site was first attempted on revolution 18, but fuel-cell difficulties which denied the use of the platform were apparently responsible for lack of acquisition of the ground site.

The second scheduled attempt to see the pattern near Laredo was on revolution 33. Acquisition of the site was achieved by the command pilot but not by the pilot, and no readout of rectangle orientation was made.

At the request of the experimenters, the third attempt at Laredo, scheduled originally for revolution 45, was made on revolution 48 in order to secure a higher sun and a shorter slant range. Success was achieved on this pass and is described in the paragraphs on results.

Unfavorable cloud conditions caused the fourth scheduled observation at the Texas site, on revolution 60, to be scrubbed. Thereafter, lack of thruster control made observation of the ground patterns impossible, although excellent weather conditions prevailed on three scheduled occasions at Laredo (revolutions 75, 92 and 107) and once at the Australian site (revolution 88). Long range visual acquisition of the smoke markers used at both sites was reported in each instance, but the drifting spacecraft was not properly oriented near the closest approach to the pattern to enable observations to be made. A fleeting glimpse of the Laredo pattern during drifting flight on revolution 92 enabled it to be successfully photographed with hand cameras. Another fleeting glimpse of the pattern was also reported on revolution 107.

Results of Observations in Gemini V

Quantitative observation of ground markings was achieved only once during Gemini V. This observation occurred during revolution 48 at the ground observation site near Laredo, Texas, at 18:16:14 on the third day of the flight. Despite early acquisition of the smoke marker by the command pilot and further acquisition by him of the target pattern itself well before the point of closest approach, the pilot could not acquire the markings until the spacecraft had been turned to eliminate sunlight on his window. Telemetry records from the inflight photometer show that the pilot's window produced a heavy veil of scattered light until the spacecraft was rotated. Elimination of the morning sun on the pilot's window enabled him to make visual contact with the pattern in time to make a quick observation of the orientation of some rectangles. It may be noted that, during approach, the reduction of contrast due to light scattered by the window was more severe than that due to light scattered by the atmosphere.

An ambiguity exists between the transcription of the radio report made at the time of the pass and the written record in the flight log. The writing was made "blind" while the pilot was actually looking at the pattern; it is a diagram drawn in the manner depicted in the Gemini V flight plan, the Mission Operation Plan, the Description of Experiment, and other documents. The orientation of the rectangles in the sixth and seventh squares appears to have been correctly noted. The verbal report given several seconds later correctly records the orientation of the rectangle in the sixth square if it is assumed that the spoken words describe the appearance of the pattern as seen from a position east of the array while going away from the site.

Despite the hurried nature of the only apparently successful quantitative observation of a ground site during Gemini V, there seems to be a reasonable probability that the sighting was a valid indication of the pilot's correctly discriminating the rectangles in the sixth and seventh squares. Since he did not respond to squares 8 through 12, it can only be inferred that his threshold lay at square 6 or higher.

Tentative values of the apparent contrast and angular size of the sixth and seventh rectangles at the Laredo site at the time of the observation are plotted in figure 25 . The solid line represents the preflight visual performance of Astronaut Conrad as measured in the vision research van. The dashed lines represent the 1- and 2-sigma limits of his visual performance. The positions of the plotted points indicate that his visual performance at the time of revolution 48 was within the statistical range of his preflight visual performance.

Observations in Gemini VII

Observations of the Texas ground pattern site were made on revolutions 16, 17, and 31 under very favorable weather conditions Heavy clouds blanketed the site throughout the remainder of the mission, however, and no further observations of the site were possible. Contamination of the outer surface of the pilot's window made observation of the ground pattern difficult and the result uncertain. The contamination, which was observed to have occurred during launch, was mapped during revolution 19 by means of a window scan with the inflight photometer in the manner described in an earlier section. Figure 26 shows some numerical results of this scan and figure 27 is a photograph of a shaded pencil sketch intended to portray the appearance of the window deduced from the telemetered scan curves. Comparison of this sketch with a similar one made by the pilot during flight shows good correlation.

Figures 26 and 27 show that the command pilot's window was not measurably contaminated on its inboard side. Successful observations of the ground pattern were made by the command pilot through this clear portion of his window on revolutions 17 and 31. No direct sunlight fell on the window during those observations.

Results of Observations in Gemini VII

The results of observations by the command pilot on revolutions 17 and 31 of Gemini VII are shown in figure 28 . These observations occurred at 27:04:49 and 49:26:48 on the second and third day of the flight, respectively.

In figure 28 the circled points represent the apparent contrast and angular size of the largest rectangles in the ground pattern. Apparent contrast was calculated on the basis of measured directional luminances of the white panels and their backgrounds of plowed soil, of atmospheric optical properties measured in the direction of the path of sight to the point of closest approach, and of a small allowance for contrast loss in the spacecraft window based upon window scan data and readings of the inflight photometer at the time of the two observations. Angular sizes and apparent contrast were both somewhat larger for revolution 31 than for revolution 17 because the slant range was shorter and because the spacecraft passed north of the site, thereby causing the background soil to appear darker, as can be noted by comparing figure 20 with figure 29 . The orientations of those rectangles indicated by double circles were reported correctly but those represented by single circles were either reported incorrectly or not reported at all.

The solid line in figure 28 represents the preflight visual performance of Borman as measured in the vision research van. The dashed lines represent the $-\sigma$, $+\sigma$, and $+2\sigma$ contrast limits of his visual performance. The positions of the plotted points indicate that his visual performance was precisely in accordance with his preflight visual thresholds.

CONCLUSIONS

The stated objectives of experiment S-8/D-13 were both achieved successfully. Data from the inflight vision tester show that no change was detected in the visual performance of any of the four astronauts who composed the crews of Gemini V and Gemini VII. Results from observations of the ground site near Laredo, Texas, confirm that the visual performance of the astronauts during space flight was within the statistical range of their preflight visual performance and demonstrate that laboratory visual data can be combined with environmental optical data to predict correctly the limiting visual capability of astronauts to discriminate small objects on the surface of the earth in daylight.

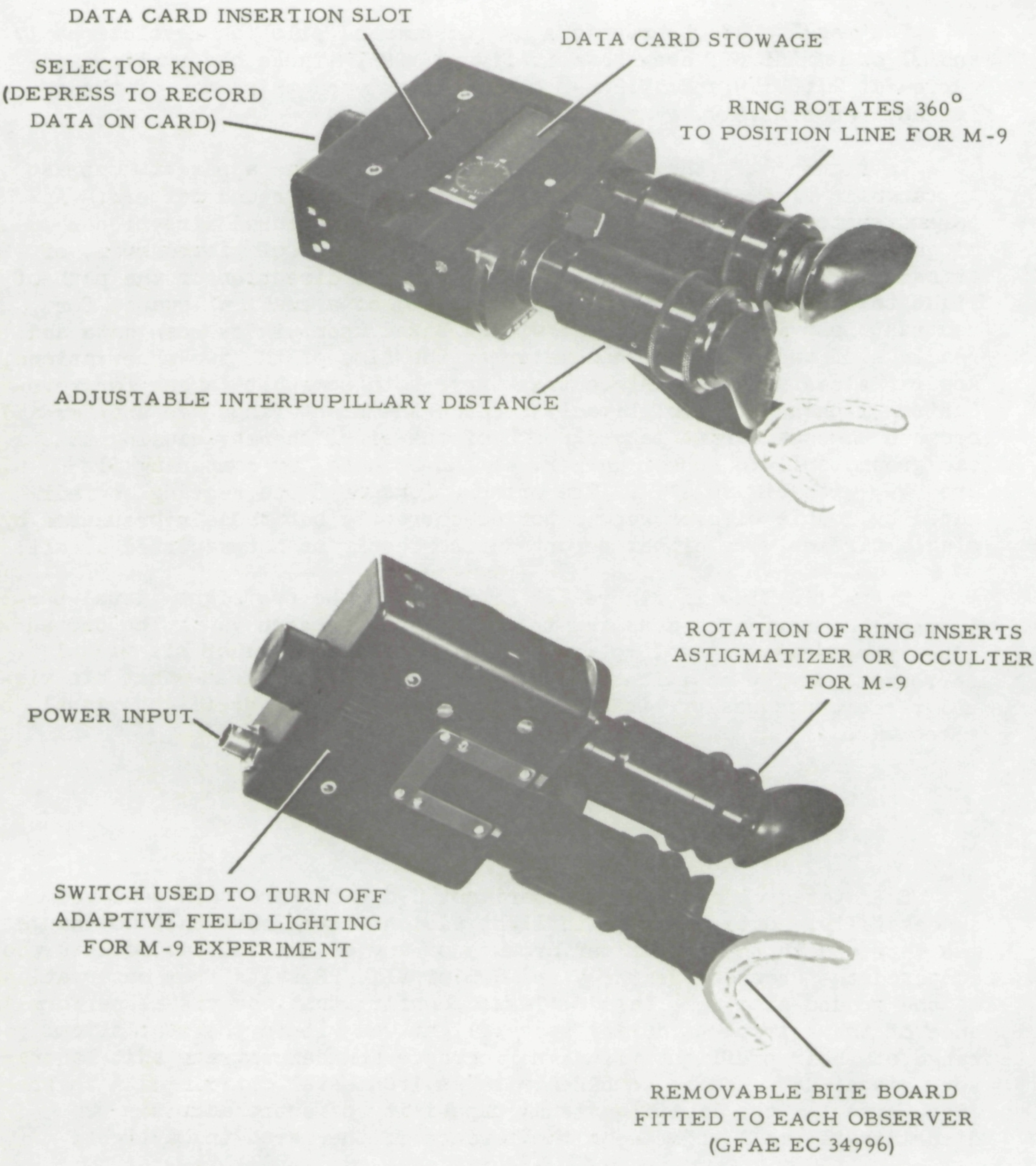

Figure 1 . - In-flight vision tester.

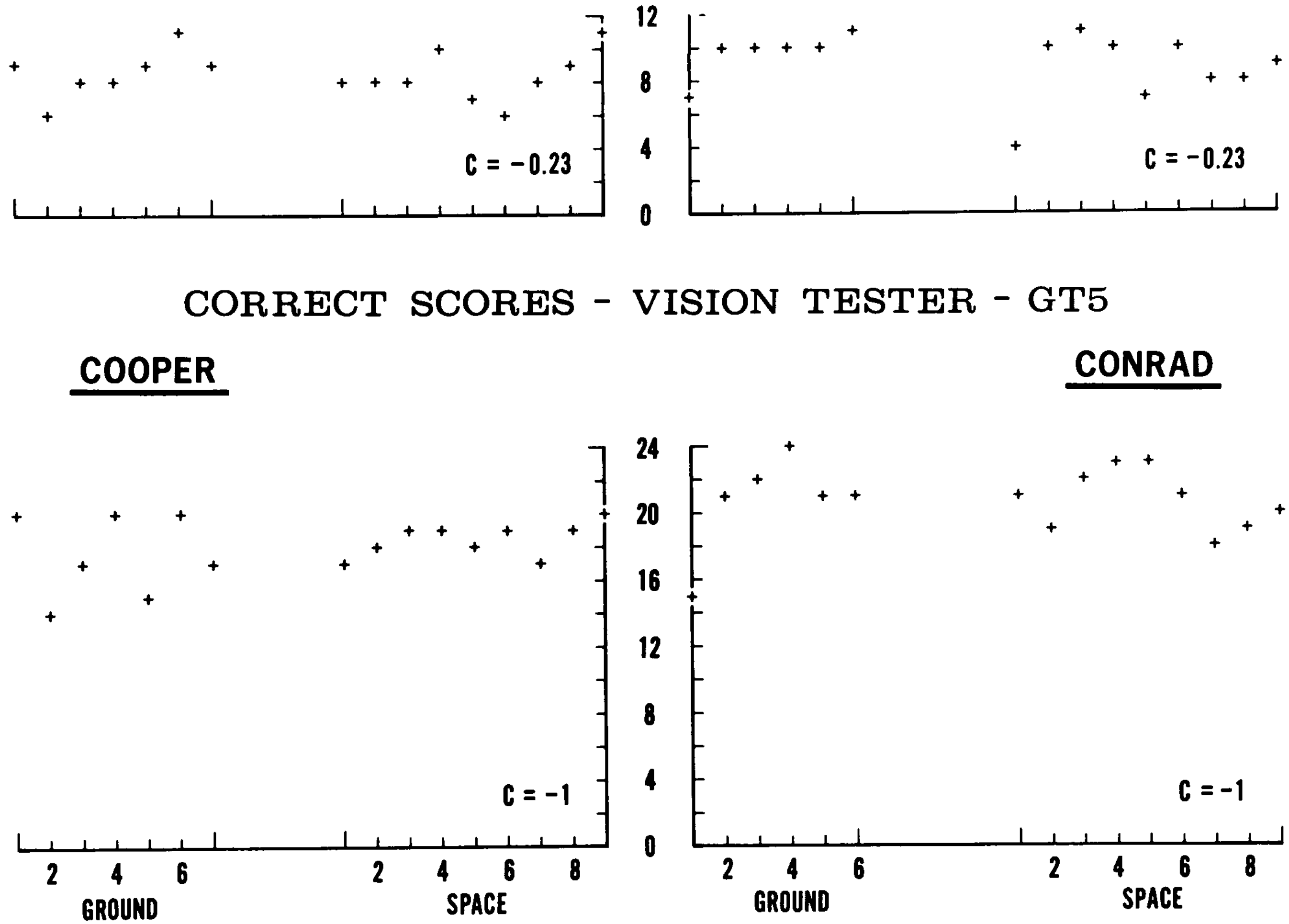

Figure 2. - Correct scores for the vision tester.

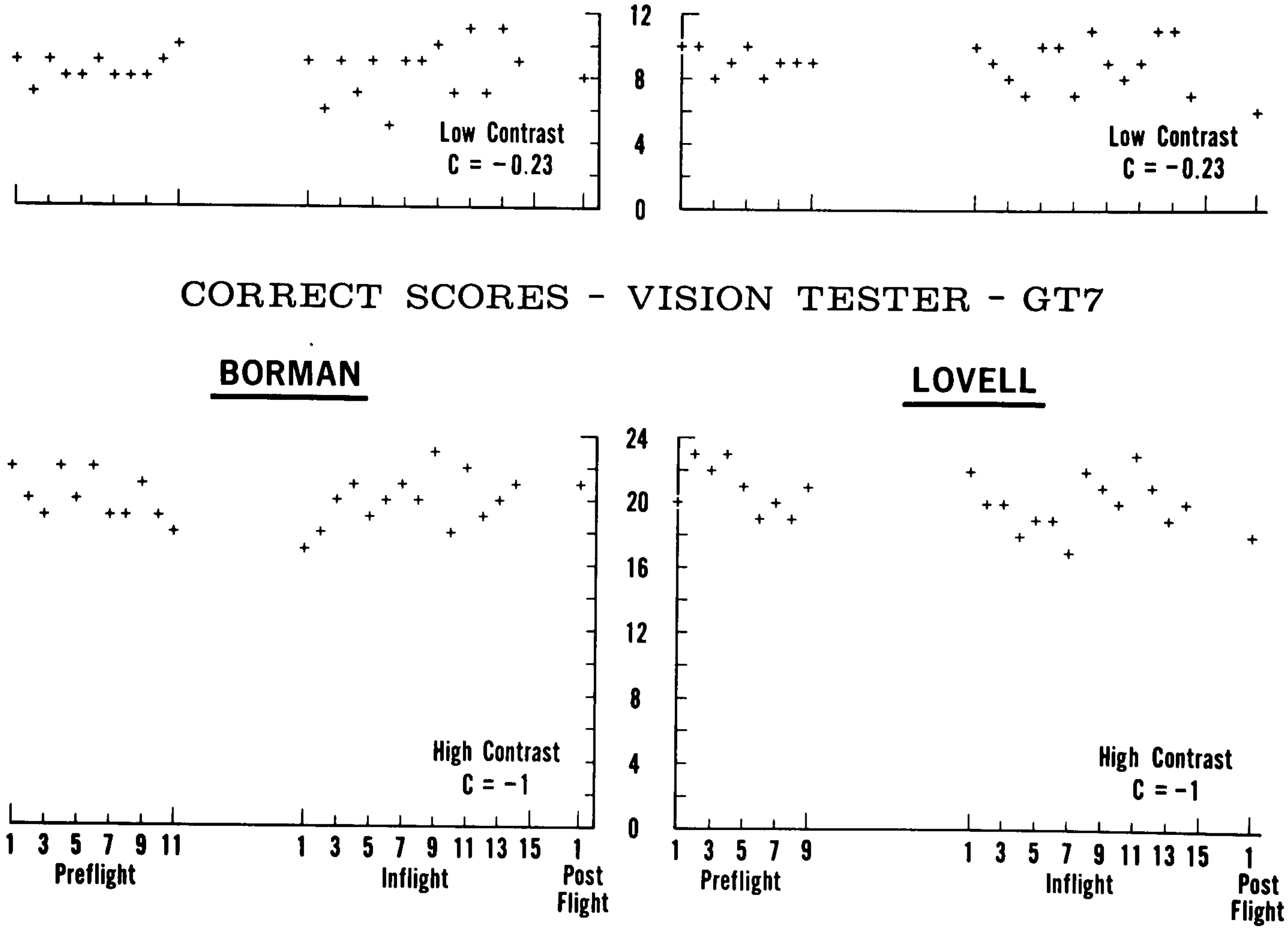

Figure 3. - Correct scores for the vision tester, Gemini VII.

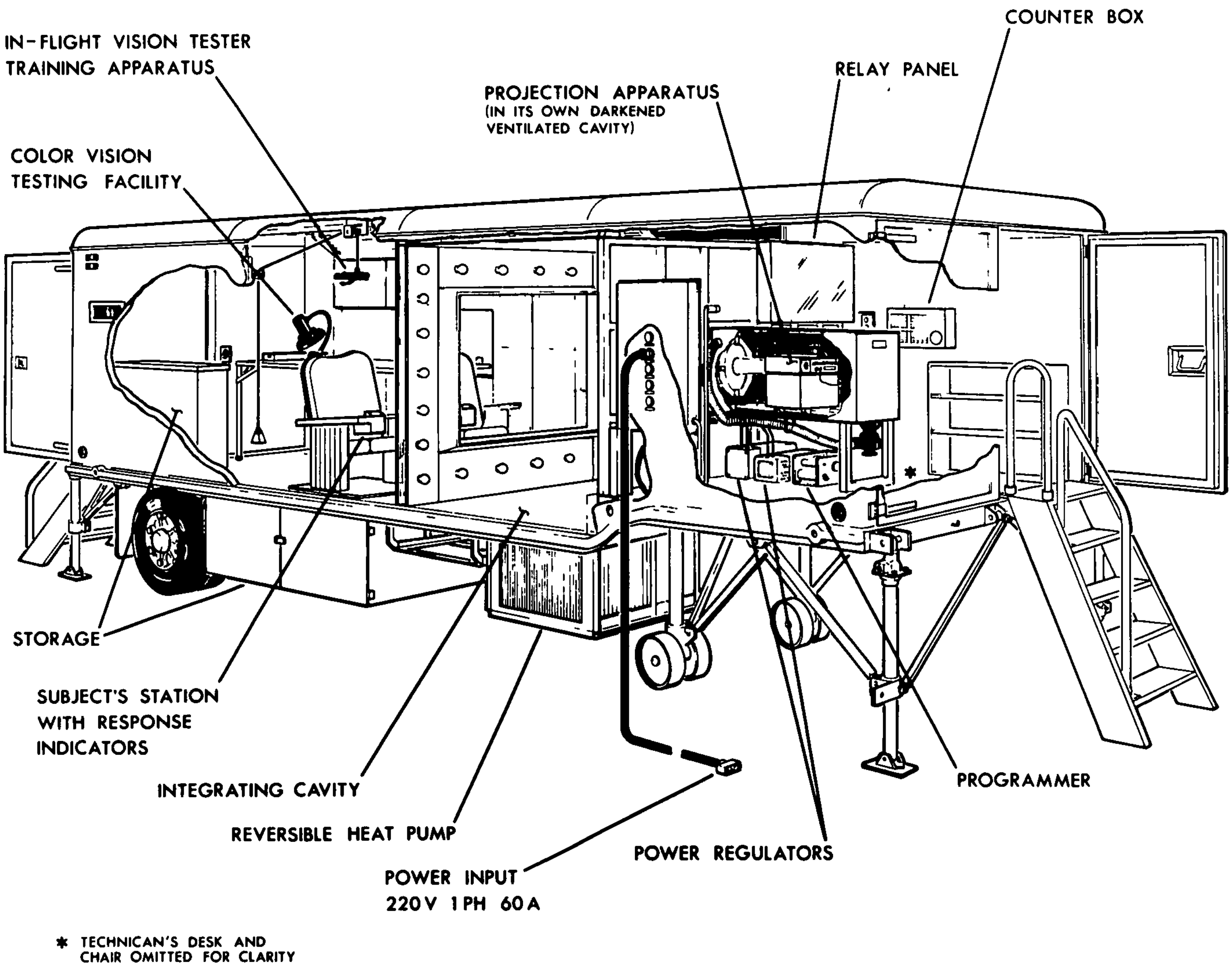

Figure 4. - Vision research and training van.

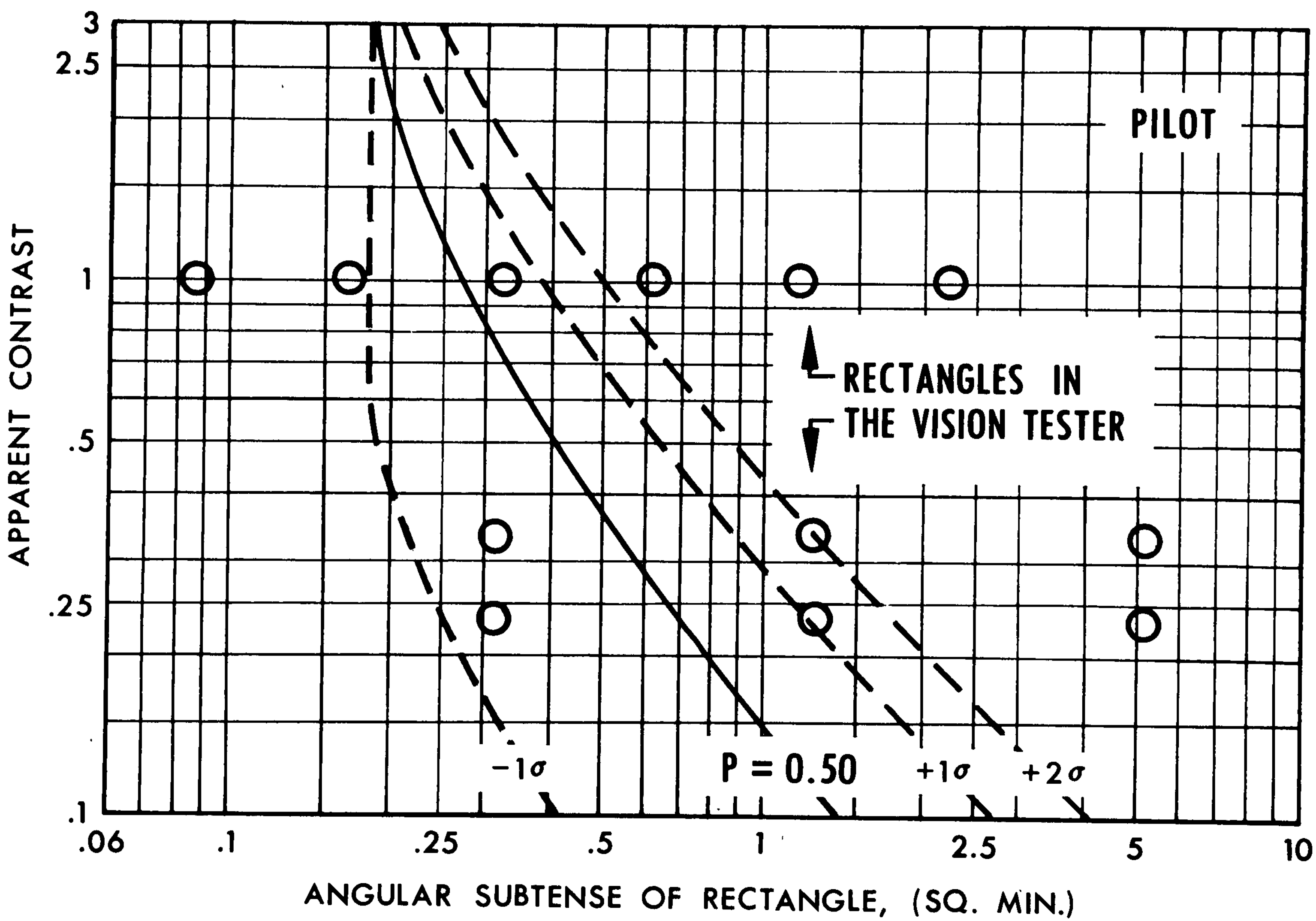

Figure 5 . – Logarithmic plot of preflight visual thresholds.

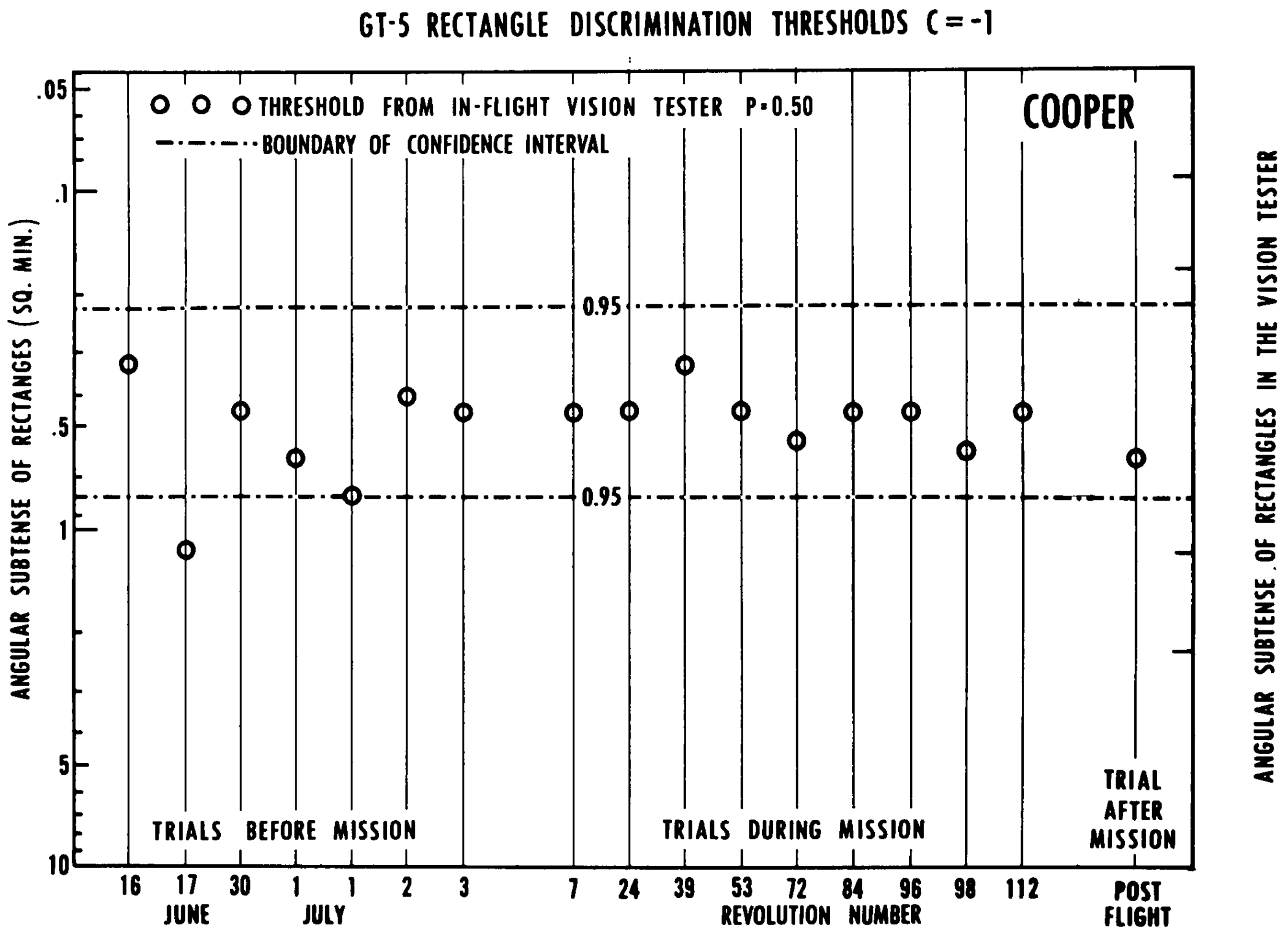

Figure 6. - Gemini V command pilot's rectangle discrimination thresholds C = -1.

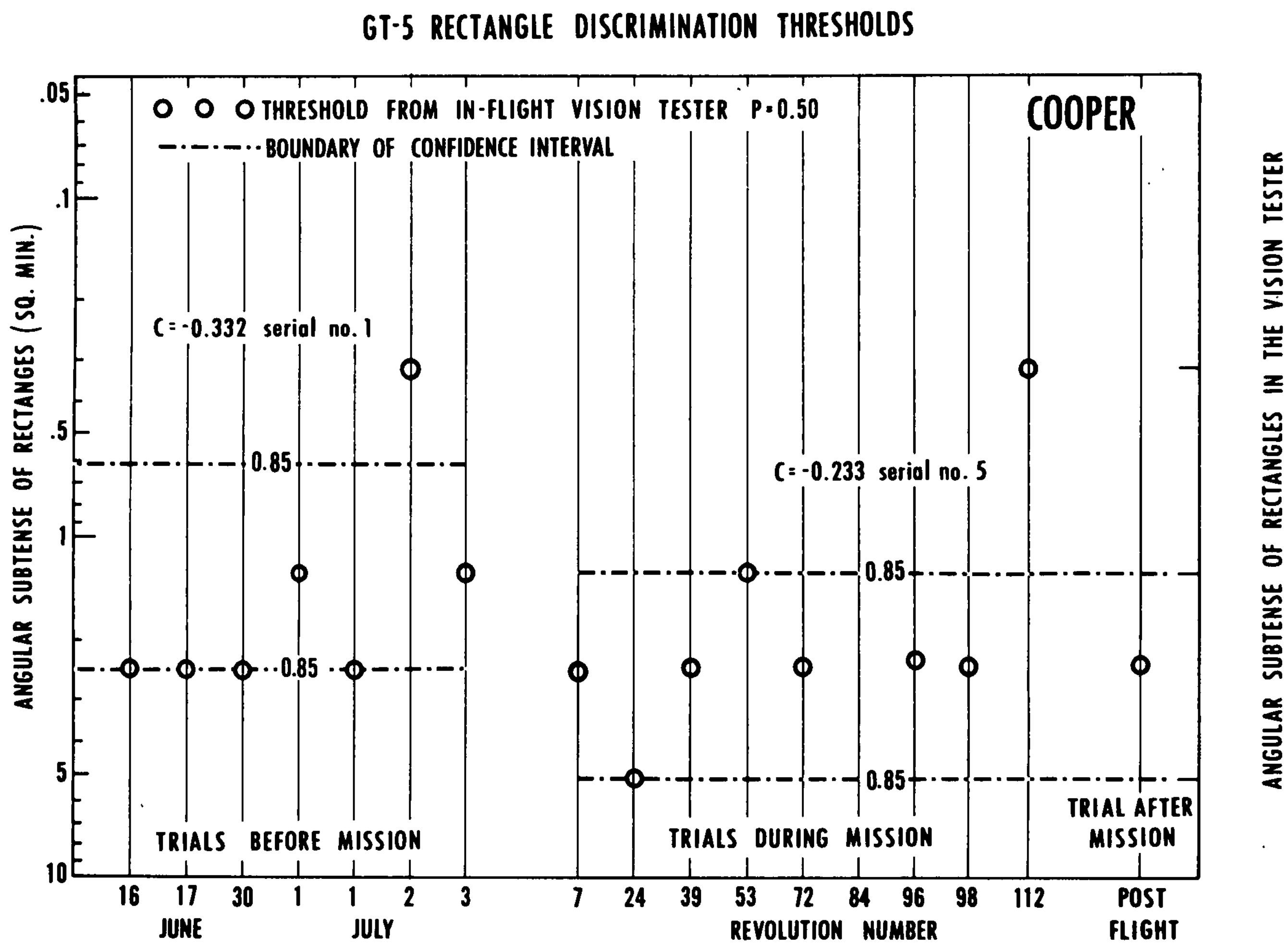

Figure 7. - Gemini V command pilot's rectangle discrimination thresholds.

GT-5 RECTANGLE DISCRIMINATION THRESHOLDS C = -1

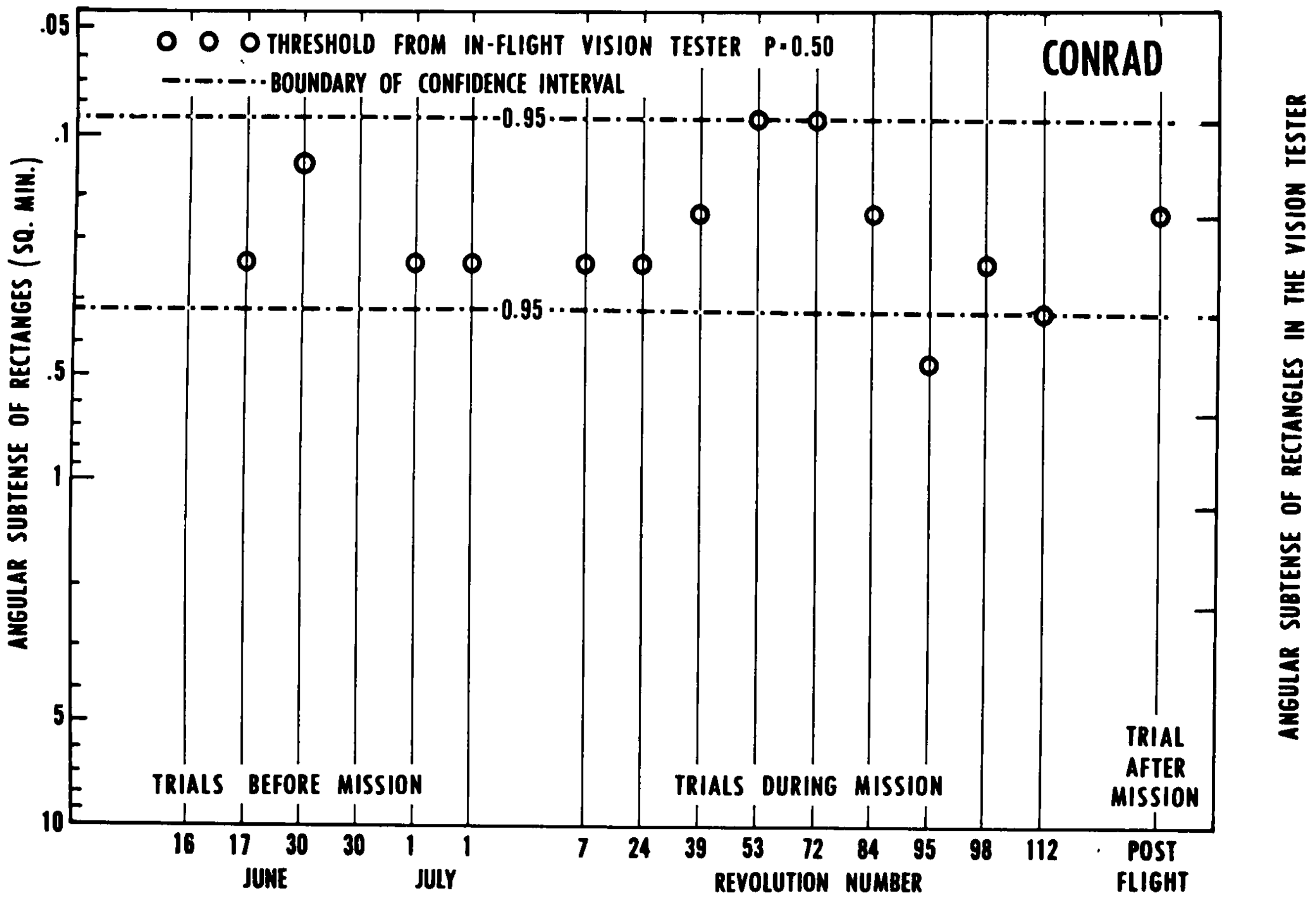

Figure 8. - Gemini V pilot's rectangle discrimination thresholds C = -1.

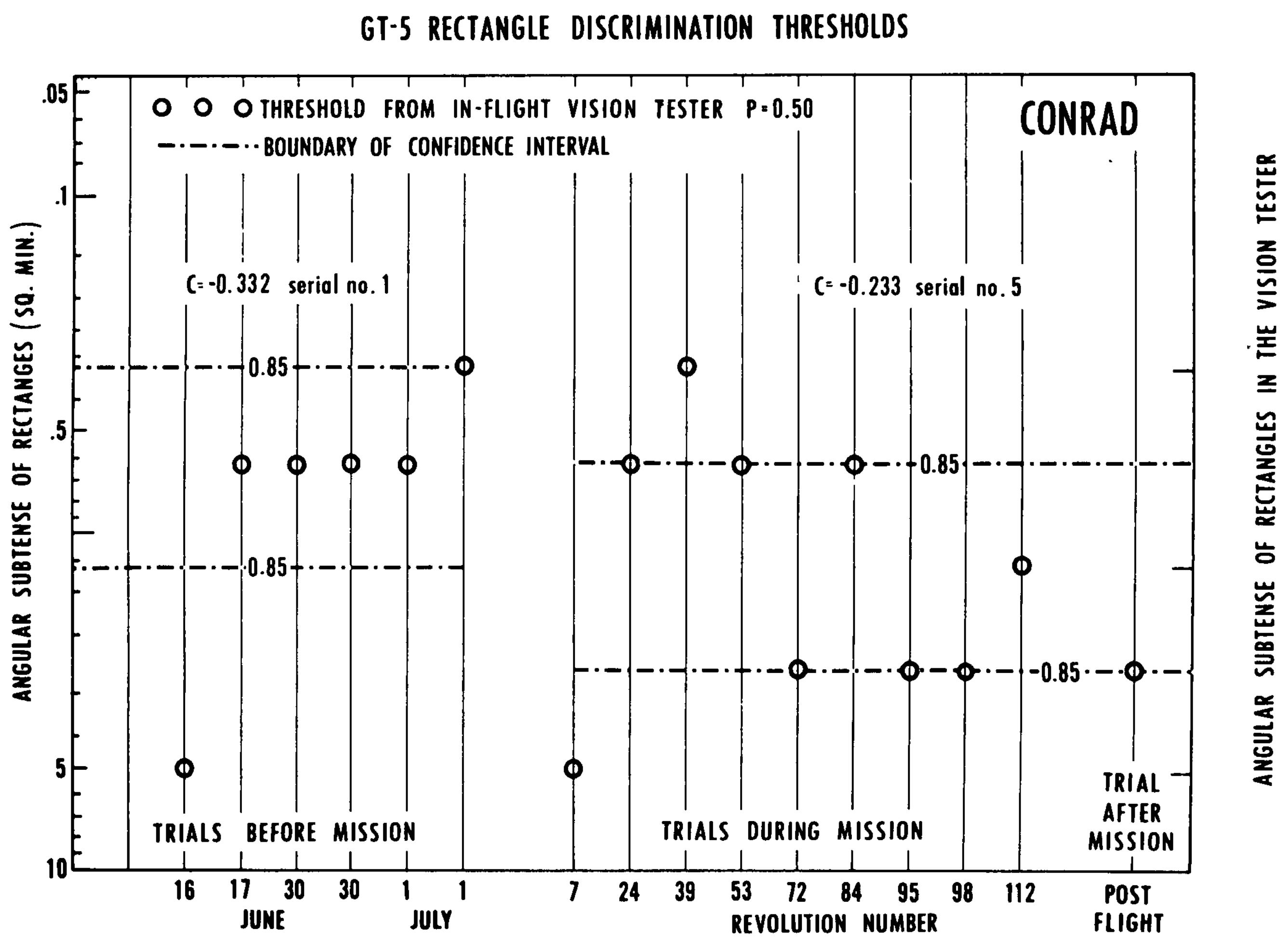

Figure 9. - Gemini V pilot's rectangle discrimination thresholds.

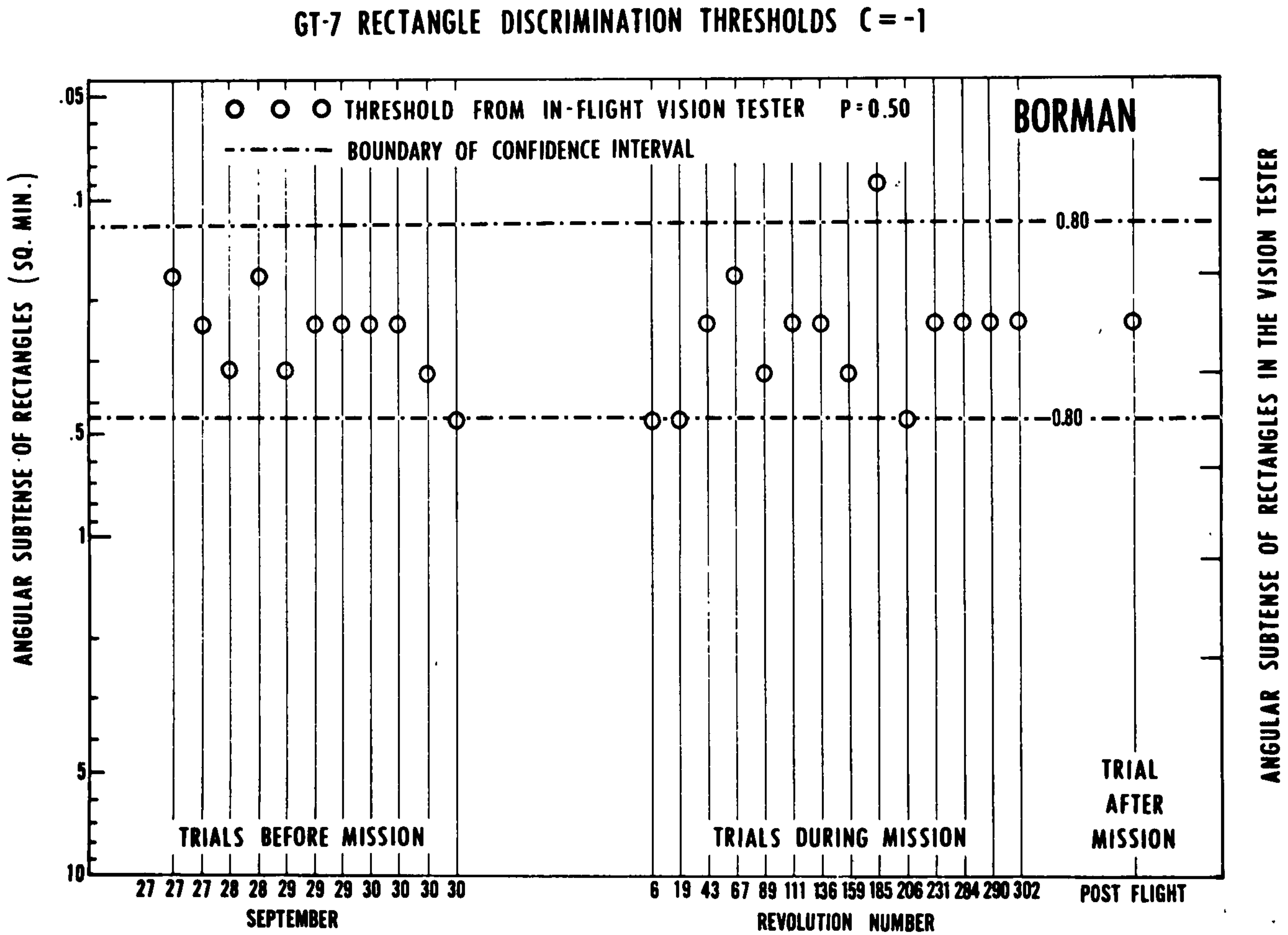

Figure 10. - Gemini VII pilot's rectangle discrimination thresholds C = -1.

GT-7 RECTANGLE DISCRIMINATION THRESHOLDS C=-0.233

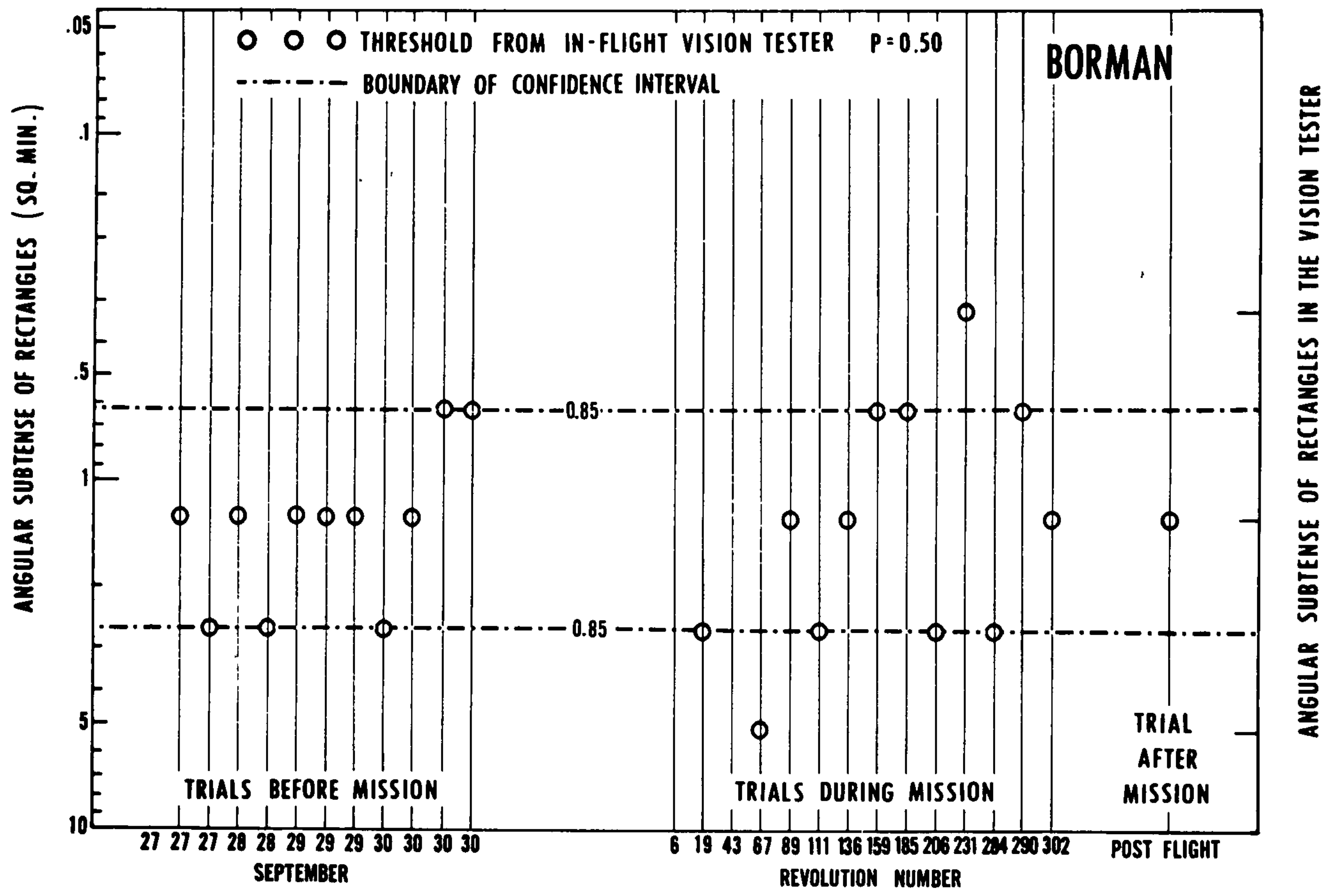

Figure 11. - Gemini VII command pilot's rectangle discrimination thresholds C = -0.233.

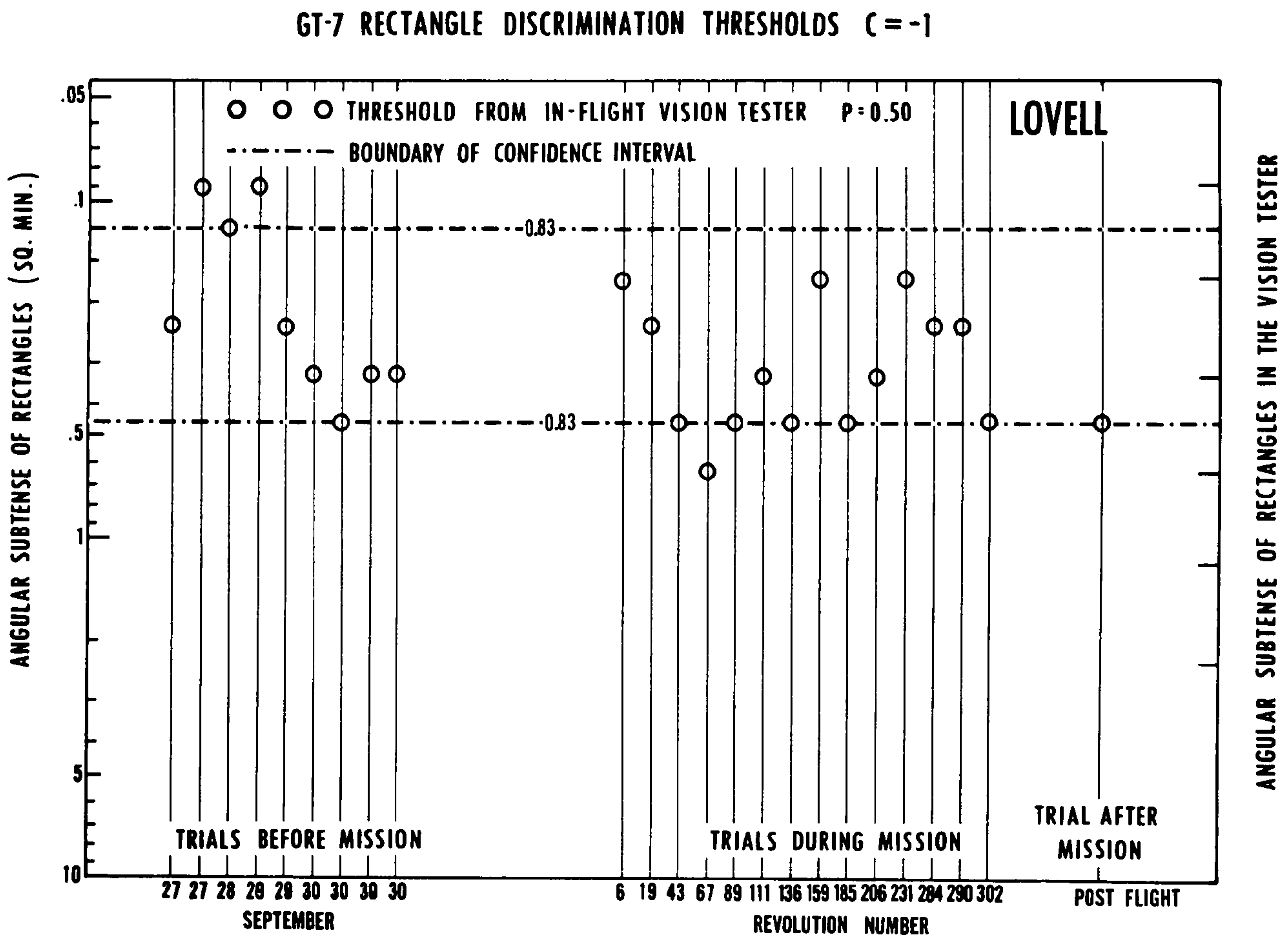

Figure 12. - Gemini VII pilot's rectangle discrimination thresholds.

GT-7 RECTANGLE DISCRIMINATION THRESHOLDS C=-0.233

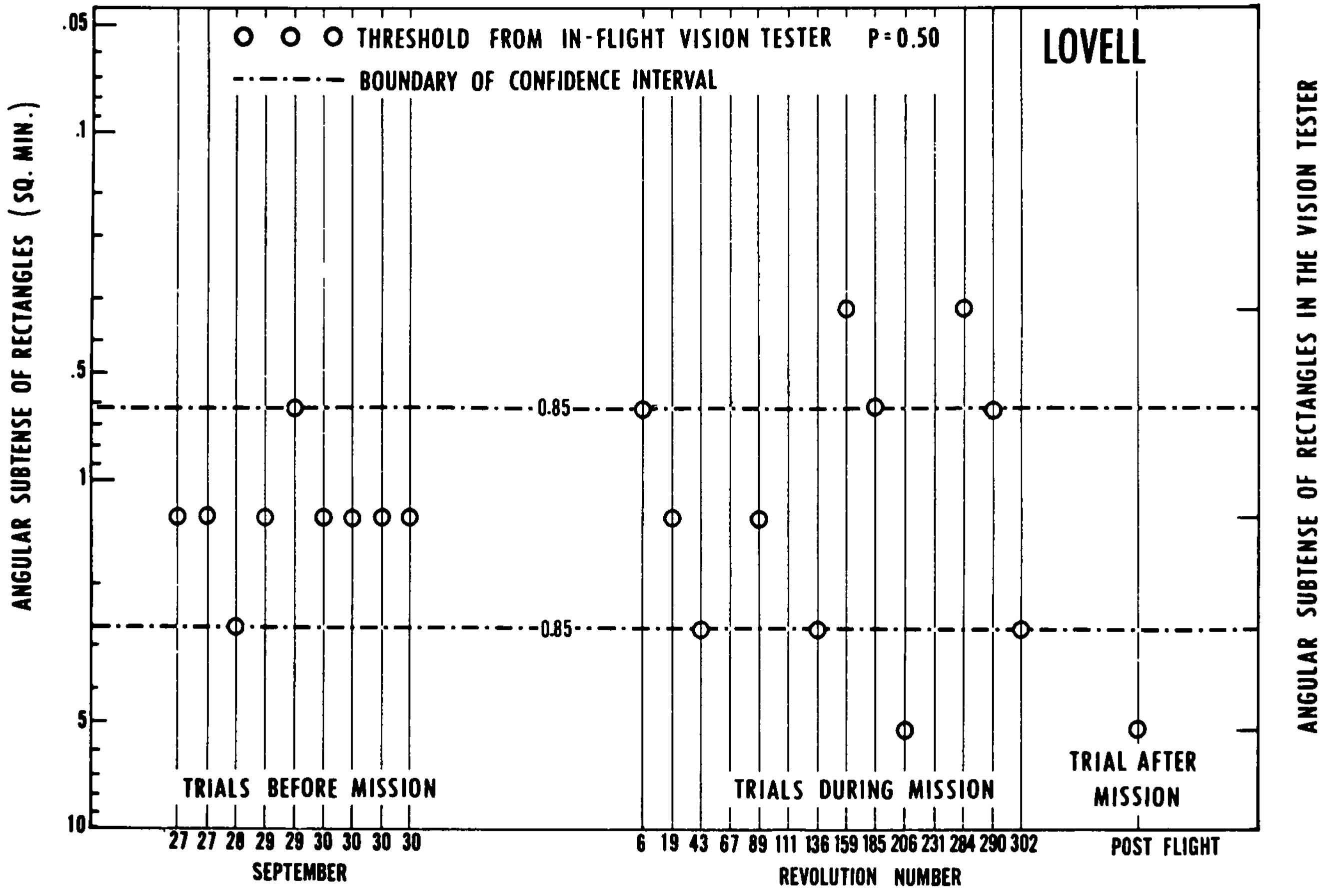

Figure 13. - Gemini VII pilot's rectangle discrimination thresholds.

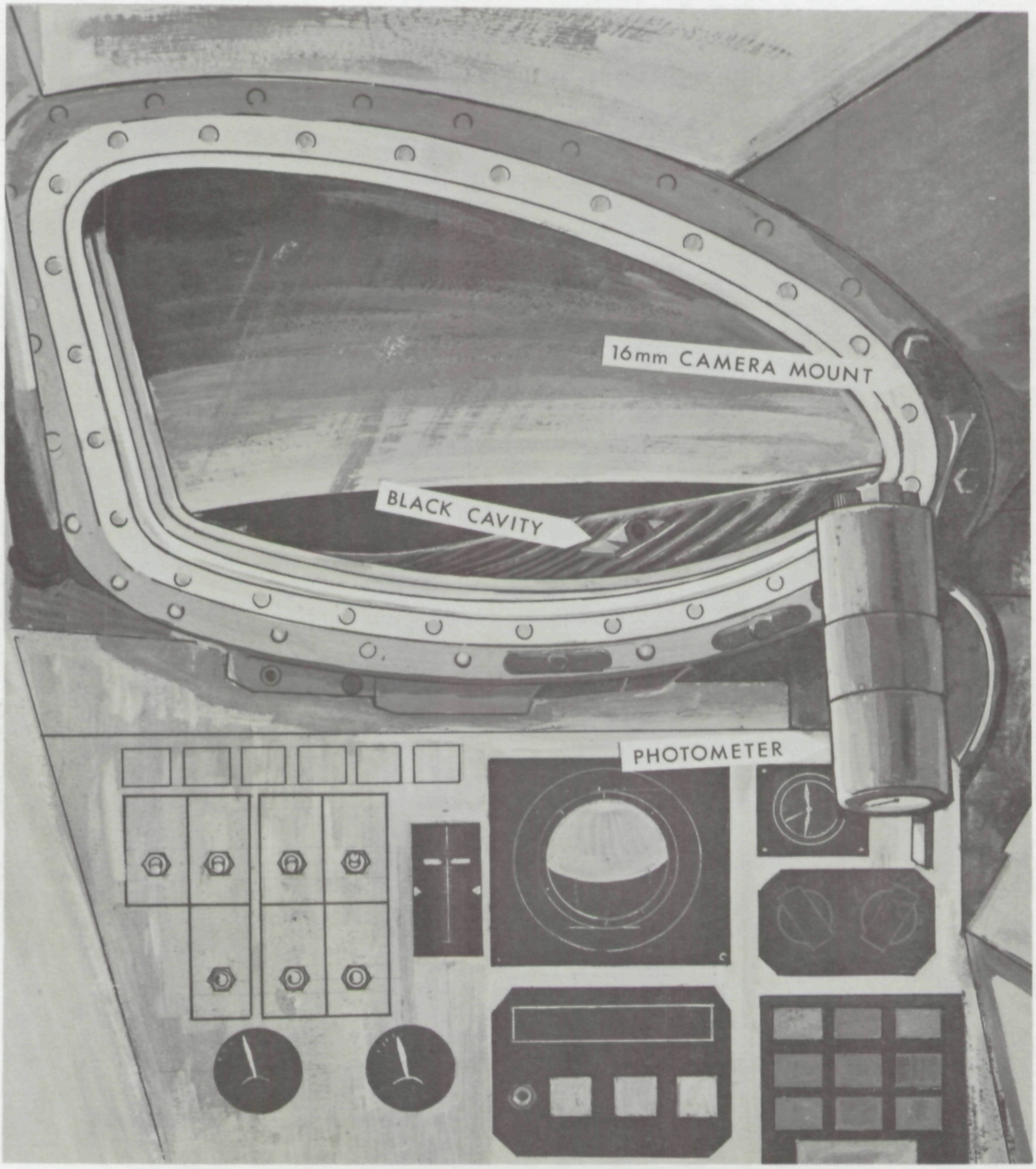

Figure 14. - Location of the in-flight photometer.

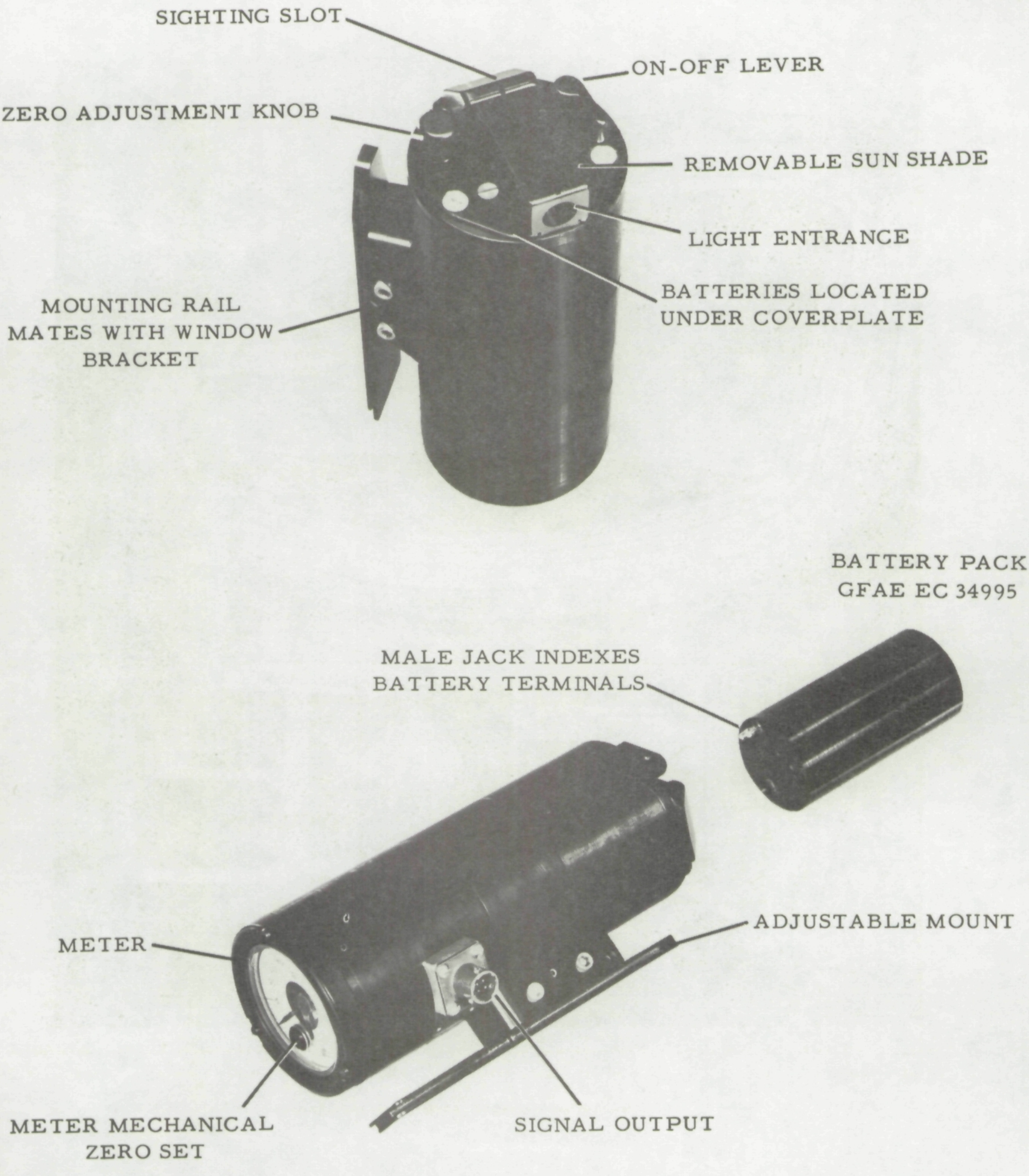

Figure 15 . - In-flight photometer components.

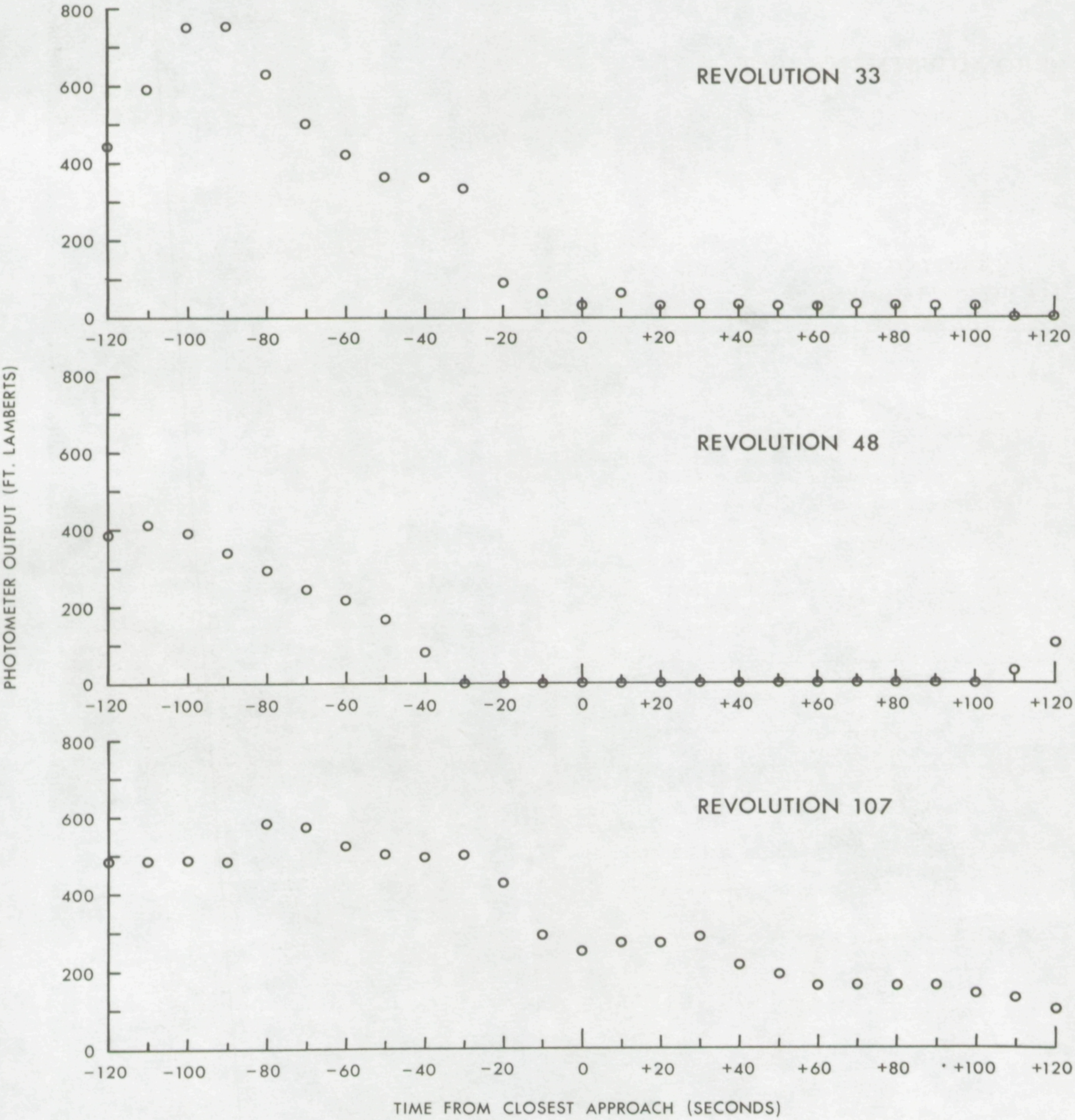

Figure 16. - Laredo site photometer data.

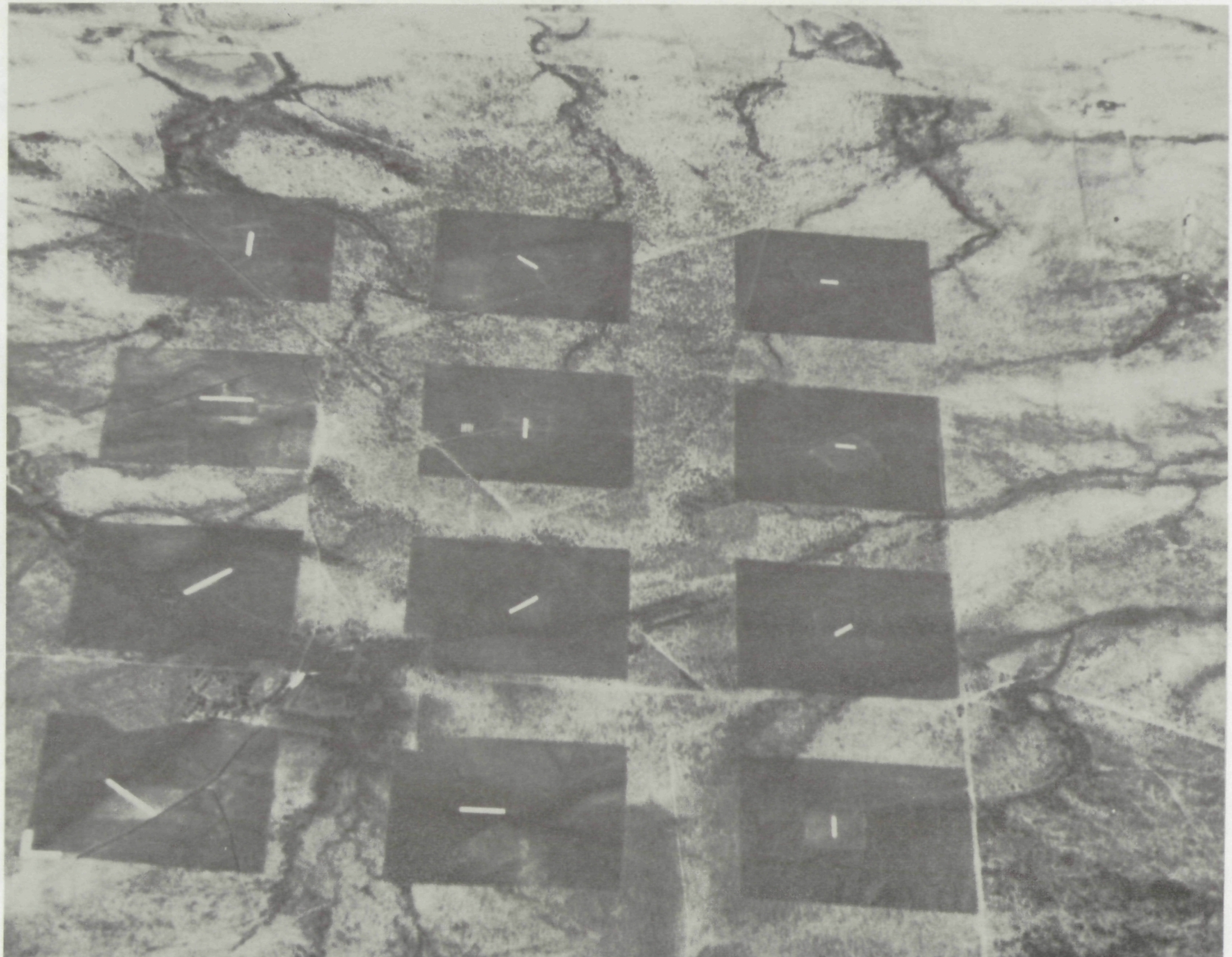

Figure 17. - Aerial photograph of the Gemini V visual acuity experiment ground pattern at Laredo, Texas.

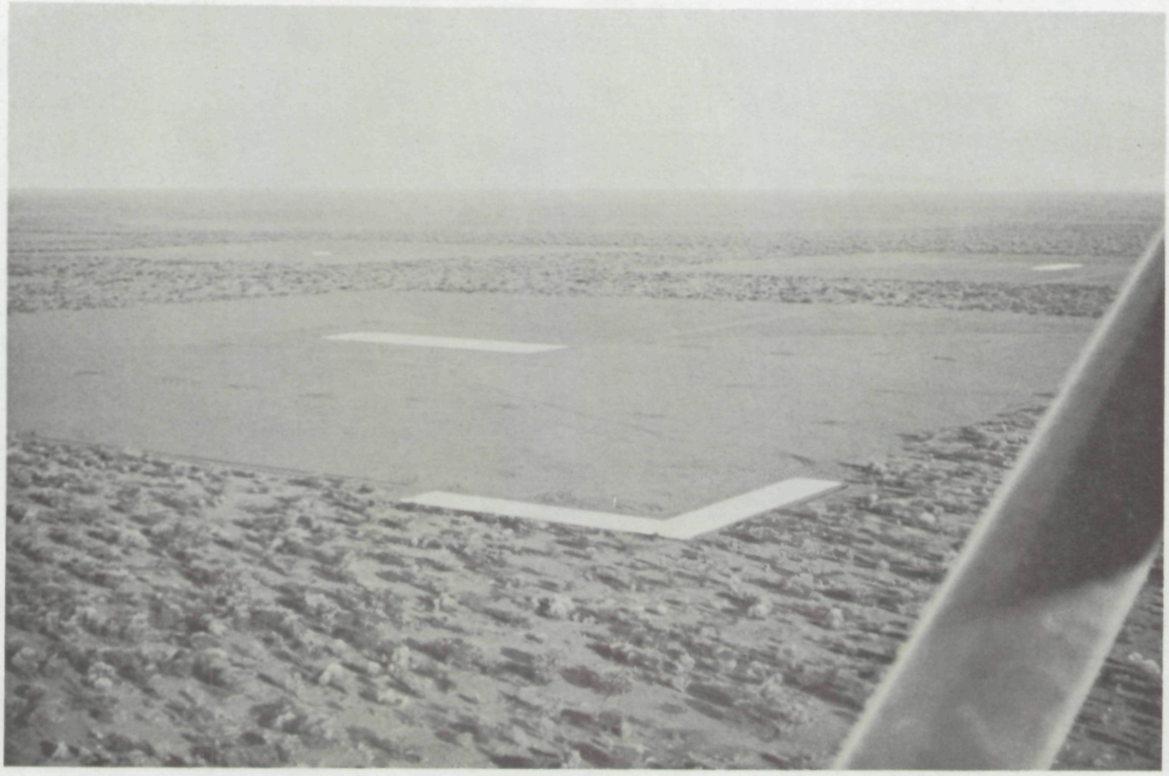

Figure 18 . - Aerial photograph of the Gemini V visual acuity experiment ground pattern at Carnarvon, Australia.

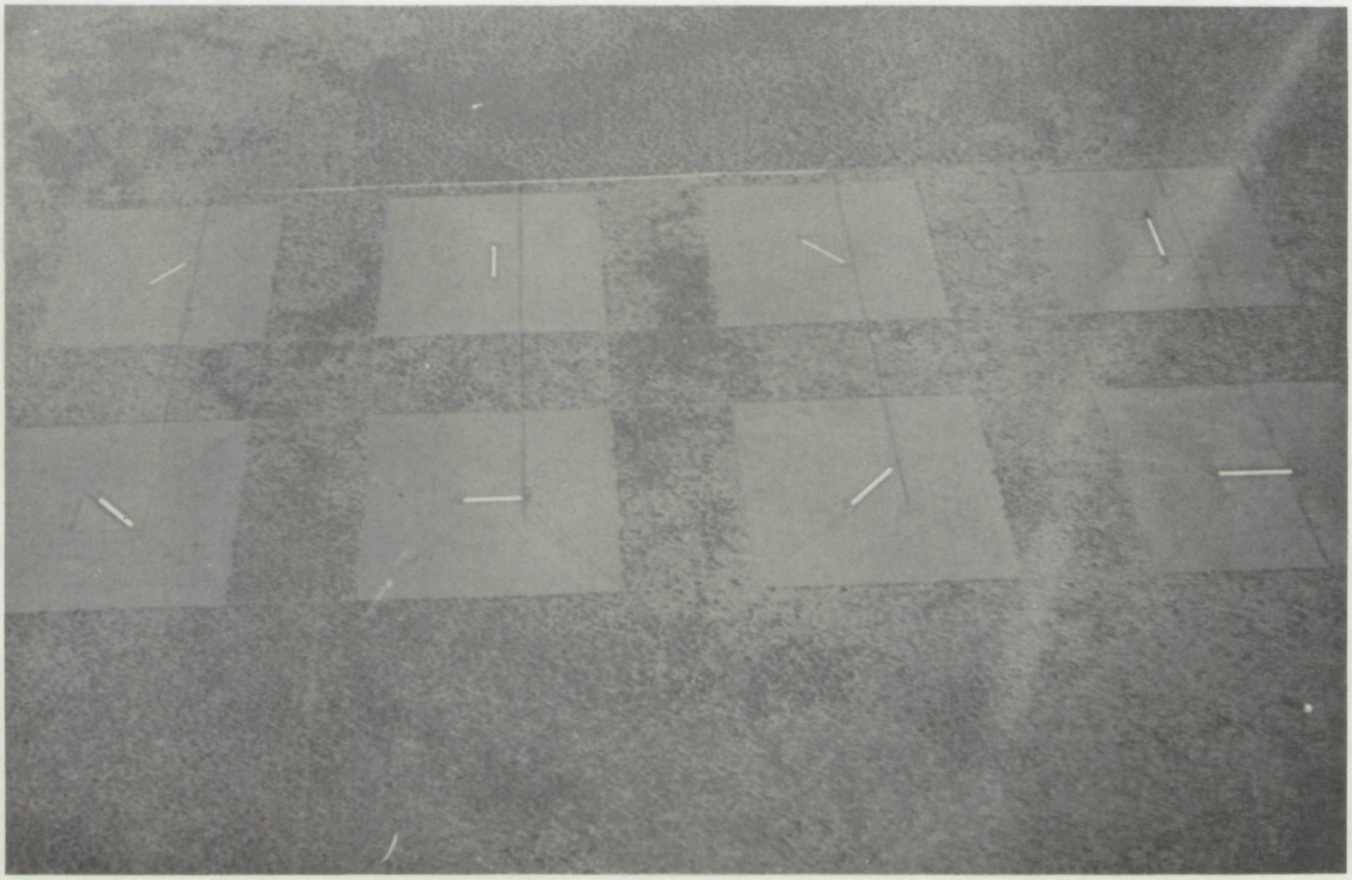

Figure 19. - Aerial photograph of the Gemini V visual acuity experiment ground pattern at Carnarvon, Australia.

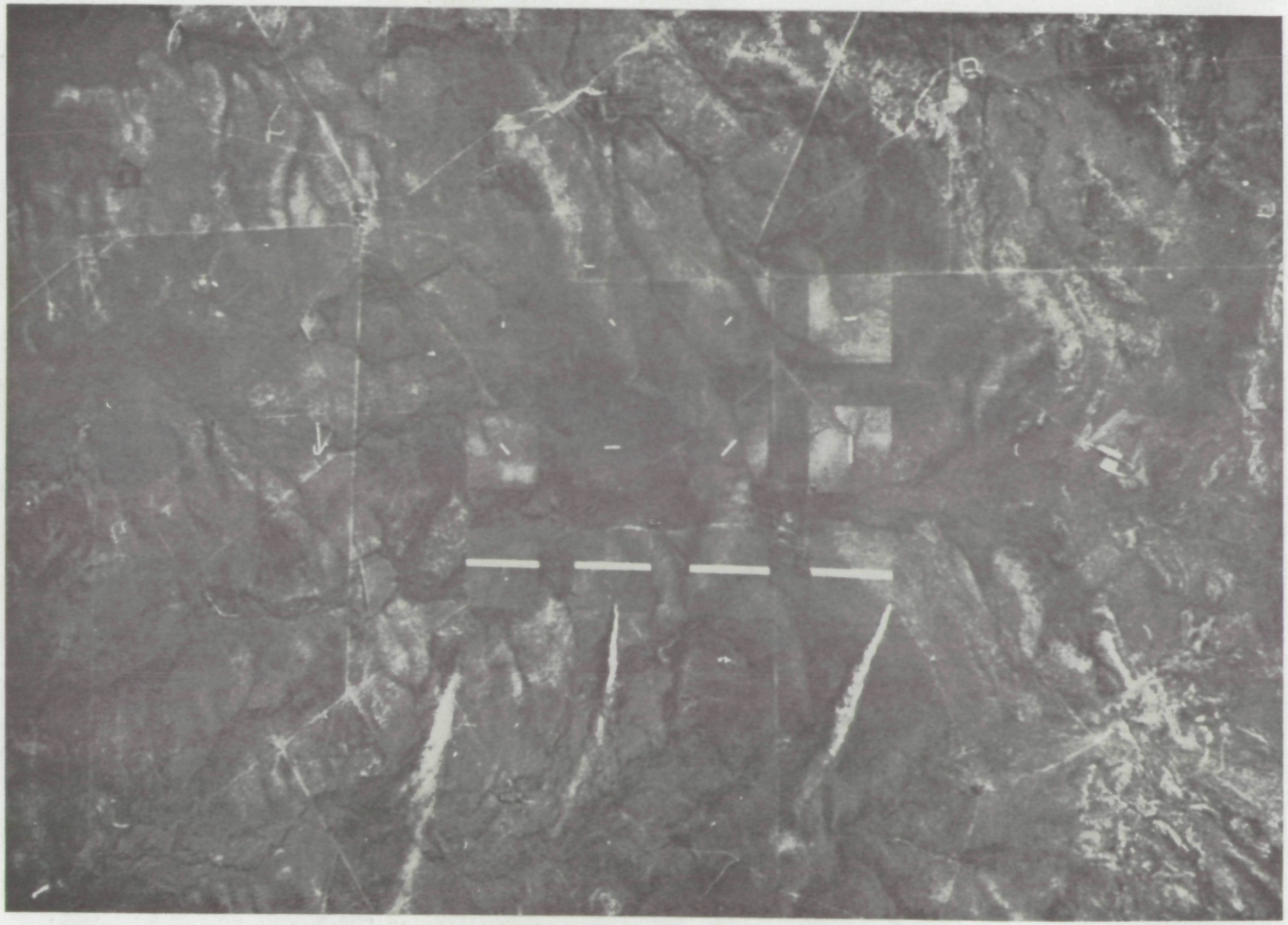

Figure 20. - Photograph of the Gemini VII visual acuity experiment ground pattern at Laredo, Texas (rev. 17).

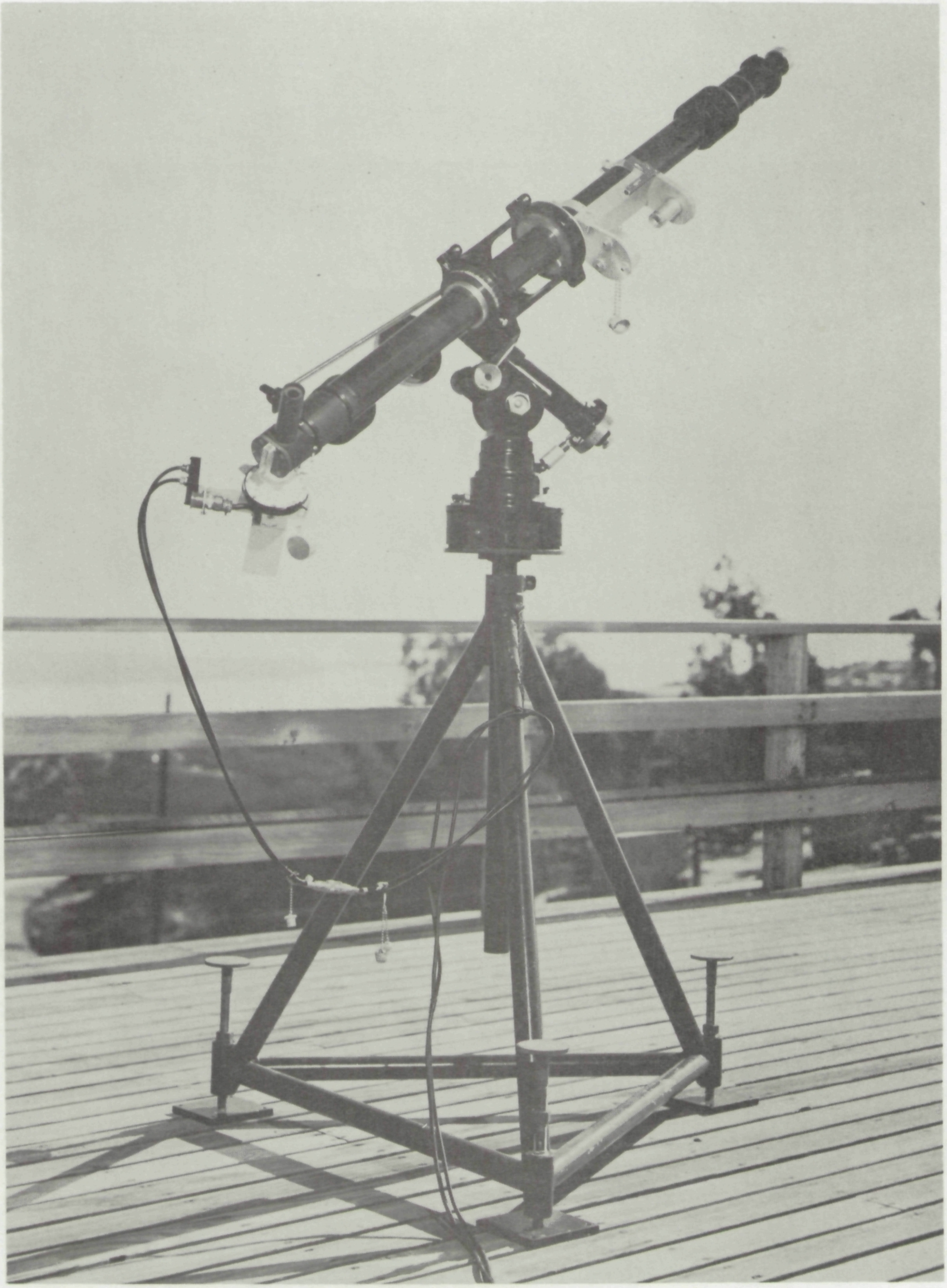

Figure 21 . - Ground site tripod-mounted photoelectric photometer.

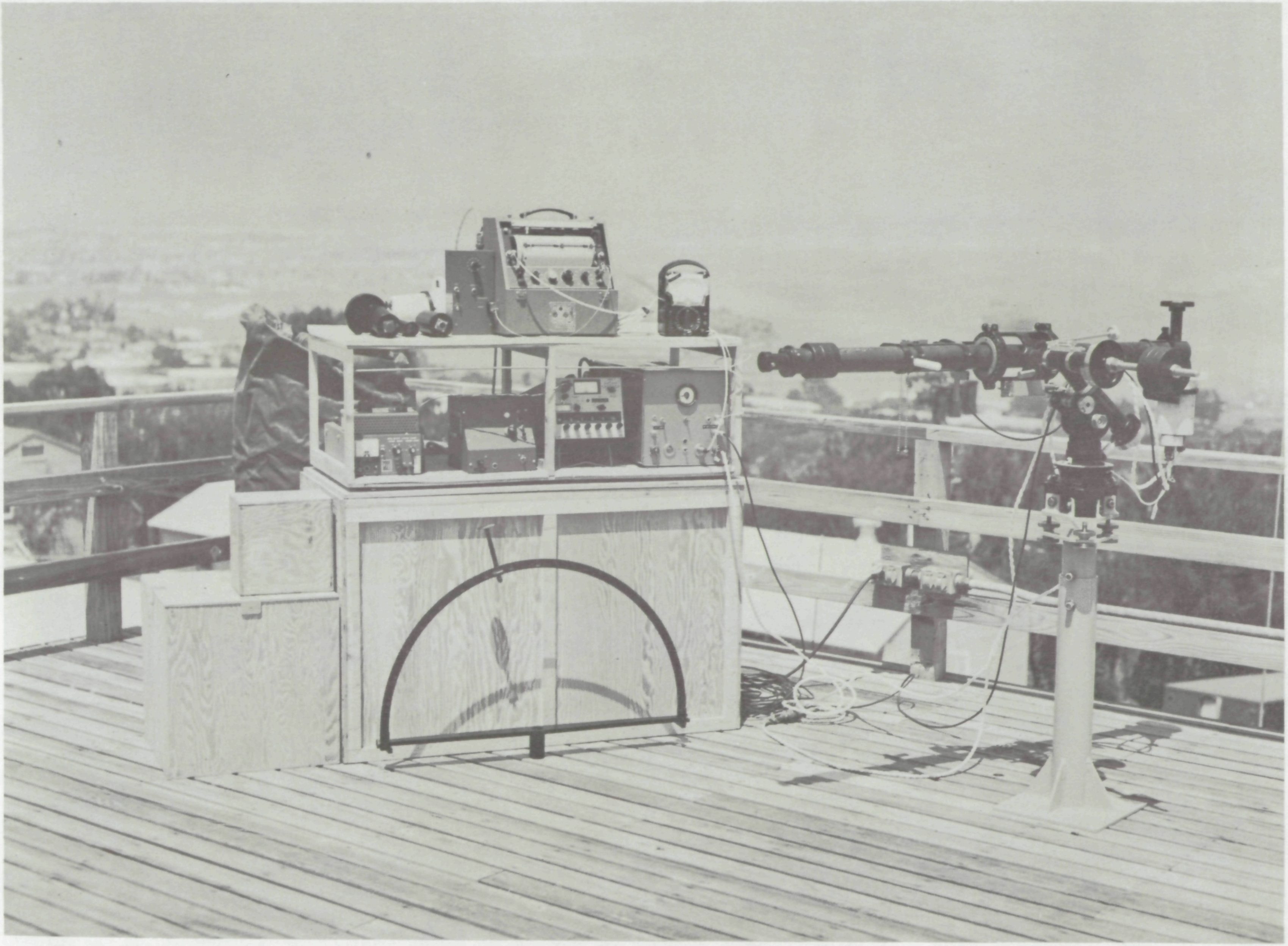

Figure 22 . - Ground site photoelectric photometer with recording unit.

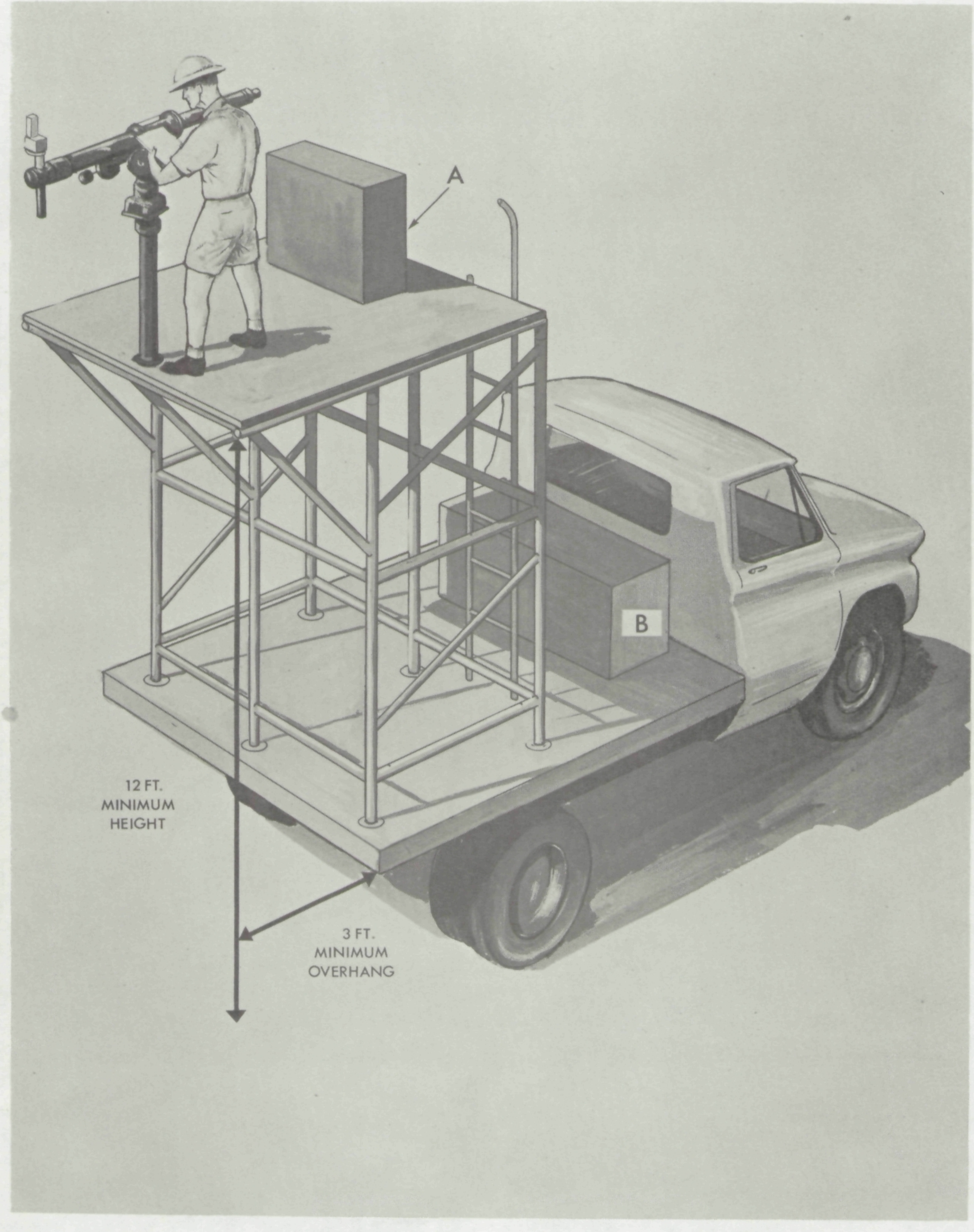

Figure 23. - Ground site photoelectric photometer mounted on a truck.

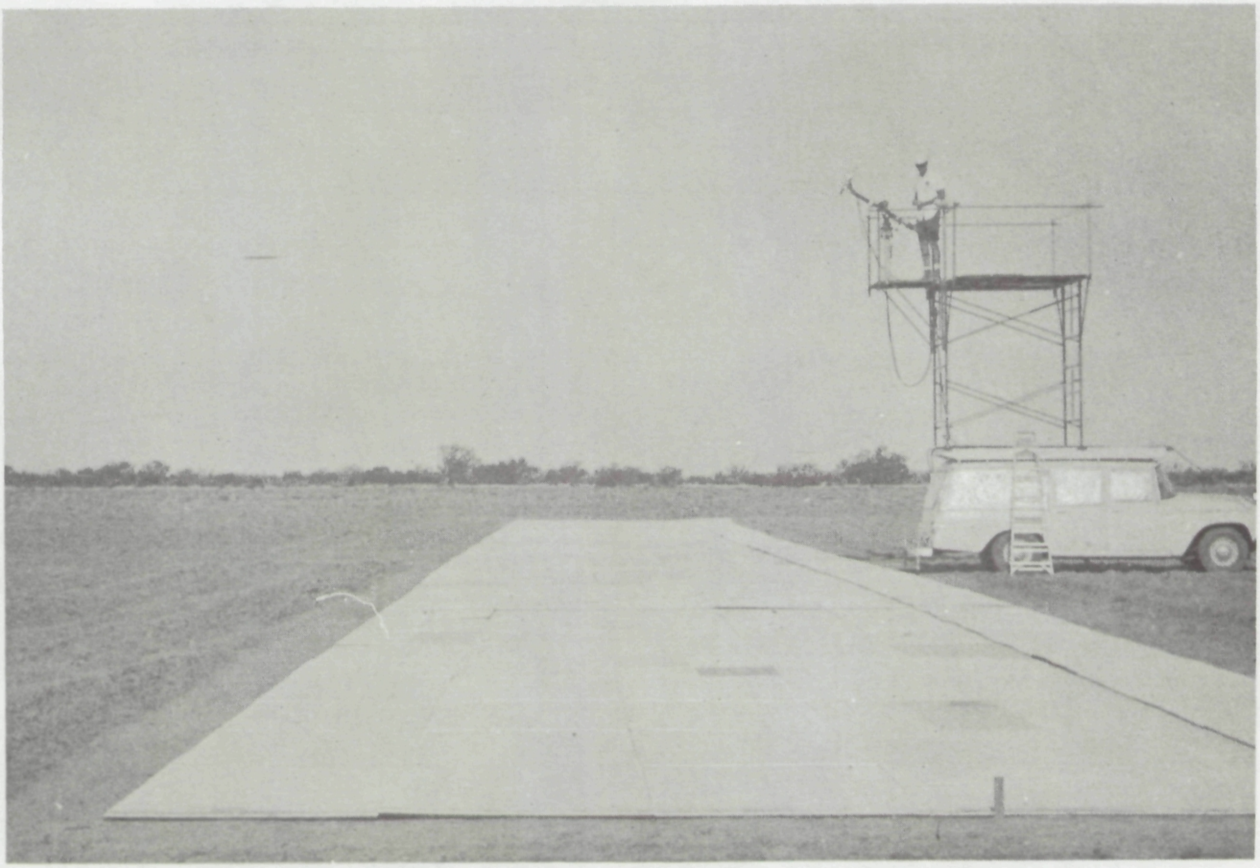

Figure 24. - Photograph of truck-mounted photoelectric photometer.

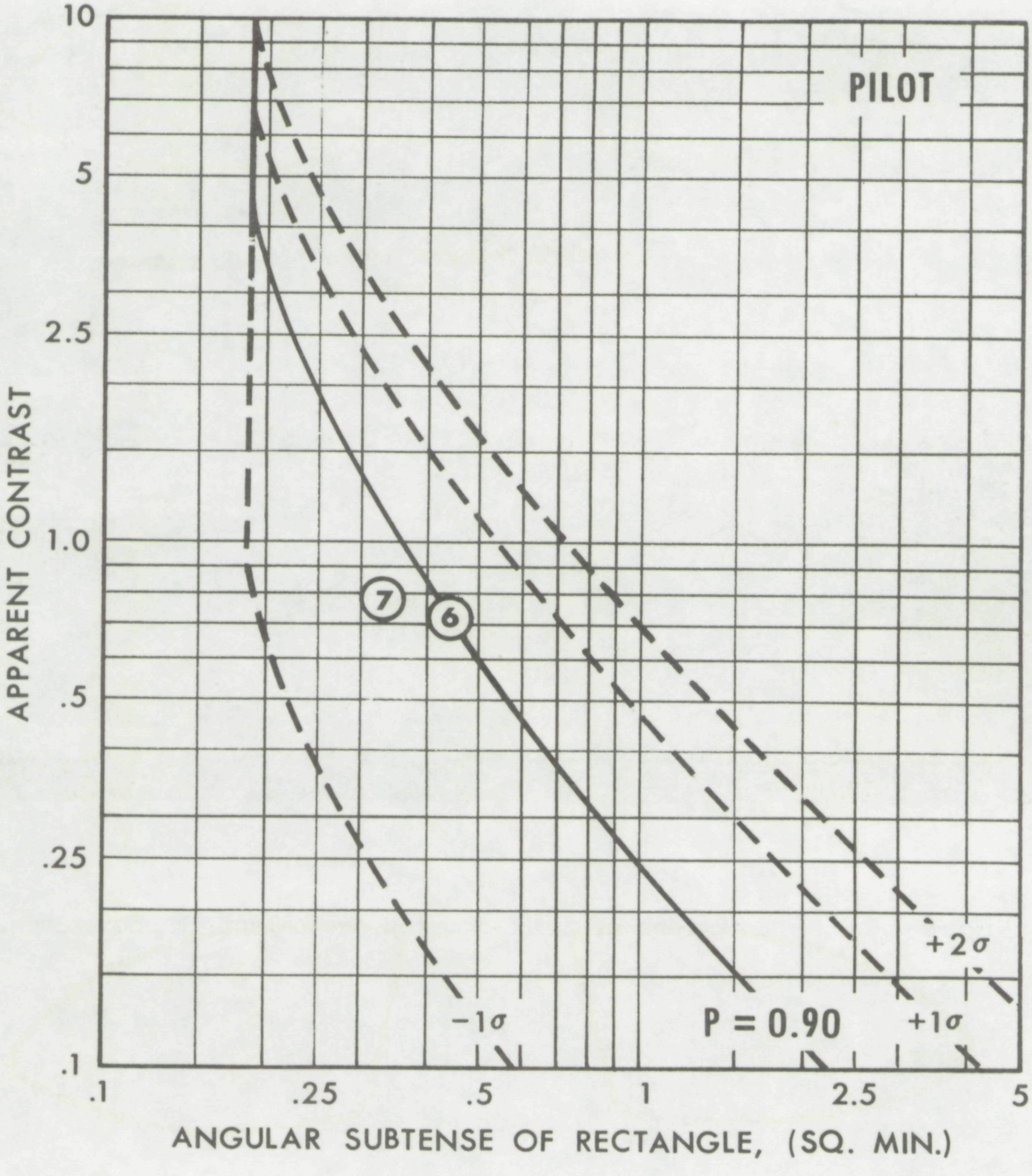

Figure 25. - Apparent contrast versus angular size of the sixth and seventh rectangles.

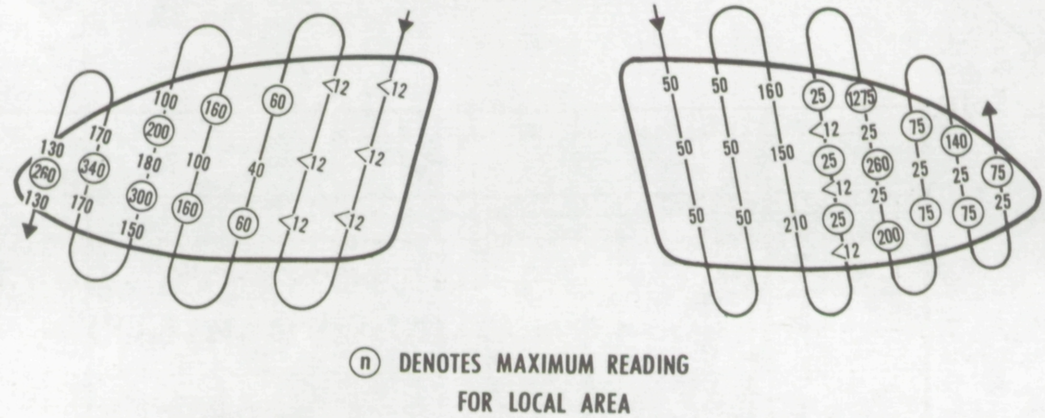

Figure 26. - Results of window scan (numerical values of luminance in foot-lamberts).

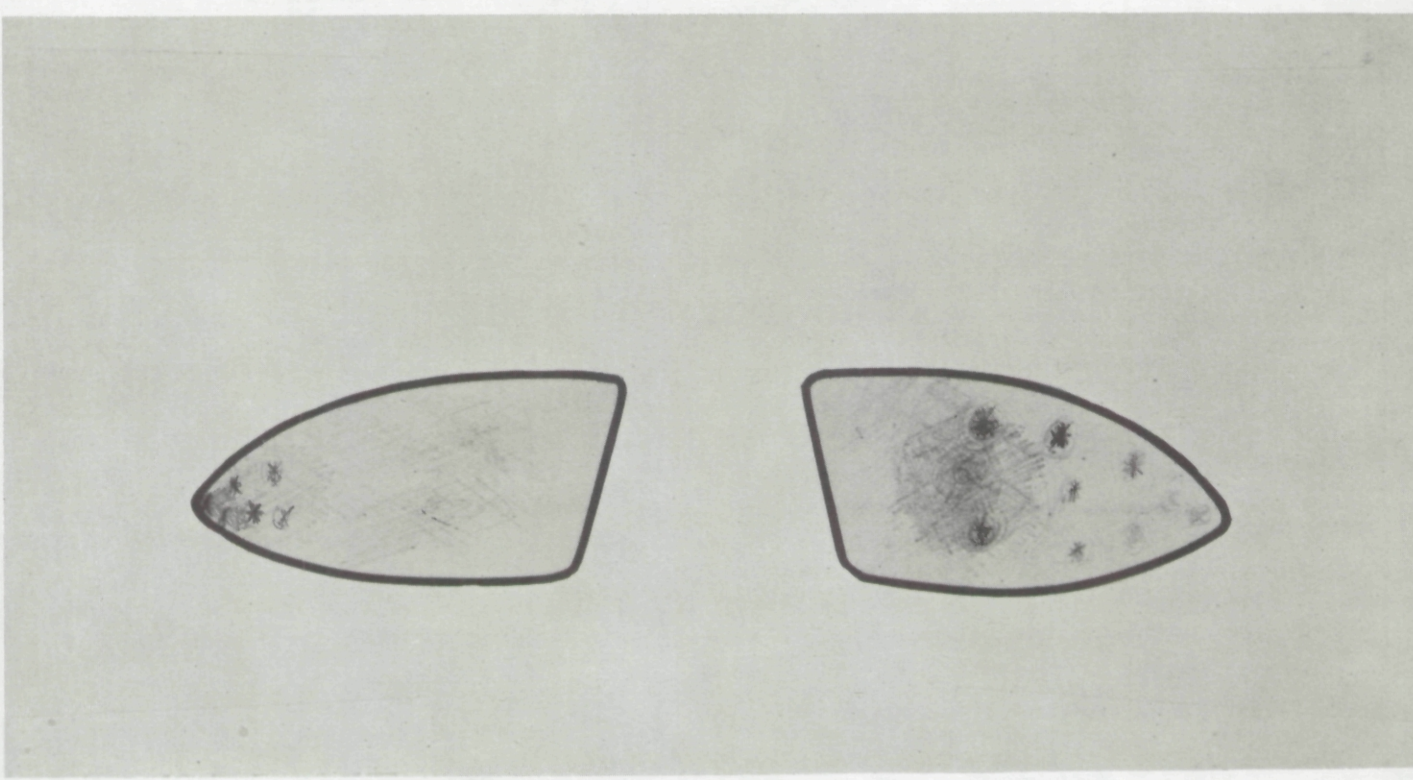

Figure 27. - Photograph of shaded pencil sketch of window contamination.

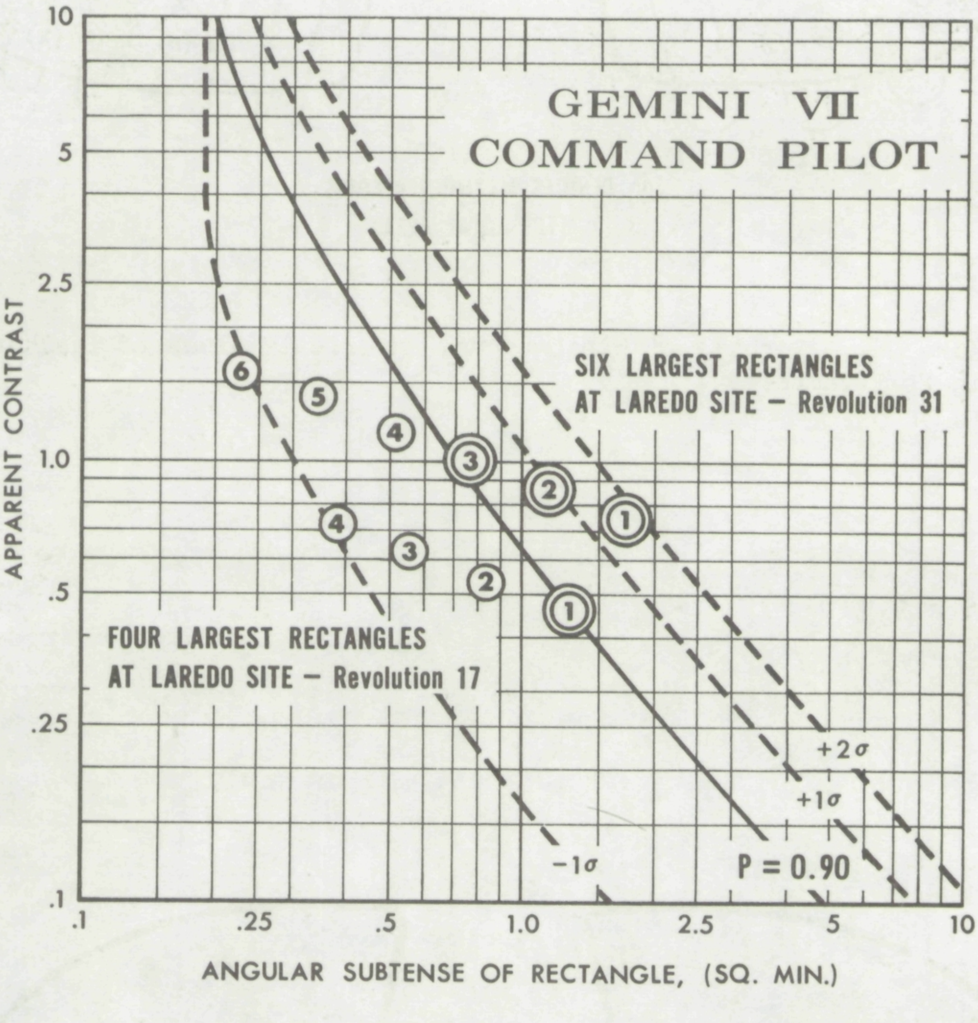

Figure 28. - Apparent contrast versus angular size of rectangles.

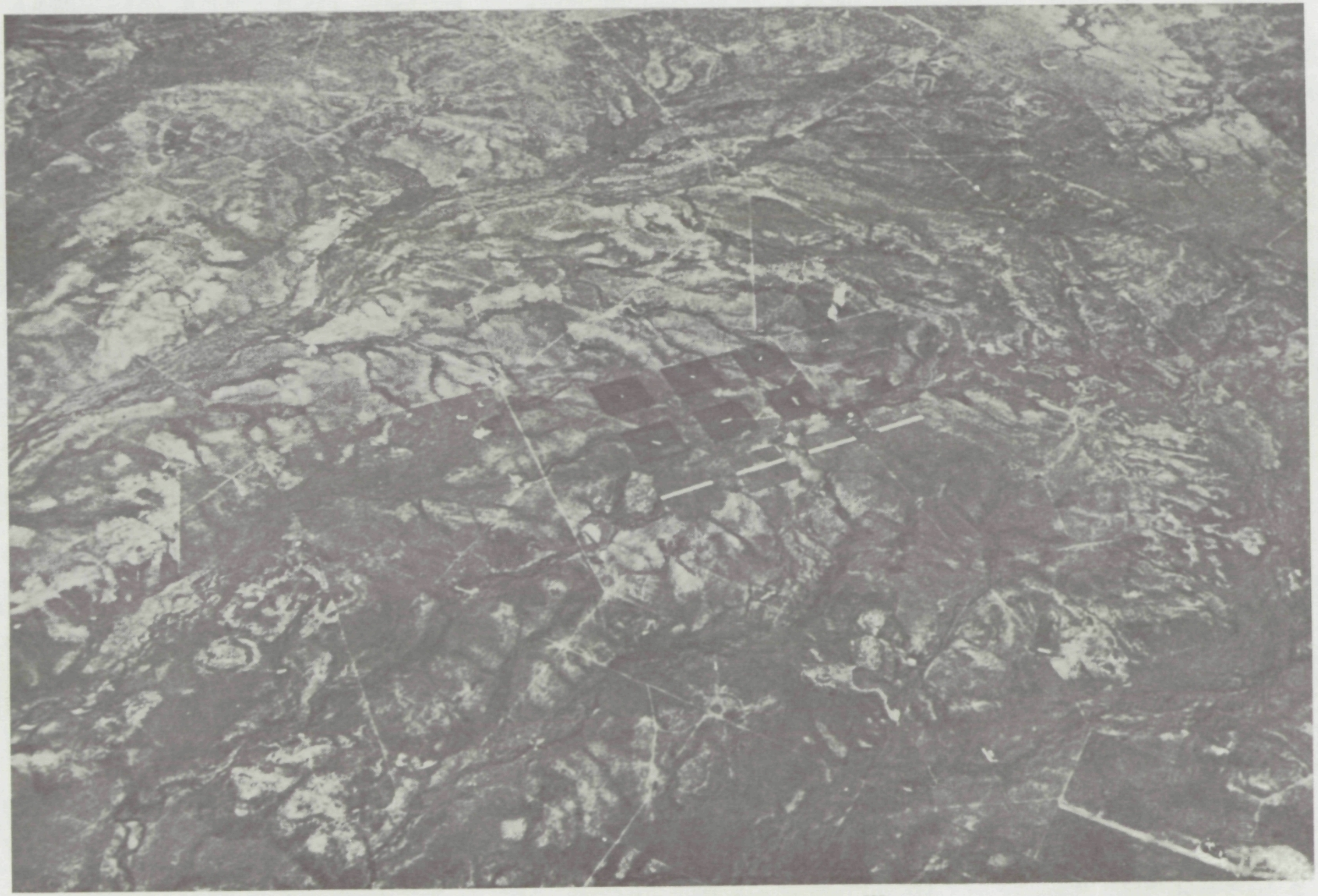

Figure 29. - Photograph of the Gemini VII visual acuity experiment at Laredo, Texas (rev. 31).

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13. ABSTRACT

Preflight, in-flight, and postflight tests of the visual acuity of both members of the Gemini V and Gemini VII crews showed no statistically significant change in their visual capability. Observations of a prepared and monitored pattern of rectangles made at a ground site near Laredo, Texas confirmed that the visual performance of the astronauts in space was within the statistical range of their respective preflight thresholds, and that laboratory visual acuity data can be combined with environmental optical data to predict correctly man's limiting visual capability to discriminate small objects on the surface of the earth in daytime.

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