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MODEL

CONTRACT NAS 9-7198

ISSUE NO.

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ABSTRACT

This document is submitted in response to the requirement for a Final Report in the Statement of Work in the Contract NAS 9-7198, "Parametric Vision Simulation Study." The document describes the first part of the subject study in detail including a description of simulation equipment and the study results. Part II of this report, Document D2-114040-3, contains a description of the second part of the study and an analysis of the data from the entire study.

KEY WORDS

Manned Lunar Descent
Visual Simulation
Lunar Photometric Function
Lunar Models
Apollo
Illumination
TV Projector

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1.0 SUMMARY

The Boeing Company Space Division has completed a twenty-hour simulation study for NASA/MSC under Contract NAS 9-7198. This document reports on the first 12 hours of simulation tests. Results of the remaining 8 hours of simulation, which were accomplished with a modified descent trajectory, and a complete analysis of the data obtained from the entire simulation program are given in D2-114040-3, "Parametric Vision Simulation Study - Final Report - Part II."

The simulation, performed on the Boeing Space Flight Simulator, duplicated the visual conditions to be encountered during the manned landing on the lunar surface. The simulated landing occurred on the morning terminator during the final phases of the retrograde orbit descent under a range of initial flight path angles from 13° to 19° and sun angle from 7° to 30°. Typical visual conditions that might actually be encountered by the astronauts under these trajectories and sun angle relations during lunar descent are shown in Figure 1, a photo of the Lunar Pyrenees, taken by Lunar Orbiter V.

Simulation results indicate that sun angles of about 7° from the local horizon produce reasonably good visibility whereas sun angles above approximately 15° produce very poor visibility. The effect of flight path angle on visibility was minor although test subjects indicated some preference for the higher trajectory angle. The study was subjective in nature because of the need to form value judgements on terrain visibility.

2.0 INTRODUCTION

2.1 Statement of the Problem

The astronaut plays a major role in descent missions. He provides trajectory monitoring and landing point re-designation, if required, during the approach (high gate to low gate) phases of the mission. (High gate and low gate corres-

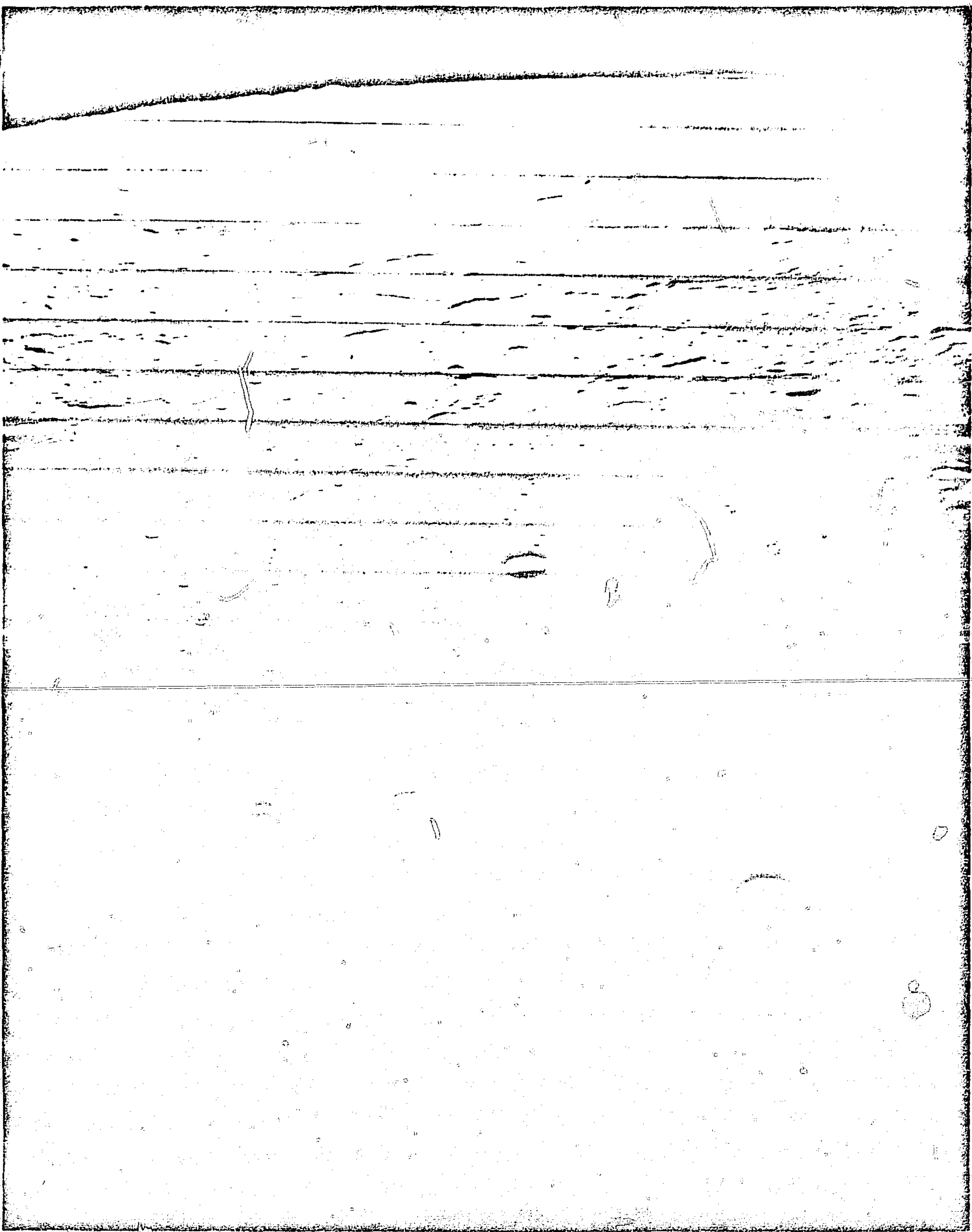

Figure 1 DOWN-SUN PHOTO OF THE MOON TAKEN BY LUNAR ORBITER V

pond to altitudes of about 10,000 feet and 500 feet respectively). During the landing phase (below 500 feet) the astronaut provides primary control using visual cues for navigation and guidance.

In the late 1950's it was suspected that, because of the Moon's peculiar reflection characteristics, certain lighting angles would cause extremely poor visibility conditions on the lunar surface which would affect the astronauts ability to assess the roughness of potential landing sites. This suspicion triggered a number of scientific and engineering studies.

The Jet Propulsion Laboratory published a Lunar Photometric Model in 1963 in support of the Ranger Program (Reference 3). In the same year NASA/OMSF published a Lunar Photometric model (Reference 4). Also in 1963, Hapke and Van Horn (Reference 5) published a paper in which they described results of an investigation to find a material that duplicates the lunar photometric function. In addition to being successful, the investigations enabled them to conclude, "The surface of the Moon is covered with a layer of fine rock dust composed of particles of the order of 10-micron average diameter and that 90 percent of the volume of this layer is void."

Eastman Kodak Company, in 1965, (Reference 7) conducted a study wherein dusted models were prepared for use in studying the lunar reflection characteristics on photography for the Lunar Orbiter satellite.

V. Hamza of Bellcom, Inc., (Reference 8) summarized results of previous analyses to determine what an astronaut could be expected to see. Data in Reference 8 indicated that if the sun, astronaut and landing site were in the same plane, (See Figure 2), sun angles between 20° and 55° gave poor visibility for the 17° flight path angle assumed for the study. Visibility was good when the sun

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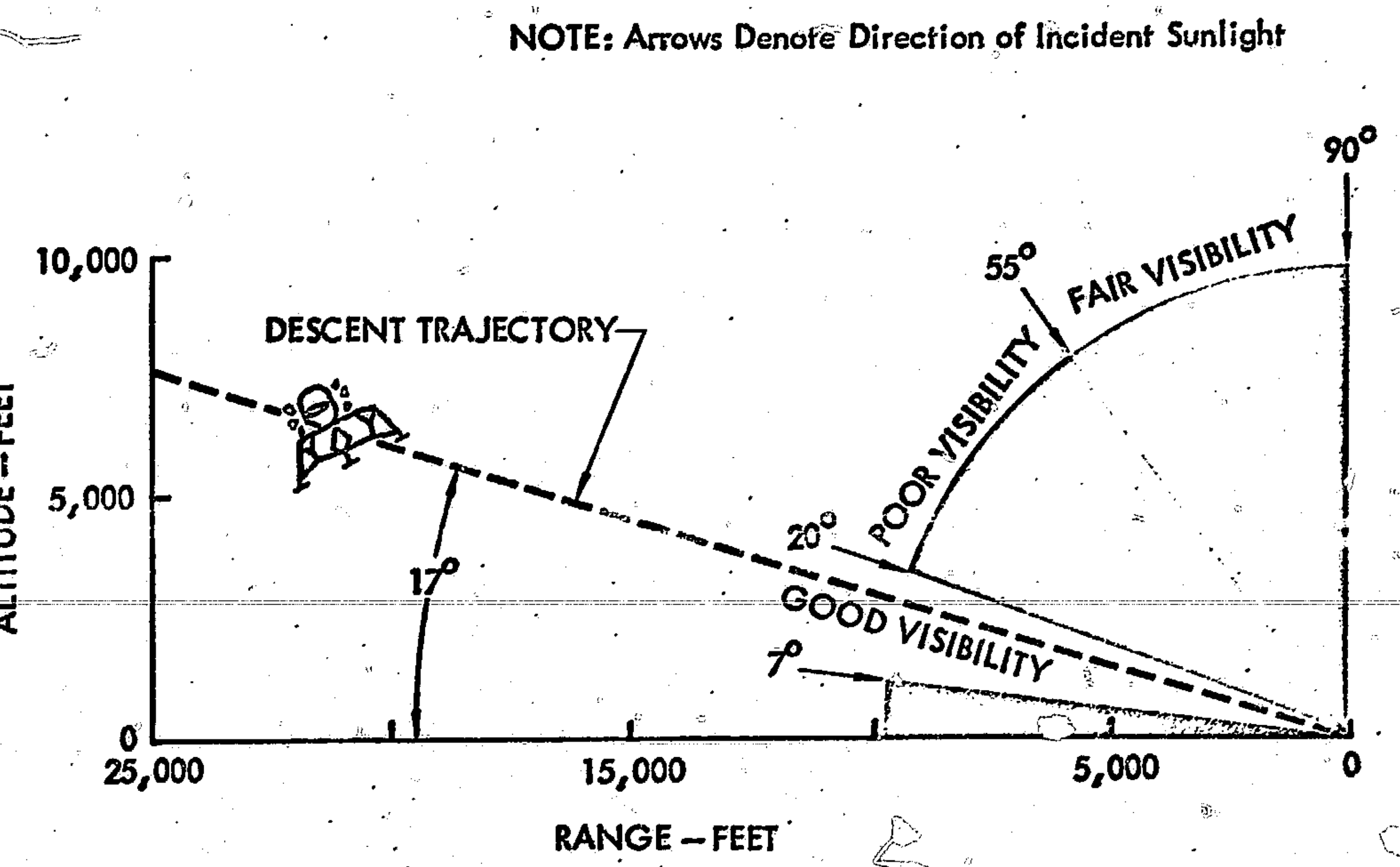

Figure 2 PREVIOUS ESTIMATES OF VISUAL PROBLEMS ASSOCIATED WITH LUNAR LANDING

was below 20° down to about 7° and fair above 55° up to about 90°. Since the Lunar Module (LM) was to land near the morning terminator because of the heating problem it became evident that the astronaut would have difficulty seeing the landing site.

The most notable engineering studies were those conducted by NASA/MSC to simulate lunar landings under earthshine conditions (1965). In this simulation a helicopter was used to overfly lava beds resembling the lunar surface in Northern California. The results of this simulation are reported in Reference 6.

Most recently, Lunar Orbiter V took some down-sun photographs which show the "washout" effect very dramatically. Figure 1 shows one of these photographs. It was taken when the spacecraft was 1° S and 48° E with the camera looking directly west at the Lunar Pyrenees. The crater at the center is Secchi X. Previous investigations are essentially an analytical rather than an experimental evaluation of the problem, and provide absolute bounds or limits under which visibility is completely impaired. The Parametric Vision Simulation Study attempts to provide an experimental evaluation of the problem by using trained observers to re-examine the bounds and to determine acceptable or unacceptable conditions of visibility between the bounds.

2.2 Program Features

By using the knowledge obtained by these investigators and the facilities available in the existing Boeing Space Flight Simulator, Boeing was able to perform a realistic manned lunar descent simulation having the following salient features:

1) Duplication of low, nominal and high trajectories (13°, 16° and 19° initial flight path angles, respectively).
2) Duplication of the essential photometric properties of the lunar surface by utilizing special models based on Lunar Orbiter photographs

and coated with a special surface covering. for proper reflectance.

3) Duplication of 7°, 11°, 15°, 20° and 25° sun angles and a projection system which provides the astronaut with an accurately sim lated visual scene.

The following additional features were also included:

1) The use of representative three-dimensional lunar surface models illuminated by a well collimated artificial sun source.

2) Use of an instrumented crew station which duplicates the commander's field of view and provides room for an observer.

3) Recording the voice comments during simulated flight by magnetic tape recorder and recording of written opinions on a questionnaire after completion of the scheduled series of simulated flights.

4) Limited pitch, roll and yaw capability during the pre-programmed trajectories.

Figure 3 shows a diagram of the visual simulator system. Details including equipment specifications required by the contract are given in Appendices III and IV.

3.0 SIMULATION PROCEDURE

The simulation procedure consisted of a pre-simulation briefing including familiarization runs, a series of test runs and a post-simulation de-briefing.

The pre-simulation briefing consisted of a description of the facility, a description of the simulation and a series of two or more familiarization runs. In particular, subjects were briefed on the trajectory description, operation of the hand controller, cockpit displays, limitations of simulator equipment, and screen brightness and brightness distribution effects upon the simulated lunar surface lighting environment. Additional instructions were given on the methods to be used in recording voice data during the simulation. A description of the written

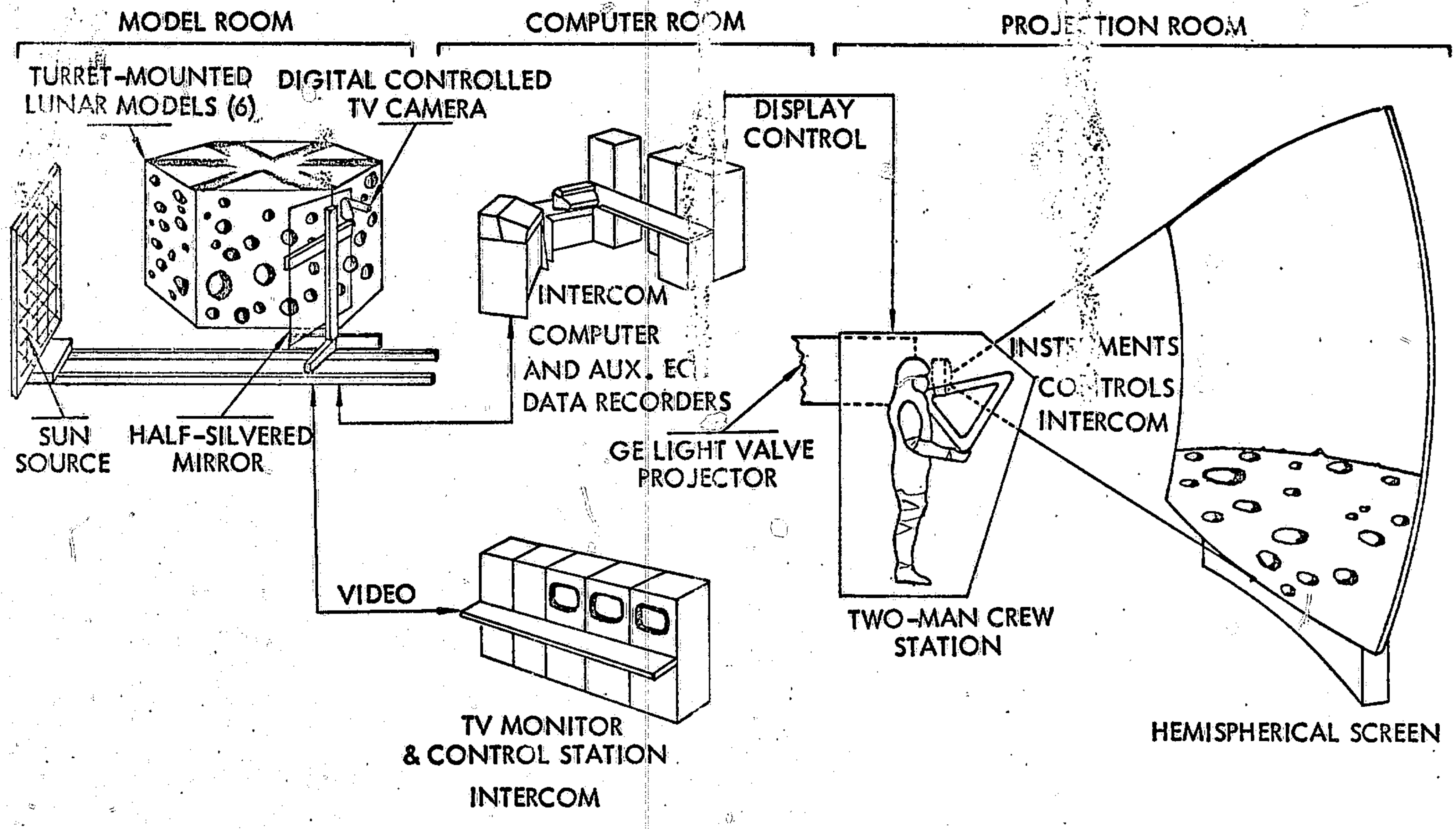

Figure 3. VISUAL SIMULATOR SYSTEM

questionnaire to be completed after the data runs was included.

The eye height of each test subject was adjusted to the same position with respect to markings on the simulated crew station window. This was accomplished by adjusting the height of the platform on which the subject stood.

Each test run was initiated on command from the crew station. An intercom system permitted discussion with an operator at the computer console and with technicians in the model room. The test runs utilized a series of three models during the descent trajectory. The portion of the trajectory represented by each of the three models is shown in Figure 4. This figure also shows the elapsed time on each model, the scale of each model, and the geometrical arrangement of area in which topographical features are repeated in two or more models. The models have been constructed such that the landing site and surrounding topographical features are visible in each of the three models used for flying the segmented trajectory from highgate to about 450 feet of altitude.

Figure 5 shows areas of the moon used as references for constructing the lunar models. Details of model building and the technique of dusting for reproducing the photometric properties of the lunar surface are given in Appendix III.

A nominal set of 30 data runs was completed by each subject. The runs began with 7° sun angle and the 13° trajectory, followed by the 16° and 19° trajectories in order. The sun angle was changed to the next higher sun angle which was 15° for the first test subject, but which was changed at the request of NASA/MSC to 11°. The ascending order of trajectory angles was again followed as for the previous sun angle. This procedure was followed until all sun angles and trajectories had been completed on the "rough" series of models. Following this, the same procedure was followed for the "smooth" series which, when completed,

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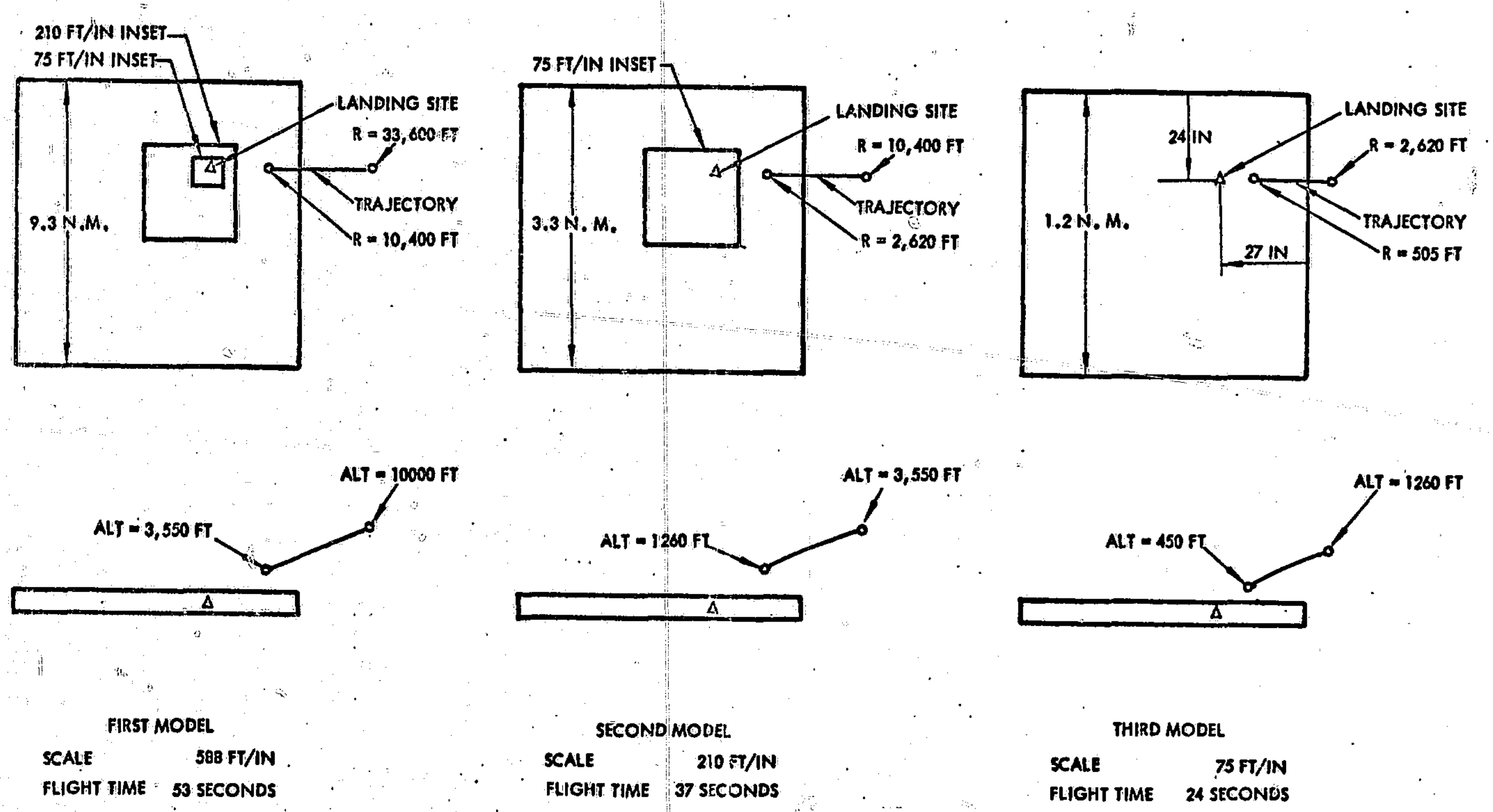
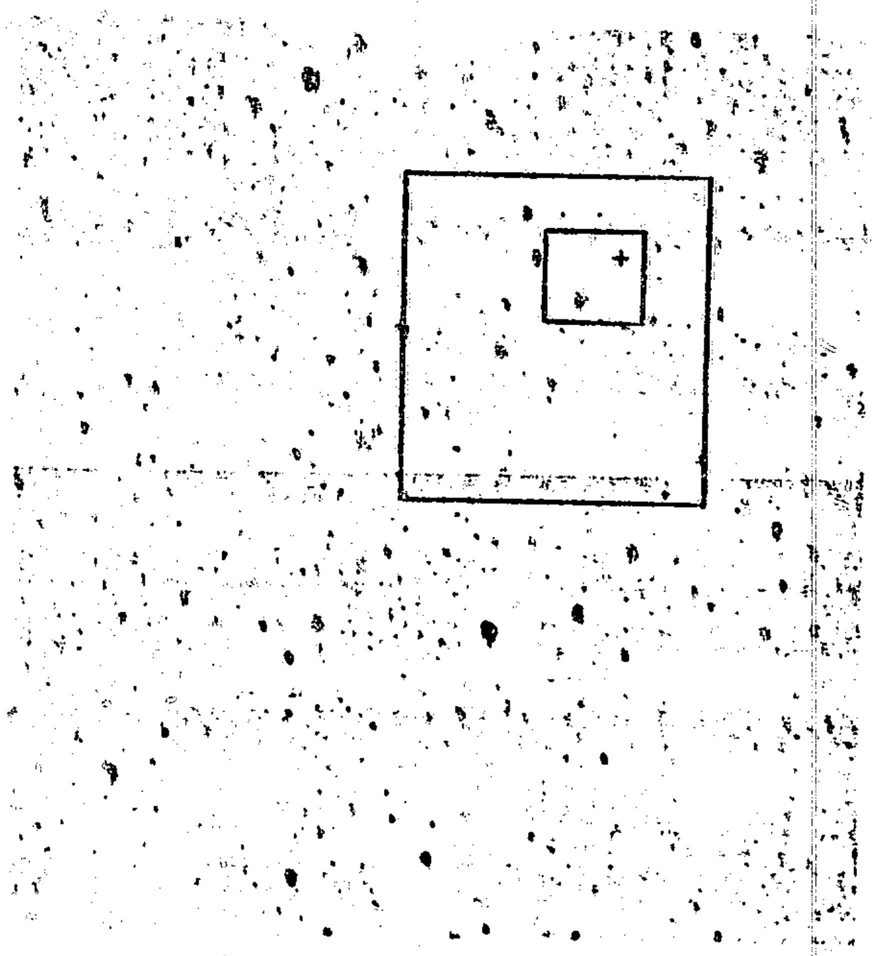


Figure 4 MODEL TRAJECTORIES

SMOOTH SERIES

FLAMSTEED AREA



ROUGH SERIES

GAMBART AREA

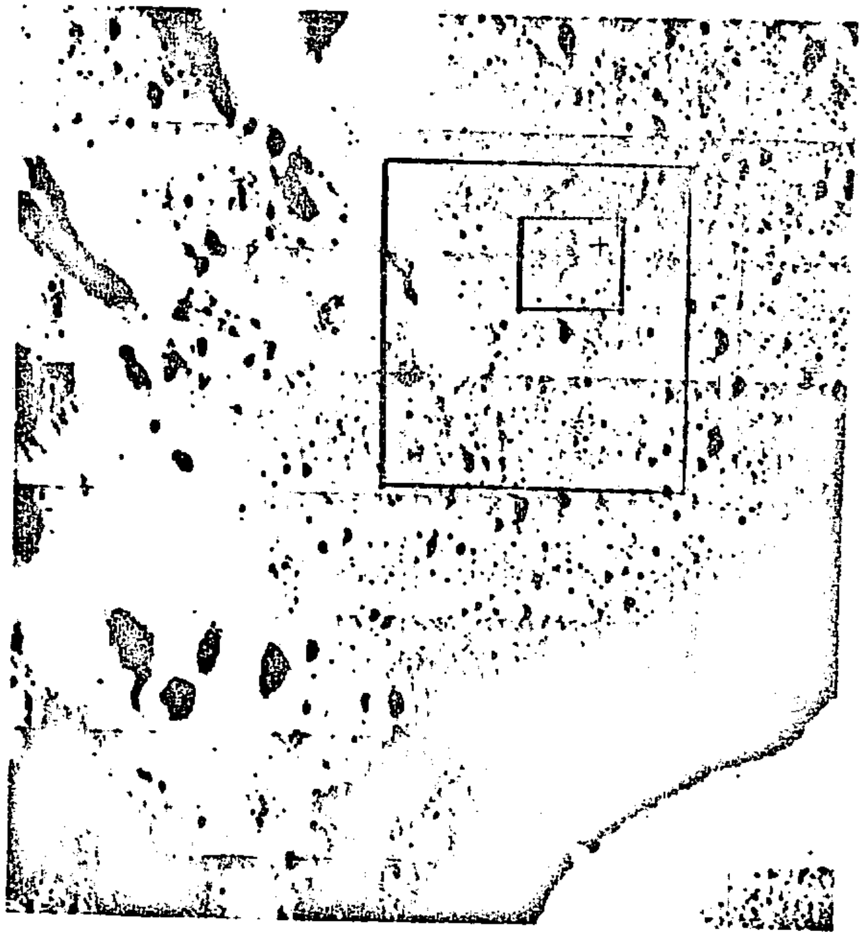


Figure 5 L.O. 1 REFERENCE PHOTOS USED IN CONSTRUCTION OF MODELS

finished the runs for that subject. No attempt was made to randomize the procedure because of the relatively few runs performed by each subject.

During the data runs the subject was asked to comment verbally on what he was able to see on the screen. His comments were recorded on magnetic tape. He was also asked at one particular point in a particular descent trajectory to measure the angle by means of the landing point designator representing the limits of good visibility.

During the de-briefing period which followed, subjects were asked for general impressions and more specifically to fill out a questionnaire.

This completed the simulation except for a round table discussion which was held after several subjects had completed their runs.

4.0 SIMULATION RESULTS

Data acquired through the questionnaire, subjects visibility estimates during runs and voice comments recorded on tape were analyzed for information concerning sun angles, trajectories and secondary parameters.

Sun Angle

All subjects reported that lunar surface visibility decreased with increasing sun angle. At 7° visibility was "fairly good", but at 20° and above it was essentially zero. Table 1 shows the estimates of visibility in degrees from the bottom of the window for each of the subjects. These measurements corroborate completely the subject's intuitive reports.

Trajectory

Subject's rating of trajectory angle was mixed. All evidence suggests that the actual differences are quite small. Figure 6 shows the average subjective rating

Table 1

ESTIMATED VERTICAL FIELD OF VIEW AT THE 19° TRAJECTORY

	SUN ANGLE	7°	11°	15°	20°	25°	30°
	SUBJECTS						
ROUGH TERRAIN	1	15°	-	12°	5°	0	0
	2	15°	12°	12°	-	4°	0
	3	14°	9°	-	0	0	0
	4	14°	-	12°	0	0	-
SMOOTH TERRAIN	1	18°	-	10°	2°	0	0
	2	18°	-	9°	0	0	0

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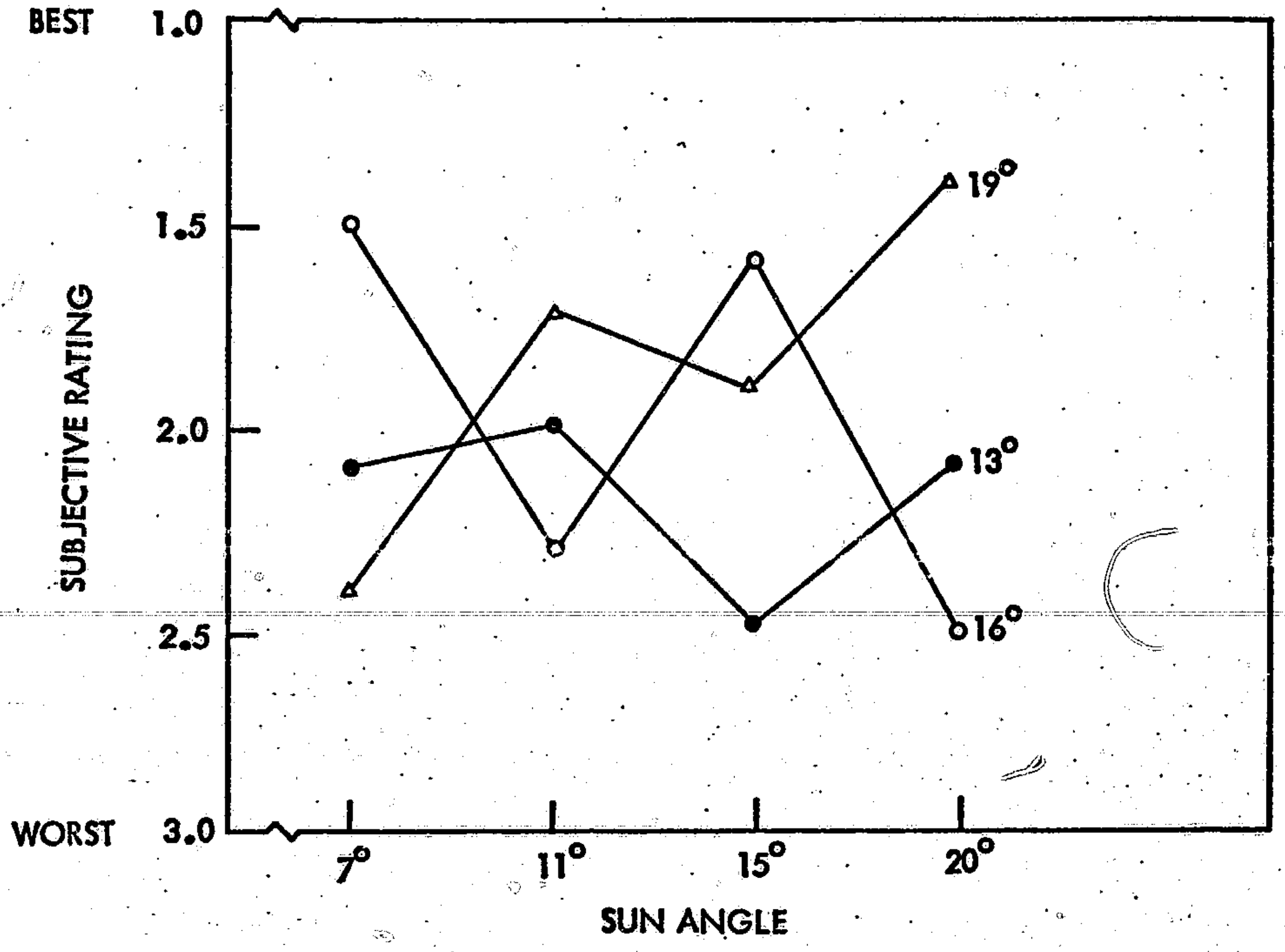

Figure 6 MEAN SUBJECTIVE RATING OF VISIBILITY PROVIDED BY TRAJECTORY ANGLE

from the questionnaires as a function of sun angle with trajectory angle as the parameter.

During the runs for the 7° sun angle, the subjects made vertical field of view estimations for each trajectory. Complete data was only available for the rough terain condition. As the flight path angle increased from 13° to 19° during the course of running the three trajectories, the mean estimated vertical field of view increased from 12° to 14.5°, respectively. While the differences were small, the 19° trajectory did appear to provide the greatest visibility.

Secondary Parameters

On the simulation questionnaire, the subjects indicated their preference for either the rough or smooth terrain texture in terms of the visibility provided for early recognition of landmarks and landing. The data were inadequate to provide any selection of texture. Only two subjects completed the runs on both the rough and smooth terrain, one reporting a preference for the smooth, and one reporting no difference.

The subjects ordered five types of terrain according to their ease of recognition. The terrain types to be ordered were: rill, large crater, small crater, hill, and debris pile. All subjects reported the recognition of rills to be best and large craters second best. There was little difference in the recognition of hills and small craters. The debris piles were judged to be the least easy to recognize if they were seen at all.

Two items on the questionnaire were concerned with visibility to the center and side of the flight path. All subjects indicated that side viewing afforded the best visibility of the lunar terrain. There was some indication that at the lowest sun angles the effect of view angle was small.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The requirement for presenting a relatively broad spectrum of landing conditions, the availability of only four subjects for a short duration, and equipment constraints precluded a complete empirical assessment of the parameters associated with the lunar landing simulation. While the visual display of the lunar simulation did not provide the brightness or resolution that would be expected on the lunar surface, these decrements provided a conservative position from which the subjective data was assessed.

1. Sun angle appears to have the greatest effect upon visibility. As the sun angle increases from 7° to 15°, visibility decreases slightly. Visibility should fall sharply, however, at the 20° sun angle and be virtually non-existant at the 30° sun angle. A further investigation of the visibility effects of sun angle should be conducted in order to reveal the nature of the visibility degradation. Of particular interest would be the 15° to 20° sun angle range wherein the visibility was sharply reduced, and the 0° to 7° sun angles where a large part of the terrain is in shadow.
2. The effect of trajectory angle on visibility is not as dramatic as sun angle. Visibility may be slightly improved at the higher trajectories; however, the significance of this indication should be the subject of further investigation.
3. No conclusions concerning the general terrain texture (rough or smooth) may be drawn from this simulation, except that subjects unanimously preferred to have landmarks in the visual scene which stood out from the background.

LIST OF REFERENCES

1. Boeing Document D2-113091-1, Technical Proposal, Parametric Vision Simulation.

2. Boeing Document D2-113091-3, Supplementary Proposal, Parametric Vision Simulation.

3. Jet Propulsion Laboratory Technical Report No. 32-384 (Rev.), Ranger Preflight Science Analysis and the Lunar Photometric Model. 1963.

4. OMSF Program Directive, M-DE 8020.008A, Natural Environment and Physical Standards, Aug. 1963.

5. B. Hapke and H. Van Horn, "Photometric Studies of Complex Surfaces With Applications to the Moon," Journal of Geophysical Research, Vol. 68, No. 15, Aug. 1, 1963.

6. NASA Technical Note TM D-2999, Lunar Landing and Site Selection Study, Sept. 1965.

7. Eastman Kodak Final Report, Lunar Photo Study Contract NAS 9-3826, 1 Dec. 1964-1 Oct. 1965, Z-3481.

8. Bellcomm. Report TM-66-1012-6, Lunar Lighting Conditions for the Apollo Lunar Landing Mission, May 17, 1966.

9. Boeing Document D2-113372-1, Description of the Boeing Space Flight Simulator and Associated Simulation Facilities.

10. Boeing Letter 2-1101-94-2-135-OR, 9-4-4648-2 dated 21 April 1967 to NASA/MSC, BG72.

APPENDIX I - DE-BRIEFING DATA

1.0 INTRODUCTION

As was mentioned in the body of the report, the de-briefing consisted of asking the subjects to fill out a questionnaire and to make verbal comments on the simulation. The results are given in this appendix.

2.0 QUESTIONNAIRE

Figure I-1 shows the questionnaire used in this study. Table I-1 presents the raw data from the questionnaires for the four initial subjects Neil Anderson, Joel Rosenzweig, Richard Gordon and Jeanne Lee.

The Table begins with question No. 2 of the questionnaire. Question No. 1 was not included because the answers to it are given more detail in the answers to the other questions. When an ordered answer is given in the table, the best condition appears at the left and the worst on the right. In question No. 2 the notation 25°/30° means the subject could not tell any significant difference between the 25° sun angle and the 30° sun angle.

FIGURE I-1 SIMULATION QUESTIONNAIRE

TEST SUBJECT ______________________________
OBSERVER ______________________________
DATE ______________________________

1. Visibility Rating (circle best)

a. Model ______________
Sun Angle
Trajectory

1 2 3	4 5 6	7 8 9
2 3 1	5 6 4	8 9 7
10 11 12	13 14 15	
11 12 10	14 15 13	

b. Model ______________
Sun Angle
Trajectory

16 17 18	19 20 21	22 23 24
17 18 16	20 21 19	23 24 22
25 26 27	28 29 30	
26 27 25	29 30 28	

2. In terms of visibility provided, order the following sun angles from best (1) to worst (5):

7°, 15°, 20°, 25°, 30°

1________ 2________ 3________ 4________ 5________

3. In terms of overall visibility provided, order the following trajectories from best (1) to worst (3):

13°, 16°, 19°

1________ 2________ 3________

4. Indicate the terrain which provided the best visibility:

________ Rough ________ Smooth

5. Was visibility better to the side or in the center of the flight path?

________ Side ________ Center

6. Would you prefer a dog-leg maneuver to improve visibility?

________ Yes ________ No

7. In terms of ease of recognition, order each of the following types of terrain from best (1) to worst (5):

Large crater, Small crater, Hill, Rill, Debris pile

1________ 2________ 3________ 4________ 5________

TABLE I-1 ANSWERS TO QUESTIONNAIRE

	2. Sun angles ordered best to worst:	3. Trajectories ordered best to worst:	4. Terrain providing best visibility:
Neil Anderson	7°, 15°, 20°, 25°/30°, 25°/30°	19°, 16°, 13°	Smooth
Joel Rosenzweig	7°, 11°, 15°, 20°, 25°	19°, 16°, 13°	Rough, Note #2
Richard Gordon	7°, 11°, 15°, 20°, 25°	Note #1	Note #2
Jeanne Lee	7°, 11°, 15°/20°, 25°, 30°	19°, 16°, 13°	Note #3

	5. Visibility to side of flight path:	6. Dog-leg maneuver desired:	7. Terrain feature recognition ordered best to worst:
Neil Anderson	Better to the side.	Yes	Rill, large crater, hill, debris pile, small crater
Joel Rosenzweig	Better to the side	Note #5	Rill, large crater, hill small crater, debris pile
Richard Gordon	Better to the side	Note #6	Rill, large crater, small crater, hill, debris pile
Jeanne Lee	Better to the side	Yes	Rill, large crater, small crater, hill, Note #4

Note #1: "Didn't seem to matter in the low sun angle cases (7° to 11°). Higher trajectories (19°) seemed better with high sun angles."

Note #2: Joel Rosenzweig and Richard Gordon flew only the rough terrain series during data collection runs, but Joel Rosenzweig flew the smooth series during the familiarization runs and observed during Jeanne Lee's runs.

Note #3: "About the same contrast."

Note #4: Jeanne Lee could not definitely identify the debris piles although she could detect something in areas where debris piles were located.

Note #5: Joel Rosenzweig withheld judgement on whether a dog-leg maneuver would be desirable or not.

Note #6: "Probably not at low sun angles."

3.0 VERBAL DE-BRIEFING COMMENTS

The intent of the verbal de-briefing was to obtain each subject's overall impression of the simulation, and a discussion of those factors having the greatest impact on the test subject. Also, suggestions for improving the simulation and collecting the data were solicited.

The following test subjects were interviewed: Neil Anderson, Jeanne Lee, Dick Gordon, and Joel Rosenzweig. Their comments are as follows:

3.1 Neil Anderson - 8/22/67

Neil Anderson claimed that best visibility was obtained on flights over the smooth sequence of the models. This was because the smooth models had rills which could be easily identified. Rills were more prominent than craters as landmarks. Small craters were the most difficult to see. One of the surprises was the great difference in appearance between the rough and smooth models.

The rough models could be used for high-altitude landmark identification because this series of models had more large craters.

Mr. Anderson suggested cutting down on the number of runs for the 25° and 30° sun angles and concentrating on the low angles (e.g., 7°, 11°, 15°, and 20°). (Editor's note: It was due to Mr. Anderson's request that the 11° sun angle was included. This occurred after his runs were completed) Even the 20° sun angle might not have to be included in the runs. The 30° and 15° sun angle may provide about the same visibility.

One way of obtaining data on feature identification might be to pick out a feature and determine at what point in time along a trajectory the test subject can see it.

Other comments made by Neil Anderson were as follows:

Familiarization runs should be made with the smooth model.

Be sure that the test subject knows where the landing site is located.

3.2 Jeanne Lee - 9/23/67

With sun angles of 25° and 30°, there was no visibility and test subject could not make decision to land, with a re-designation, he may be able to make a decision. Operational procedures should be formulated for lunar descent.

With sun angles of 11° or less, test subject can see enough to land. Greater sun angles may be acceptable if test subject looks out toward the left and uses some visible features for re-designation. Re-designation decision may have to be made awfully fast.

As a result of the simulation Miss Lee can tell now what identifies a gross landmark. A 400 foot crater can be seen, but a 40 foot one cannot be seen, etc.

(Editor's Note: This is clearly a function of range and visual conditions. The point here is that gross features are probably ten times larger than fine features at any given range under specific visual conditions).

The band of visibility for most sun angles appears to be too narrow for pattern recognition. It may be possible to use known landmarks in the vicinity of the landing site if the sun angle is below 11°.

She stated that each team of apollo astronauts should concentrate and really study three landing sites. Other crews should concentrate on other sets of three landing sites.

More information on landing sites should be extracted from Lunar Orbiter and other data sources.

She mentioned that she could not determine the slope of the landing site from the simulation. Debris piles, etc., could not be identified although they could be detected.

3.3 Astronaut Dick Gordon - 8/24/67

The lunar landing simulation performed by Dick Gordon utilized only the rough set of Lunar models because of a projection lamp failure.

Dick Gordon made the comment that "he can't believe it's that bad" after he had completed the test runs. "If the simulation is valid, it provides a very dramatic display of what is going on," according to Cdr. Gordon.

The smallest landmark discernable from an altitude of 500 feet was a crater with a diameter of 37 feet. Cdr. Gordon mentioned that the entire rim of some craters should be visible probably because of the difference in the albedo of the ejecta from that of surrounding material.

(Editor's Note: No attempt was made to duplicate albedo differences on the models used in this simulation).

Dick Gordon mentioned that in landing, identifiable features should be located to the left of the landing ellipse. At high gate, this ellipse covers an area which is 20,000 feet by 10,000 feet.

Cdr. Gordon stated that for the better sun angles ($< 11°$), essentially the same visibility is provided for each of the trajectory angles (13°, 16° and 19°) utilized for the simulation.

He made the comment that there was "something here for a training device; the trajectory should be made continuous."

It was recommended that the simulation should be placed on movie film which would be compatible with the MSC LMS. Cdr. Gordon suggested that a study be made to determine what would have to be done to make the movie compatible.

APPENDIX II - TAPE TRANSCRIPTION

1.0 INTRODUCTION

As was mentioned in the body of the report, each subject was invited to make verbal comments during the runs. At the completion of the simulation, these verbal comments were extracted and typed for inclusion in this report. Those comments are given in the following pages of this appendix.

In planning the simulation it was initially thought that the time at which an event occurred could be found by measuring the lapse time from the start of a run when listening to the tape afterward. During Mr. Anderson's runs it became evident that this would be very time consuming because of the many comments that were being made. It was decided that data reduction could be simplified if the test engineer were to call out the time during the runs. This procedure was adopted after Mr. Anderson had completed his runs on the rough model at the 15° sun angle and continued throughout the rest of the simulation. The result, as anticipated, was a considerable saving in data reduction time.

The length of tape required to record the voice comments was determined prior to the simulation on the basis of a recording speed 1 7/8" per second. Afterwards it was discovered that the tape ran out because the recorder ran at 3 3/4" per second. This regretable error resulted in the loss of taped comments by Mr. Anderson during the 11° and 15° sun angle runs on the smooth model series and by Mr. Rosenzweig during the entire set of runs on the smooth model series.

A projection lamp failure at the end of Cdr. Gordon's runs on the rough series forced a lengthy shut down for repairs and resulted in inability to perform the smooth model series runs.

2.0 TEST SUBJECT: NEIL ANDERSON

<u>13° flight path, 7° sun angle - Rough models:</u>

The visibility on the first model started off at between 25° and 30° to the side.

(Editor's Note: The implication here is that a redesignation greater than 30° is required at this point in the run.)

On the second model it was down to about 15° to 20° and on the final model was down to between 5° and 10° to the side. There were no comments about the landing site. At the end, visibility dead ahead came up to about 48°. Features were distinguished early in flight at about 60°, on the LPD zero line.

<u>16° flight path, 7° sun angle - Rough models:</u>

Definition off the side was first noticed at the end of the first model. No mention was made through the flight regarding recognition of the landing site. The subject felt that the second trajectory was better than the first in that things were more visible near the bottom of the field of view. He also felt that he could see things further in front of him than on the 13° flight path.

<u>19° flight path, 7° sun angle - Rough models:</u>

The subject felt that the visibility was better at the start of the trajectory. He also felt that he could see further out all through the trajectory. No mention was made of having recognized the landing site. The subject felt that the longer the time between runs, the more difficult it was to compare two given runs.

<u>13° flight path, 15° sun angle - Rough models:</u>

There was no definition at all early in the flight. Near the end of the first model craters in close and at 25° to 30° left became visible. Craters dead ahead became visible by the middle of the second model, and at the beginning of the third model the landing site was visible.

16° flight path, 15° sun angle - Rough models:

By the middle of the first model there was definition off to the side and by the end of the first model there was definition forward. By the middle of the second model the landing site was visible and was very clearly defined at the beginning of the third model, but nothing was visible beyond the landing site.

19° flight path, 15° sun angle - Rough models:

There was definition to the side early on the first model and by the middle of the first model there was definition forward, but close in. The landing site became visible near the end of the first model and by the middle of the second model there were craters and rills clearly visible beyond the landing site. The washout ellipse on this particular sun angle was larger than it had been on any of the previous runs. The subject commented that he thought there might be visibility beyond the landing site at the 7° sun angle.

13° flight path, 20° sun angle - Rough models:

At the start of the first run there was no definition or visible characteristics on the screen. Towards the end of the run certain characteristics became visible.

60 seconds - There is no visibility.

75 seconds - There is slight definition forward.

End of model 2 - The landing site is not visible.

99 seconds - The landing site is not visible.

110 seconds - The landing site is still not visible.

- The landing site was never visible through the whole run. There were some shadowy craters visible at the lower end of the field of view.

<u>16° flight path, 20° sun angle - Rough models:</u>

18 seconds - There is nothing visible.

30 seconds - There are no features discernable.

- During the first model the washout ellipse went clear to the bottom of the visual field.

58 seconds - There is one crater dead ahead and very low.

73 seconds - The landing site is not visible.

80 seconds - There is some visibility outside the washout area.

End of model No. 2 - The landing site was just becoming visible.

105 seconds - The landing site is just barely in sight with poor definition.

111 seconds - The landing site is being washed out.

End of Run - The landing site is no longer in sight.

<u>19° flight path, 20° sun angle, Rough models:</u>

20 seconds - There is some definition at about 15° left.

50 seconds - The visual scene has not improved.

58 seconds - The landing site is not visible. There is a crater dead ahead and visible.

68 seconds - The outline of the landing site is visible.

End of Model No. 2 - The landing site was barely visible.

92 seconds - The landing site is barely visible.

101 seconds - The landing site is being washed out.

107 seconds - The rill and crater beyond are washed out.

112 seconds - There goes the crater.

- During the 20° sun angles the landing site disappeared completely during the run.

13° flight path, 25° sun angle - Rough models:

10 seconds - The initial view is washed out.

37 seconds - There are no discernable targets.

61 seconds - There are no targets visible.

82 seconds - There are no targets visible.

92 seconds - Some targets came into view on the left side.

105 seconds - The landing point is not visible.

116 seconds - A few craters were visible any place.

16° flight path, 25° sun angle - Rough models:

10 seconds - Some dim craters are visible off to the left.

50 seconds - A few dim blurry targets are visible off to the left.

60 seconds - There is nothing visible.

96 seconds - A few targets are visible slightly to the left.

95 seconds - The target is not visible, but a few craters are visible at the lower left corner.

106 seconds - The landing site is not visible.

\- The landing site was not visible through the whole run.

19° flight path, 25° sun angle - Rough models:

11 seconds - No targets are visible.

35 seconds - Some faded targets are visible in the lower left hand corner.

60 seconds - A crater is visible in the lower left.

73 seconds - The landing site is not visible and very few targets are visible.

95 seconds - One crater is going out of sight at the lowe... left.

111 seconds - Craters are starting to come in, but the landing site is not visible.

End of Run - Some craters are visible off to the side, but nothing is visible straight ahead.

<u>13° flight path, 30° sun angle - Rough models:</u>

10 seconds - There are no features in sight except for some hazy ones off on the far left.

- Everything up to and including about 40° off to the left is completely washed out.

62 seconds - There is absolutely nothing in sight.

81 seconds - There are still no discernable features.

97 seconds - No features at all.

115 seconds - A few dim features are seen off to the left.

<u>16° flight path, 30° sun angle - Rough models:</u>

10 seconds - There are a few minor targets way off to the left.

18 seconds - Everything else is fogged up.

40 seconds - Some fuzzy features to the left and left front are visible.

58 seconds - No targets.

80 seconds - A few features are becoming visible.

93 seconds - There are no targets in sight.

105 seconds - A few targets are becoming visible off to the left front.

111 seconds - Some features are identifiable off to the left, but nothing straight ahead.

<u>19° flight path, 30° sun angle - Rough models:</u>

10 seconds - Some features are identifiable off to the far left.

40 seconds - A few very faint targets are in the left front.

50 seconds - More targets are becoming visible all the time off to the left.

66 seconds - Very faint features are visible in the lower left.

73 seconds - The landing site is not visible.

105 seconds - The landing site is not visible, but there are targets and features visible in the lower left.

112 seconds - The features are degrading.

End of Run - Nothing is identifiable.

<u>13° flight path, 7° sun angle - Smooth models:</u>

12 seconds - Several features are distinguishable off to the left and almost up to the center line.

25 seconds - I thought I recognized the landing site.

73 seconds - There is a crater just to the left of the center line.

85 seconds - The ridge line running from left to right is just visible.

<u>13° flight path, 20° sun angle - Smooth models:</u>

15 seconds - There are no identifiable features.

30 seconds - It is completely washed out.

End of First Model - There were no identifiable features on the first model at this sun angle.

60 seconds - There are no features in sight.

87 seconds - A few ridges and rills are visible on the left side of the screen.

End of Model No. 2 - Nothing is visible on the LPD zero line.

109 seconds - The landing site is not visible.

- There are certain features in the lower portion of the screen that can be seen. The landing site was never visible on the run.

<u>16° flight path, 20° sun angle - Smooth models:</u>

27 seconds - The contrast is poor. There are no targets visible.

60 seconds - The screen is completely washed out, nothing visible.

75 seconds - A few ridge lines or rill lines are visible in the lower left.

85 seconds - There are craters in the lower left.

- I can determine a visual difference between the rough and smooth models, but I can't tell which is rough and which is smooth.

103 seconds - The landing site is not visible.

110 seconds - The landing site is faintly visible.

113 seconds - It would be impossible to make a landing.

19° flight path, 20° sun angle - Smooth models:

15 seconds - Everything is washed out.

26 seconds - There is some definition in left foreground.

45 seconds - There are some ridges visible to the left of center line.

63 seconds - There are no craters in sight.

73 seconds - There are some ridge lines visible off to the left, but nothing dead ahead.

End of Model No. 2 - Some craters were picked up at 63° on the LPD.

94 seconds - The landing site is not visible.

- A few targets are visible dead ahead, but they are in very close.

<u>19° flight path, 30° sun angle - Smooth models:</u>

5 seconds - The screen is completely obliterated.

15 seconds - It is impossible to tell motion.

40 seconds - A few small craters way over at the left side are visible.

72 seconds - There are a few ridge lines and rill lines visible on the left and foreground.

End of Model No. 2 - The landing site was not in sight nor was any area in the direct fore front of the picture.

End of Model No. 3 - There is no definition except for a few craters in the lower foreground.

End of Run - Its just barely possible to tell motion by looking off to the side.

3.0 TEST SUBJECT: JOEL ROSENZWEIG

13° flight path, 7° sun angle - Rough models:

15 seconds - Gross terrain features are recognizable, but not well enough to pick out the landing site.

28 seconds - Relative motion cues are better off to the left than they are straight ahead.

40 seconds - The rill is starting to make an appearance.

51 seconds - I can see the general vicinity of the landing site, but probably not clear enough to determine whether it is acceptable or not.

70 seconds - I've got a fairly good fix on the landing site, but you cannot tell the quality.

- Earlier in the run the horizon had some fairly good landmarks on it, but the only ones you would be able to appreciate from that altitude would be the gross landmarks and later in the run the horizon started to get whited out. So I don't think the landmarks coming over the horizon would be very useful at this sun angle.

100 seconds - All the terrain features in the area of the landing site are recognizable.

110 seconds - Most all the small terrain features appear good.

- Some of the smaller features appeared whited out, but almost all of the features in the foreground appeared usable at the end of the run.

End of the third model - The visibility in the foreground off to the left doesn't appear to be appreciably better than straight ahead, however, the horizon features show up better off to the left than they do straight ahead.

<u>16° flight path, 7° sun angle - Rough models:</u>

10 seconds - The terrain features don't appear to be much different than they were on the first run.

- I am able to see the general vicinity of the landing site, but only due to training and recognition.

29 seconds - No characteristics or qualities are visible.

35 seconds - Gross landmarks are still very good off to the left and in the foreground.

50 seconds - The landing site is visible, but the quality is still not discernable.

- After the end of the first model you have to stop and think when you see a shadow whether it's on the front or the back of the terrain features so you can determine whether it is a hill or a crater.

57 seconds - The landing site shows up fairly well.

70 seconds - There is reasonably good quality in all areas above 30°, below the horizon is starting to white out.

80 seconds - Can't determine whether to land at this landing site or not.

96 seconds - Everything looks fairly useful in the landing site vicinity.

102 seconds - Things are better off to the left, the horizon is whited out about 60° above the landing site.

- I feel that as far as the pilot s are concerned a preference for one trajectory over another will be based more upon the approach velocity or speed rather than upon ~~XXX~~ visibility for a given sun angle.

19° flight path, 7° sun angle - Rough models:

10 seconds - Things look pretty much as on the first run.

20 seconds - Good surface terrain contrast.

29 seconds - Just about picking out the vicinity of the landing site, but could not make any quality determination.

38 seconds - Have the landing site.

50 seconds - Would venture first guess as to whether it's good or bad.

- It appears that the early part of the descent from 10,000 feet on down on the first map you pick up the landing site at the bottom of the descent at the latter portion of the first trajectory when you start to discern the landing site. Earlier than that you have to make your way towards it using gross landmarks. You don't have any capability using an LPD.

56 seconds - I have a good fix on the landing site.

66 seconds - The small terrain features have not started showing up.

71 seconds - The small terrain features have shown up.

75 seconds - Good fix on the landing site.

- At the end of the run you had adequate visual perception of what the characteristics of the landing site are. The best method for using the LPD is to make your redesignation as early as possible in the descent, and with these conditions it appears you will have gone half way through your descent before you will be able to pick out the landing point well enough to use the LPD. Now maybe thats a matter of training, I don't know and with a little more training on the actual terrain you may have been able to pick it out earlier.

97 seconds - I belive you are in good enough position to determine your landing capabilities.

105 seconds - A lot of other good landing sites are apparent in this position.

<u>13° flight path, 11° sun angle - Rough models:</u>

8 seconds - The surface texture visibility is much less than the earlier runs.

13 seconds - Much better off to the left, but I don't feel it is useable.

23 seconds - A series of rills are visible, but the landing site is not.

35 seconds - Everything is visible up around where the landing site is supposed to be.

50 seconds - I have the vicinity of the landing site, but no quality estimate.

- I don't think you would be able to make any landing site judgements at all on the first model. I may be a little more pessimistic than the others.

65 seconds - I have the vicinity of the landing site probably discretely enough to designate, but I cannot really determine the quality.

76 seconds - The terrain features are starting to show up.

84 seconds - I can judge the terrain features, but still not a quality judgement.

End of model - I can pick out prominent terrain features, but still not enough to be able to determine whether it is acceptable or not.

92 seconds - The foreground features are fairly good.

108 seconds - I still wouldn't commit to a landing at this point though.

116 seconds - I wouldn't commit yet, but I know where the landing site is.

<u>16° flight path, 11° sun angle - Rough models:</u>

10 seconds - The foreground features show up, but nothing on the horizon.

18 seconds - At 25° left you might be able to pick out some gross landmarks and be able to use them for navigation.

26 seconds - I have the rill areas that define the landing site, but I

33 seconds - cannot see the landing site yet.

42 seconds - The rills and the larger craters do show up.

51 seconds - I see the vicinity of the landing site.

55 seconds - I have the landing site vicinity, but no quality judgement.

66 seconds - About 14° below the horizon it is whited out.

75 seconds - The landing site is fairly discernable.

81 seconds - I appreciate terrain features.

- At the end of that map I could at least fly away from a bad landing site.

96 seconds - I could probably judge landing or not.

101 seconds - Other good landing sites are visible, and the foreground is better.

- The best features seem to be the series of rills and the craters right before the rills.

<u>19° flight path, 11° sun angle - Rough models:</u>

24 seconds - The rills show up earlier and prominent features show up earlier than it did on the other trajectories.

33 seconds - I have the vicinity of the landing site.

46 seconds - The horizon wash out is a little more extensive.

- You could probably make the redesignation at the end of the first model.

55 seconds - I've got the landing site well determined, but the terrain is impossible to determine.

63 seconds - I could redesignate away from a bad one.

71 seconds - The small terrain features are showing up now.

End of second model - Good landing sites do show up.

95 seconds - Terrain judgement can be easily done now at 95 seconds.

110 seconds - [illegible] ould not redesignate down range at this time it's whited out.

- There is a wide variety of landing sites though that you could redesignate to or from on the last 20 seconds of the last model.

I think that the significant thing though that you want to point out is that you went through half of your descent before you were able to get a real good check on the guidance on whether you actually had a landing site at that point or were unable to make any redesignations. This is entirely subjective, of course, but I think it would probably be more difficult to make determinations if you were to wind up in a completely flat area with no obstacles or craters in it. But if you could be assured that any area in that area were good, but the pattern that you get from certain landmarks helps you to distinguish by knowing in advance how big they are you can distinguish smaller terrain features.

13° flight path, 15° sun angle - Rough model:

5 seconds - Gross horizon features may be visible.

17 seconds - The first gross crater comes into view and its no better off to

21 seconds - the left.

25 seconds - Nothing.

31 seconds - No usable landmarks.

46 seconds - Some craters and landmarks way off to the left.

- You can tell something is down there, but you could not make any judgement as to position or quality. For all practical purposes you have no appreciation of the landing point.

60 seconds - Some landing sites are showing up in the foreground, but not well enough to position yourself.

86 seconds - The rills in the area of the landing site are visible and I can just barely make out the landing site.

104 seconds - Still no quality estimate on the landing site.

110 seconds - The landing site is now drifting into the washed out area.

- I would say that I wasn't able to determine the quality of the landing site throughout the entire run.

<u>16° flight path, 15° sun angle - Rough models:</u>

25 seconds - Some rills are showing up.

- Probably obtain nothing on that model except the most gross landmarks.

60 seconds - I have the vicinity of the landing site.

74 seconds - The washout is approaching the landing site.

84 seconds - I could redesignate away from a bad one, but I could not tell if it was good.

- At this point the visibility is markedly better off to the left than it is dead ahead.

93 seconds - The terrain features in the foreground are apparent.

102 seconds - You can determine some features in the landing site vicinity, but its on the verge of being whited out.

- You never did see the entire sector of terrain features and it approached the white out area at better then 16°. From the horizon on down it was whited out.

<u>19° flight path, 15° sun angle - Rough models:</u>

14 seconds - Some larger rills are showing up.

20 seconds - I can see some large craters that I know to be in the area of the landing site.

30 seconds - I still haven't got the landing site.

43 seconds - I'm in the vicinity of the landing site.

50 seconds - I can see the site, but no quality.

74 seconds - I don't see the landing site, its right on the edge of the white out area now.

- The white out area is 16° below the horizon.

83 seconds - The white out area is starting to slide into the landing area.

94 seconds - The site is visible, but terrain features cannot be determined.

104 seconds - Its starting to white out.

109 seconds - Its getting worse at the landing site, I could redesignate to the left.

- Almost everything down to 48° on the LPD was whited out on the last portion.

4.0 TEST SUBJECT: JEANNE LEE

13° flight path, 7° sun angle - Rough models:

10 seconds - The craters are very visible off to the left.

36 seconds - The shadows show between the rills and the bright areas, but they cannot be distinguished.

45 seconds - A definite crater is not visible directly ahead up to the horizon.

54 seconds - The rill by the landing site is visible.

61 seconds - There are definite craters around 60°.

85 seconds - The model is washed out above 54°.

Beginning of third model - There is clear visibility below 53°.

110 seconds - Everything above 42° is washed out.

16° flight path, 7° sun angle - Rough models:

10 seconds - There is clear visibility below 46° and on down.

35 seconds - There is washout at 56°.

54 seconds - The landing site is still washed out.

60 seconds - The rills are visible at 60°.

68 seconds - The landing area to the horizon is washed out.

End of second model - Very clear identification of the landing site.

- Things are more identifiable by the contrast rather than by their shape or appearance except for rills which are extremely easy to detect and identify.

100 seconds - The rill and large crater are identifiable.

19° flight path, 7° sun angle - Rough models:

30 seconds - The craters below 56° are visible.

45 seconds - The landing site is not identifiable.

65 seconds - The landing site is not identifiable.

75 seconds - The landing site identifiable.

105 seconds - Craters are coming in very visible and on the landing site.

13° flight path, 11° sun angle - Rough models:

- I am concentrating very hard on what I can see and not particularly on the landing site.

10 seconds - Very washed out.

20 seconds - Craters are becoming visible at about 15°.

40 seconds - Small craters are visible off to the left, but nothing visible straight ahead.

50 seconds - No possibility of identifying the landing site.

60 seconds - Shadowing is starting to appear.

85 seconds - The landing site is identifiable, but the rill is not very clear yet.

End of run - It would be impossible to decide whether a person could land in that area or not since the features were not very visible.

100 seconds - The landing site is quite clear.

110 seconds - The terrain is washed out right at the landing site.

End of flight - The landing site is washed out.

16° flight path, 11° sun angle - Rough models:

20 seconds - The model is washed out.

30 seconds - Visibility over to the left is improving.

35 seconds - The landing site is not determinable.

50 seconds - It is washed out above 62° and up to the horizon.

60 seconds - The small craters are starting to become visible.

70 seconds - The landing site is not identifiable.

75 seconds - Can pick it out because of the shadowing on the rill.

90 seconds - It is washed out above the rill.

- I think the landing site was there because I have made a number of runs and knew where it was and knew the characteristics of the terrain around it.

95 seconds - It is washed out above 50°.

100 seconds - The landing area is definitely identified.

End of the run - The small crater to the left of the landing site was not identified. I feel that it is there, but cannot identify it positively.

<u>19° flight path, 11° sun angle - Rough models:</u>

15 seconds - The craters are quite clear off to the left down to small ones.

25 seconds - It is washed out about 54°.

30 seconds - The landing site not definable.

60 seconds - There are craters visible low in the field, but still washed out at above 54°.

75 seconds - I definitely know where the landing area is, but not able to identify it.

End of model 2 - The small crater near the landing site was visible.

90 seconds - The landing site is very clear.

100 seconds - The little crater beside the landing site is very clear.

110 seconds - The big crater by the landing site is washed out.

<u>13° flight path, 15° sun angle - Rough models:</u>

10 seconds - The large craters are barely visible to the left and some small craters down near the bottom.

22 seconds - The small craters are becoming visible over to the left.

30 seconds - It is completely washed out dead ahead.

47 seconds - It is completely washed out.

- Some craters are showing up to the left.

52 seconds - No possibility of identifying the landing site.

65 seconds - Some shadowing starting to show up dead ahead.

70 seconds - No indication of the landing site.

85 seconds - Some shadows showing up ahead and some craters showing up.

93 seconds - The rill and crater showed up.

- There is possible identification of the landing site.

97 seconds - Everything is washed out.

103 seconds - The rill and crater are washed out.

115 seconds - The shadowing that looked like the rill and crater are being seen again.

<u>16° flight path, 15° sun angle - Rough models:</u>

10 seconds - The small crater is visible off to the side.

20 seconds - There is wash out 30° to the horizon.

30 seconds - No indication of the landing site.

40 seconds - Some shadowing straight ahead, but no features available at all.

- I am only calling out shadows when I'm fairly certain they were shadows of a crater or a rill.
- Visibility to the left and at the bottom fairly clear.

65 seconds - Complete washout straight ahead.

85 seconds - The craters are becoming somewhat visible near the landing site.

- The rill by the landing site was never visible on this run at this point.
- I am only identifying the landing site once I can see the crater and the rill,

95 seconds - The large crater and the ring of craters around the landing site is visible.

105 seconds - Not sure of the rill.

109 seconds - I can determine the landing site because I know where it is.
- The craters around the landing site washed out just before flight end

<u>19° flight path, 15° sun angle - Rough Models:</u>

3 seconds - Complete washout up to the horizon from 40°.

10 seconds - A few craters visible to the left.

40 seconds - There is no indication of the landing site.

50 seconds - The washout is extending more to the left than it did before.

60 seconds - There is clear visibility on the lower portion of the screen.

80 seconds - The large craters are starting to show.

End of Model 2 - The landing site was still not visible, but the crater was starting to show.

95 seconds - The landing site is definitely visible, but the rill is not.

105 seconds - It is impossible to tell any characteristics about the landing site.

112 seconds - The large crater washed out and just at the end the smaller craters started to washout.
- I am trying to concentrate more on the landing site and and make out more detail and determine when it became visible, than I have been in the past.

<u>13° flight path, 20° sun angle - Rough models:</u>

10 seconds - Two large craters to the left are visible plus a few below them.

30 seconds - Nothing definitely visible down towards the landing site.

40 seconds - Everything is still washed out.

45 seconds - There is some washout left.

60 seconds - The washout still complete and extending to the left.

80 seconds - The landing site is still washed out and shadowing is starting to show up a little bit.

90 seconds - The contrast is improving and craters are showing up at the bottom of the window.

100 seconds - The contrast is improving towards the bottom of the window.

105 seconds - The ring of craters is starting to show a pattern.

- The landing site was never visible during the run.

<u>16° flight path, 20° sun angle - Rough models:</u>

15 seconds - There is nothing visible in the area of the landing site up to the horizon.

22 seconds - Shadowing is starting to show up at the bottom of the window.

40 seconds - Craters off to the left are becoming clearer.

- There is nothing in the area of the landing site.

60 seconds - The washout is extending over towards the left.

75 seconds - There are no craters visible in the area of the landing site.

90 seconds - The craters are visible as they go out the bottom of the window.

100 seconds - The ring of craters is visible.

105 seconds - The large crater or rill picked up to the right of the landing site.

- The landing site was becoming a little bit more visible, but started washing out right before the end of the flight.

<u>19° flight path, 20° sun angle - Rough models:</u>

10 seconds - Some craters are visible to the left.

50 seconds - Nothing is visible in the direction of the landing site, washout is complete to the horizon.

65 seconds - The shadowing is getting a little bit darker.

- During the last portion of this model the craters were visible as they neared the bottom of the window and disappeared out of sight.

100 seconds - The ring of craters to the right of the landing site and the large crater are visible. A rill was not visible. The rill was visible because it looked like two long shadows.

<u>19° flight path, 25° sun angle - Rough models:</u>

10 seconds - There is nothing visible, except two large craters way up off to the left.

30 seconds - There is nothing in view forward up to the horizon.

40 seconds - There is nothing at all visible in the direction of the landing site.

50 seconds - Some shadowing is appearing in the area of the landing site.

- Two large craters still visible off to the left.

65 seconds - There is nothing visible in the landing site area.

80 seconds - The landing site area is still washed out.

83 seconds - The washout is from 60° to the horizon.

100 seconds - A ring of craters is barely visible.

110 seconds - Picking up a little bit of dark area where the rill should be.

<u>19° flight path, 30° sun angle - Rough models:</u>

- Complete washout along 0 line.

10 seconds - There are some craters visible over to the left.

30 seconds - There is no contrast in the area of the landing site.

50 seconds - There is nothing discernable in the direction of the landing site.

65 seconds - There is nothing further in the direction of the landing site.

- Few medium sized craters off to the left are visible at 75°.

<u>13° flight path, 7° sun angle - Smooth models:</u>

25 seconds - A possible landing site picked out at about 56°.

35 seconds - Large craters directly ahead are visible.

45 seconds - There are craters far off to the left that are quite clear.

60 seconds - The craters 10° below the horizon are quite visible.

80 seconds - Large craters at 50° and craters to the right and left are visible.

90 seconds - Clear visibility runs from 50° and down.

95 seconds - Very large craters are very clear, the medium craters are not as clear.

115 seconds - The rill has washed out.

<u>16° flight path, 7° sun angle - Smooth models:</u>

10 seconds - The large crater is very visible and smaller craters towards the bottom are visible.

25 seconds - The rills are not visible.

35 seconds - Only the large craters are visible above 54°.

50 seconds - The large craters are becoming clearer.

60 seconds - The rills off to the left are visible.

70 seconds - The medium size craters are starting to come into view.

80 seconds - The pattern of the landing site is beginning to be recognized.

95 seconds - The landing site is plainly visible.

100 seconds - The landing site looks pretty good.

110 seconds - The ridge is starting to disappear, but the craters are quite clear.

- A pile of rubble is visible just as the trajectory ended.

19° flight path, 7° sun angle - Smooth models:

10 seconds - The large crater is visible at about 50°.

20 seconds - The craters off to the left all sizes are visible.

30 seconds - The landing site is not visible or discernable.

50 seconds - The rill and large crater off to the right are visible.

60 seconds - The large craters at about 48° were visible.

80 seconds - The landing site clearly visible at about 55°.

90 seconds - The large craters are very clear.

95 seconds - The landing site pattern is very clear.

110 seconds - All the craters surrounding the landing site are very clear.

- The background is starting to disappear as the trajectory ends.

13° flight path, 11° sun angle - Smooth models:

10 seconds - A crater is visible at the lower part of the window.

20 seconds - Nothing is visible in the direction of the landing site.

35 seconds - The craters are clear over to the left.

40 seconds - Shadowing is increasing in the direction of the landing site.

70 seconds - Shadows are starting to appear towards the landing site and things to the left are clear.

90 seconds - The landing site pattern is recognized.

100 seconds - The landing site pattern is clear.

105 seconds - It's washed out above the landing site.

110 seconds - The contrast around the landing site area is faded out.

16° flight path, 11° sun angle - Smooth models:

20 seconds - Dark shadows in the area of the landing site are being picked up, but are not clearly identifiable.

30 seconds - The landing area is not identifiable.

40 seconds - Small craters are visible in the lower portion of the window.

45 seconds - It is washed out down to about 45°.

53 seconds - The landing site pattern is not visible.

60 seconds - Long rills are visible.

70 seconds - Still not sure of the pattern of the landing site.

80 seconds - Three of the larger craters around the landing site are visible.

90 seconds - The landing site definitely recognized.

95 seconds - The landing area is quite clear and large areas to the left are very clear.

107 seconds - The small craters are fading out.

<u>19° flight path, 11° sun angle - Smooth models:</u>

10 seconds - The picture is washed out above 56°.

20 seconds - The two large craters at about 52° are quite clear.

30 seconds - The landing site is not visible.

40 seconds - The landing site is still not visible.

60 seconds - The landing site still not visible.

70 seconds - Three of the four craters defining the landing area are becoming visible.

80 seconds - The small craters are becoming visible.

85 seconds - All six craters surrounding the landing site are visible.

95 seconds - The landing site looks good.

100 seconds - The irregular crater far away is starting to washout.

110 seconds - The picture is beginning to washout above 48°.

<u>13° flight path, 15° sun angle - Smooth models:</u>

10 seconds - The craters to the left are not clearly defined and washed out in front.

20 seconds - Some shadows detectable in the landing area.

67 seconds - Some shadowing continues in the landing site area, but nothing plainly visible.

90 seconds - The craters to the left are somewhat visible at 80° and shadowing getting darker at landing site area.

93 seconds - The picture detail is improving in the lower portion of the screen.

100 seconds - The craters off to the left are very clear.

110 seconds - The landing site still is not visible.

<u>16° flight path, 15° sun angle - Smooth models:</u>

10 seconds - The craters are visible on the left, but not clearly defined.

35 seconds - The picture is washed out from 64° up to the horizon.

60 seconds - The craters are not clearly in view at the lower portion of the window.

70 seconds - There is no indication of the landing site.

80 seconds - Three large craters to the left of the landing site are visible, but the landing site pattern is not visible.

97 seconds - The large craters in the area of the landing site are beginning to be discernable.

110 seconds - The landing site is not recognizable.

<u>19° flight path, 15° sun angle - Smooth models:</u>

10 seconds - The picture is washed out up to the horizon.

25 seconds - The landing site is completely washed out.

35 seconds - The craters off to the left and the rills are visible.

65 seconds - There is no indication of the landing site.

75 seconds - The larger craters around the landing site are discernable.

End of the Second Model - The landing site was not clearly seen, but the large craters around it were distinguishable .

92 seconds - Three large craters to the left of the landing site are still visible.

100 seconds - They are starting to washout.

105 seconds - One of the small craters at the landing site is slightly visible.

- All features in the area of the landing site started to wash out at the end of the trajectory.

<u>13° flight path, 20° sun angle - Smooth models:</u>

12 seconds - A number of craters are visible off to the left, but are not clearly defined.

20 seconds - There is nothing visible in the area of the landing site.

40 seconds - There is nothing visible in the area of the landing site.

50 seconds - Some craters are visible off to the left, but are not clearly defined.

60 seconds - No craters are visible in the landing site area.

75 seconds - There is slight shadowing visible in the landing site area.

105 seconds - Three large craters are slightly visible and believed to be part of the landing site recognition pattern, although nothing is clearly visible in the landing site area.

115 seconds - The landing site is still completely washed out.

<u>16° flight path, 20° sun angle - Smooth models:</u>

10 seconds - A few craters way off to the left are visible.

20 seconds - Nothing is visible in the area of the landing site.

30 seconds - The shadowing at the lower end of the window is more pronounced, but nothing is discernable.

60 seconds - There is nothing at all visible in the area of the landing site.

80 seconds - There are a few craters showing up at the bottom of the window.

95 seconds - Three large craters off to the left are quite visible.

End of the run - The landing site is not visible.

<u>19° flight path, 20° sun angle - Smooth models:</u>

10 seconds - A few craters starting to show up in the lower left of the window, but the rest of the picture is completely washed out.

45 seconds - Craters come into view at the bottom and the left and go out of view very rapidly.

55 seconds - Washed out all the way up to the horizon except far over to the left.

80 seconds - Three large craters in the pattern to the left of the landing area are fairly clear.

End of the Second Model - The pattern of the actual landing site is not visible.

95 seconds - The craters to the left of the landing site are still visible.

105 seconds - Can barely detect craters in the vicinity of the landing site.

110 seconds - The craters can not be definitely identified.

<u>19° flight path, 25° sun angle - Smooth models:</u>

15 seconds - Very large craters far off to the left are visible.

25 seconds - Nothing in the landing site area.

70 seconds - Nothing in the area of the landing site, a few craters far off to the left.

80 seconds - The three large craters to the left of the landing site are recognizable, but the landing site itself is not.

100 seconds - No craters in the area of the landing site are visible.

<u>19° flight path, 30° sun angle - Smooth models:</u>

10 seconds - Some craters are distinguishable far off to the left.

20 seconds - Nothing in the area of the landing site.

40 seconds - Large crater is passing under the window.

65 seconds - Nothing visible in the area of the landing site.

83 seconds - Three large craters are distinguishable.

5.0 TEST SUBJECT: CDR. . RICHARD GORDON

13° flight path, 7° sun angle - Rough models:

- Cdr. . Gordon made no significant comments through this first run.

16° flight path, 7° sun angle - Rough models:

15 seconds - I don't see the landing site yet.

45 seconds - I can see the rill now.

70 seconds - I can pick up the crater without any doubt.

100 seconds - I could very definitely redesignate any area around the landing site except for above it, which I can't make out anything, because it is washed out.

110 seconds - The area to the left is real easy to see.

19° flight path, 7° sun angle - Rough models:

17 seconds - I can distinguish the crater at the landing site which I am going to land next to.

35 seconds - Thats about all I can tell, It's a crater and the rill behind it.

- There is no doubt about it, the rill was the first distinguishable feature that came into view.

102 seconds - The landing site is about at 42°.

- At about three seconds before the end of the trajectory the run was stopped in order to measure the smallest crater visible. The feature measured turned out to be a shallow depression that measured about 37 feet across.

13° flight path, 11° sun angle - Rough model:

20 seconds - No landing point yet that's for sure.

26 seconds - Big crater going underneath us.

- Just as the first segment ended features near the landing site were capable of being picked out.

60 seconds - Starting to pick up the rill behind the landing site as a feature.

65 seconds - Do not have the landing site yet.

72 seconds - The landing site is starting to come in.

81 seconds - Well defined view of the landing site using the crater as a landmark.

92 seconds - Could not redesignate at this point.

105 seconds - I still would not redesignate.

110 seconds - The landing site looks as good as any other site down there right now.

<u>16° flight path, 11° sun angle - Rough models:</u>

12 seconds - Just starting to pick up the rill behind the landing site.

48 seconds - I have the landing site.

- What I mean when I say that I have the landing site is that I can make out the 400 foot crater by the landing site. I cannot see the actual landing area itself.

62 seconds - The rill is very prominent and the craters to the right are very prominent.

75 seconds - The landing site itself is becoming more defined, but still cannot redesignate.

- I have the 75 foot crater as soon as the third model came on.

110 seconds - Still can't redesignate.

- That really started to washout near the end of that trajectory. During the last three seconds the craters themselves became less distinguishable.

19° flight path, 11° sun angle - Rough models:

20 seconds - I can use the craters to the left at about 25° azimuth as a landmark.

25 seconds - The rill is starting to come in.

33 seconds - The craters near the landing site are starting to show up.

40 seconds - I have the 400 foot crater.

44 seconds - I've got a 500 foot crater to the left of it, shows up pretty good.

- I don't think I would have been able to redesignate on those last two runs very well not unless we have to be worried about 75 to 80 foot objects. You could avoid those, but anything less than that I don't think I would have been able to redesignate the landing site.

60 seconds - It looks like about 52° on down things are fairly well defined.

65 seconds - The landing site is at about 62°.

68 seconds - The 75 foot crater is visible.

- When I say its distinguishable, it doesn't mean I can distinguish the shape, but I can see the shadow that I know is in the crater.

100 seconds - Starting to loose shadow definition in the craters.

105 seconds - Particularly in the 75 foot craters.

110 seconds - The 75 foot craters are becoming more and more washed out.

13° flight path, 15° sun angle - Rough models:

13 seconds - Everything is completely washed out and I see no distinguishable features.

24 seconds - Slight shadowing effect in the vicinity of the rill is apparent but I would not be able to identify it.

80 seconds - The craters are starting to appear.

85 seconds - I have the 400 foot crater behing the landing site at this time.

91 seconds - The 100 foot crater is coming into view.

- The only reason I know this is because I know where they are on the LPD. The only thing I'm picking up is the shadowed portion without any real features being defined at all. The craters themselves are not distinguishable.

105 seconds - I have a crater down at about 56°, 5° right that is distinguishable.

<u>26° flight path, 15° sun angle - Rough models:</u>

30 seconds - I have the crater thats to the left of the landing site.

40 seconds - There is a shadow there, but I can't really tell if its the right one or not.

- The rill is just starting to appear at the end of the run.

70 seconds - The crater at about 5° right of the landing site is visible. The rill is barely visible at this time.

75 seconds - The 400 foot crater is visible.

81 seconds - The 100 foot crater is perceptible.

95 seconds - The 75 foot crater is visible. Its visible as a very slight depression.

111 seconds - The landing site is washed out completely.

- the landing site disappeared completely in the last three seconds of the run, due to wash out.

<u>19° flight path, 15° sun angle - Rough models;</u>

14 seconds - I can see things from 60° down.

27 seconds - The landmarks at 15° left are good.

End of first model - The rill is starting to appear.

- Shadow is what I am using to distinguish most things by. There is not enough distinction in the bright spots to tell the edge of a rill from anything else.

62 seconds - The 400 foot crater by the landing site is visible.

75 seconds - The 100 foot crater is starting to appear.

- Actually on that run I held the shadow of the crater longer on this run than I did on the previous run. Particularly the 400 foot crater.

101 seconds - The 75 foot depression is visible.

110 seconds - Shadow is starting to make all the craters disappear.

<u>13° flight path, 20° sun angle - Rough models:</u> (Repeat)

22 seconds - It's washed out to about 25°.

- I just can't imagine it being that bad.

60 seconds - I see absolutely nothing.

90 seconds - Its coming in a little bit better, it's only bad out to about 15°.

105 seconds - I've got a crater at 56° .

- Nothing, absolutely nothing, I didn't see that 400 foot crater at all this time.

APPENDIX III
DESCRIPTION OF SIMULATION EQUIPMENT

1.0 BASIC FACILITY DESCRIPTION

The Boeing Space Flight Simulator is a fixed base visual simulator which uses a projected television display to create the visual environment external to the LM vehicle. The projected visual scene is obtained from television cameras which are observing the lunar models. The camera, acting as an analog of the vehicle being simulated, is driven by servos through six degrees of freedom. Astronaut control commands are fed from the cockpit to the computer thereby modifying the visual scene projected. To complete the simulated environment, a full range of active cockpit instrumentation is provided.

Major elements of the Space Flight Simulator used in the Parametric Vision Simulation are shown in Figure 3 in the body of this report. They are contained in three separate rooms, the projection room, the model room and the computer room, each of which is described in turn below.

2.0 PROJECTION ROOM

The projection room contains the full scale LM cockpit with its displays, controls and portable voice recorder, and the high intensity TV projector, both of which are mounted as close as possible to the center of the 30 foot diameter hemispherical screen. The plan view of the projection room is shown in Figure III-1. The two place simulated LM cockpit is of plywood construction, completely enclosed. Figure III-2 shows the cockpit as installed in the projection room. The two crew stations are stand-up and the left or commander's station is provided with an LM field-of-view window. The station on the right is provided with a large rectangular shaped window enabling the observer to view most of the screen area, including that seen by the commander. The commaner's visibility

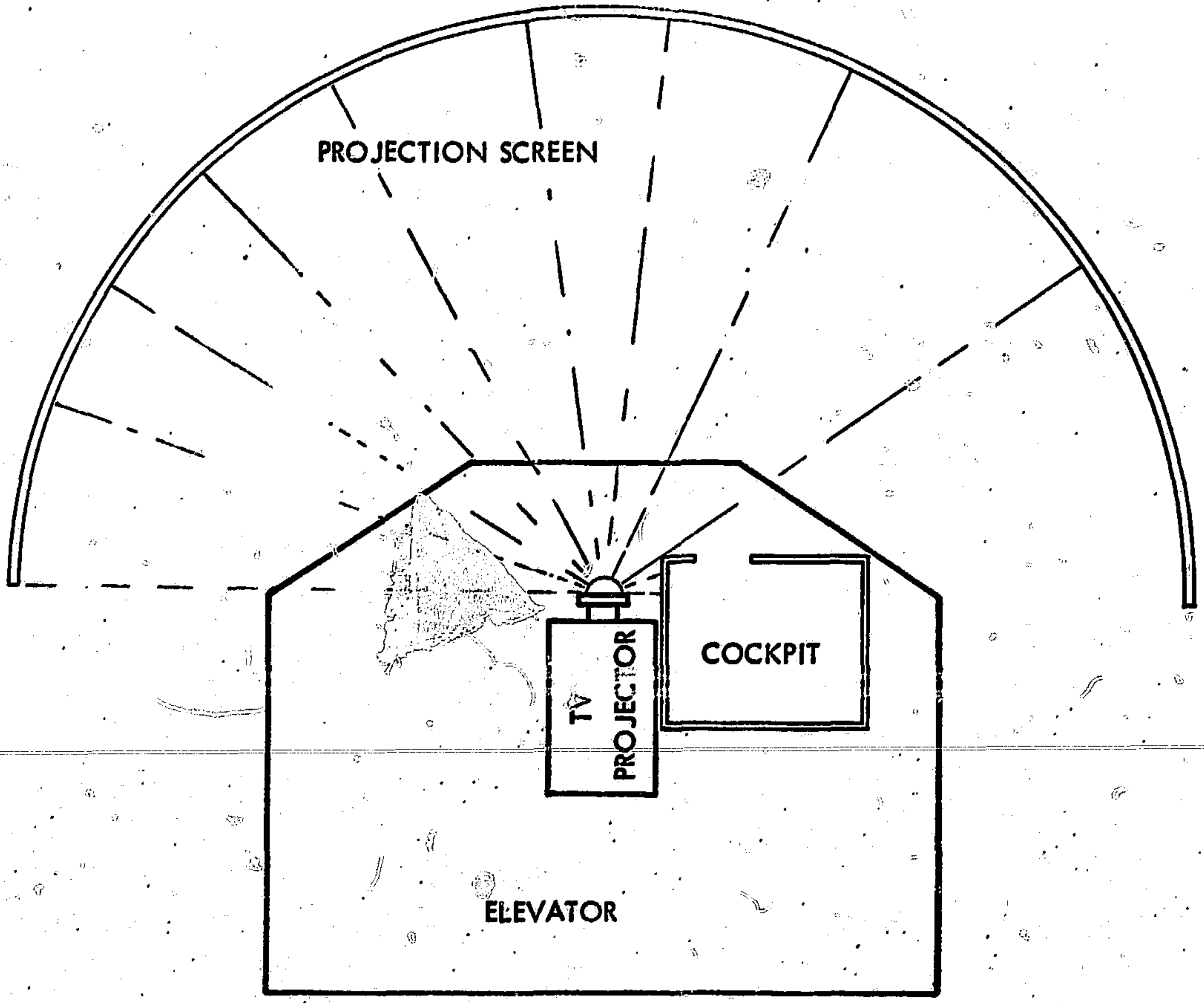

Figure III-1 PROJECTION ROOM LAYOUT

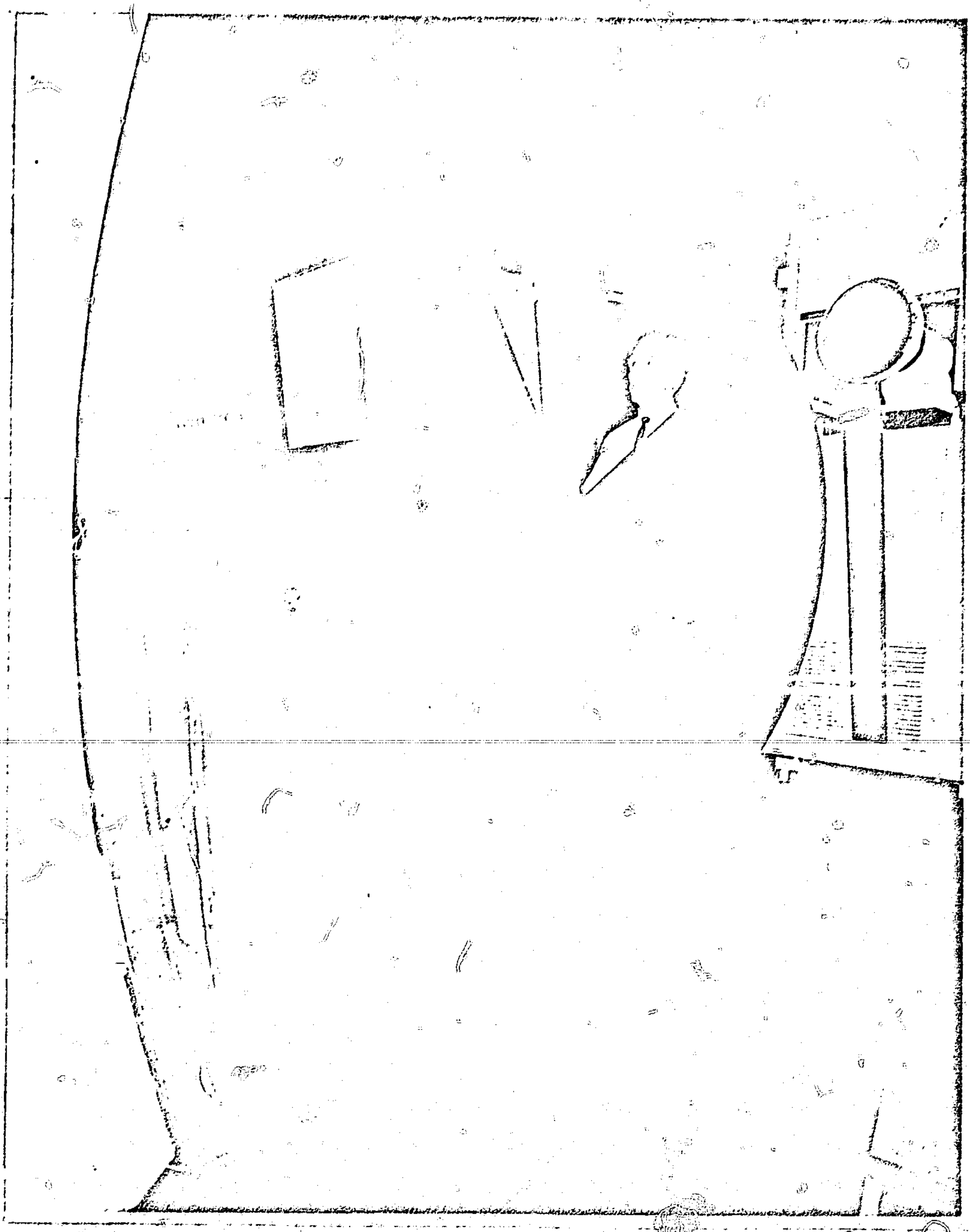

Figure III-2 L. M. COCKPIT MOCKUP

diagram is shown in Figure III-3.

The commander's window configuration and the landing point designator (LPD) are shown in Figure III-4. A double Plexiglas window with scribe lines was used to implement the landing point designator.

The flight instruments are located just to the right of the commander's window and can be viewed by both commander and observer. They include the following instruments which are numbered in Figure III-5.

1) Elapsed timer (digital readout in seconds)
2) Event timer or clock
3) Δ V indicator (digital readout in fps)
4) Flight attitude indicator (roll and pitch)
5) Yaw indicator (degrees right or left)
6) Pitch, roll and yaw rate indicators (degrees per sec)
7) Altitude and range indicators (ft)
8) Altitude rate and range rate indicators (ft. per sec.)
9) Landing point designator (on commander's window)

10, 11, 12) Instrument and cab light switches.

Additional instruments included to implement the simulation were an intercom outlet (item 13 in Figure III-5) and a portable magnetic tape voice recorder (not shown). A three-axis hand controller was mounted to the right of the commander just below the instrument panel. This controller provided up to of pitch, roll, and yaw rotational motion by the commander.

The TV projector provides a field of view of 120° in the horizontal plane and 90° in the vertical plane. Measured values of resolution, gray scale reproduction, screen brightness and brightness uniformity for the TV system from camera to pro-

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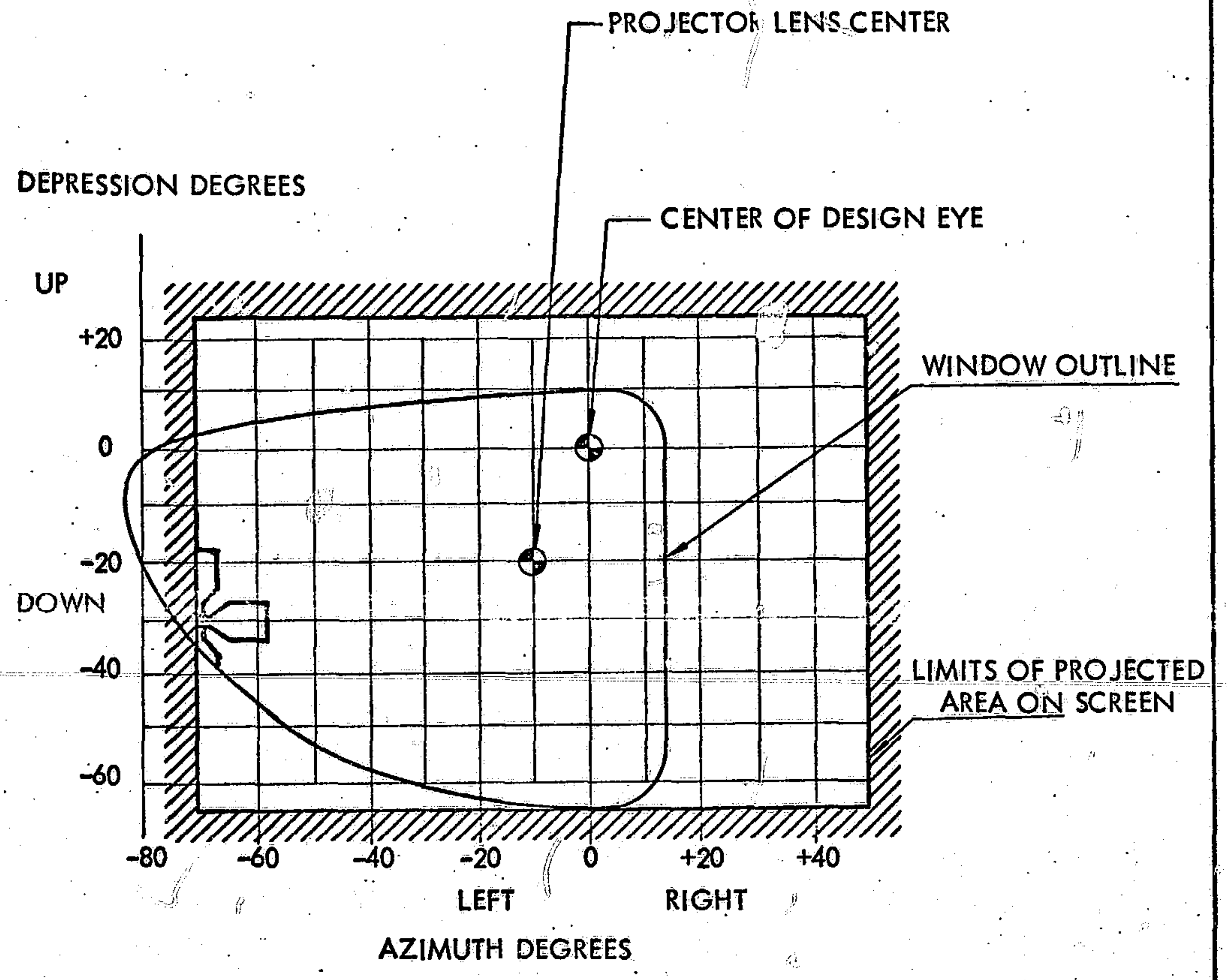

Figure III-3 VISIBILITY DIAGRAM FROM COMMANDER'S DESIGN EYE

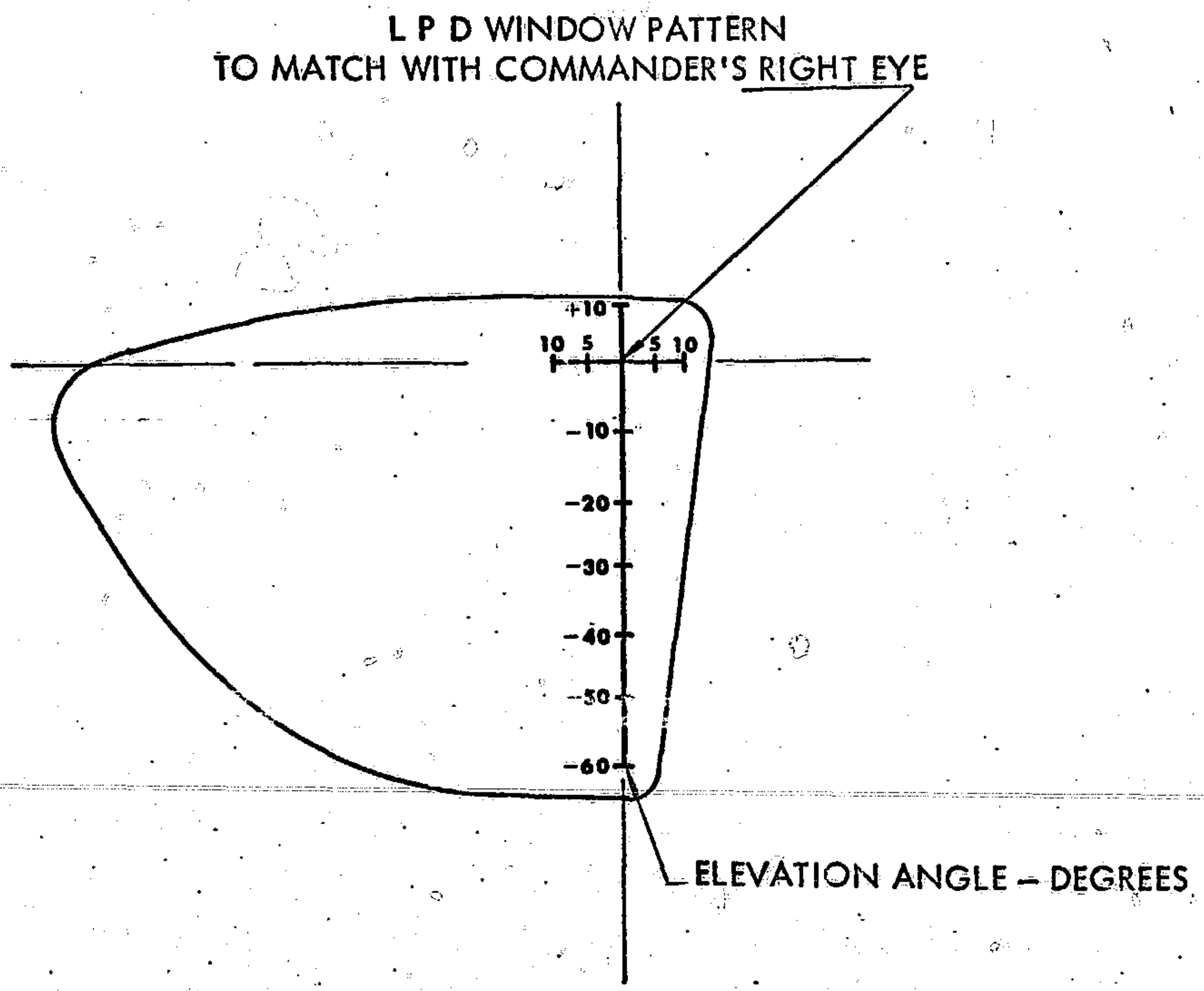

Figure III-4 COMMANDER'S WINDOW / VISIBILITY DIAGRAM & L P D

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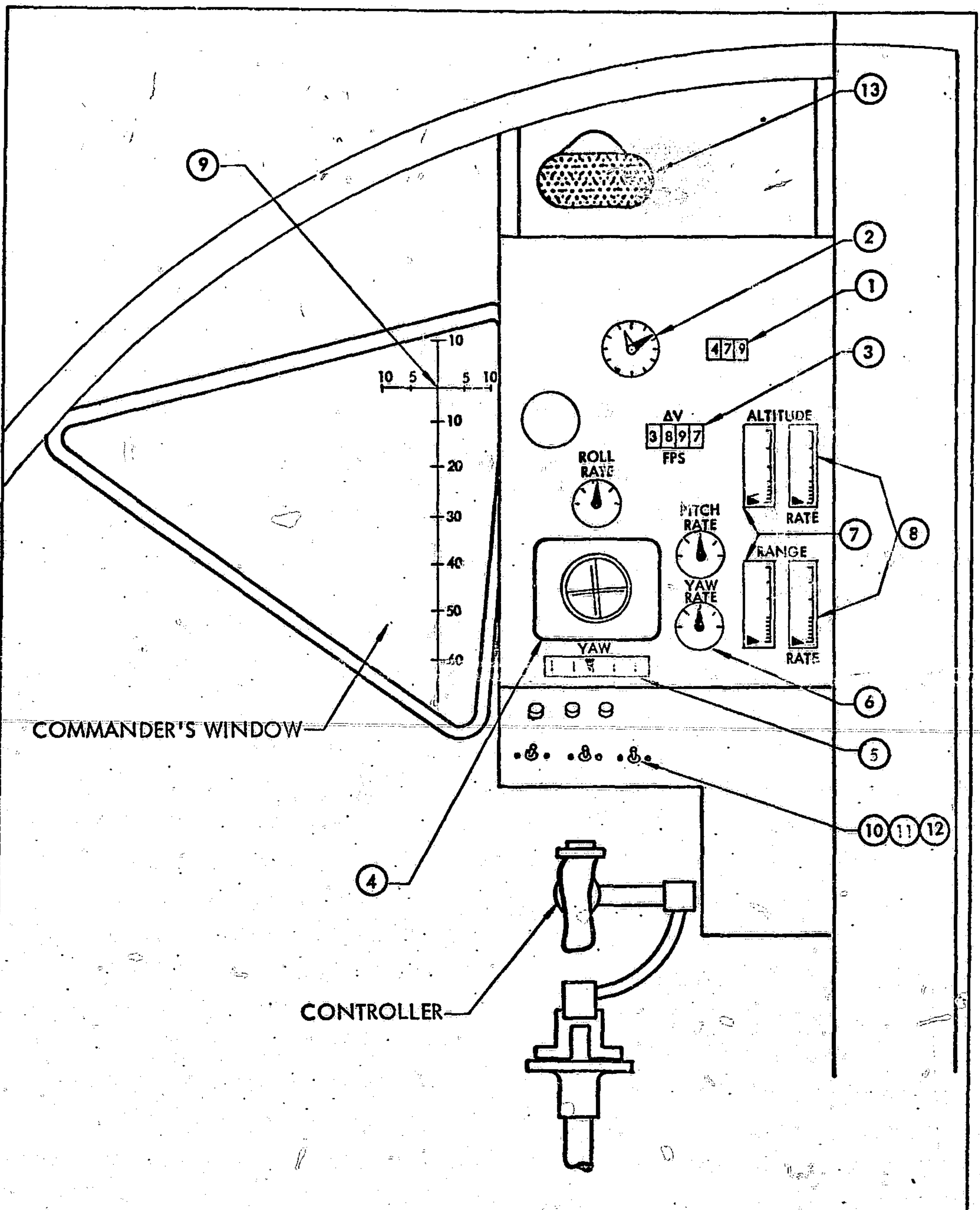

Figure III-5 COMMANDER'S INSTRUMENT PANEL (INSIDE VIEW) jector were reported in D2-114040-1, the Parametric Vision Study, Presimulation Report, and are repeated here, in Appendix IV.

3.0 MODEL ROOM

The model room contains the following components used for the Parametric Vision Simulation:

1) Model turret and six lunar models.
2) Back stop model and mounting.
3) Camera carriage and gimballed camera.
4) Half-silvered mirror and mirror mount.
5) High intensity collimated light source.
6) Honeycomb collimator.
7) Venetian blind collimator.

The following paragraphs describe in detail the major components.

Lunar Models were constructed by joining four 24" x 96" x 4" styrofoam boards together and then adding or removing material to create the various lunar features. Material is added either by gluing blocks of styrofoam to the surface or by applying a spackle/diatomite 50-50 mixture. Material is removed by rotary wire brushes and steel burs driven by small electric drill or air motors.

The number of craters per unit area as determined from Lunar Orbiter photographs were used to establish the crater distribution on the models. Location of the craters was established by a randomizing process. Two sets of three models were constructed, one set depicting a smooth mare area and the other a mountainous area adjacent to a somewhat smoother lava flow. Scales of the three models in a set are 588, 210, and 75 feet per inch. Models are designated according to their scale and their set; thus model 210S is the middle scale model of the smooth mare set while 75R is the largest scale model in the rough set. Rills, mounds and debris were added to look like typical rills, mounds and boulder strewn fields on the Lunar Orbiter photographs on which these features appeared. Exact scaling was used whenever possible, but some improvization was necessary. Lunar Orbiter photographs were used as a reference to ensure that the general appearance of the models conformed to "typical" lunar landscape and that physical reality never gave way to artistic license.

After the lunar topographic features on a given model were completed, a slurry of portland cement was brushed onto the surface. While the surface was still moist, the model was dusted with a layer of dry portland cement to provide a rough microstructure. This combination formed the base coat for the final dusting.

After the base coat was dried, it was dusted with a 5 to 1 mixture of portland cement to red portland cement coloring (iron oxide). This mixing ratio duplicates quite closely the Hapke lunar photometric function.

In order to preserve the "fairy-castle" structure of the dusted surface (and with it the photometric function), but at the same time cause the individual particles to adhere to each other so that the model could be turned on edge, the dusted models were placed in a humidity chamber, where the humidity was held at 100%, for several hours. Due to the hygroscopic nature of portland cement, each of the individual particles picked up enough water to bond it to other cement particles, thus preserving the structure.

Figures III-6 through III-11 show photographs of the six models with five features marked on each model. Photos were taken of each model from a point along the

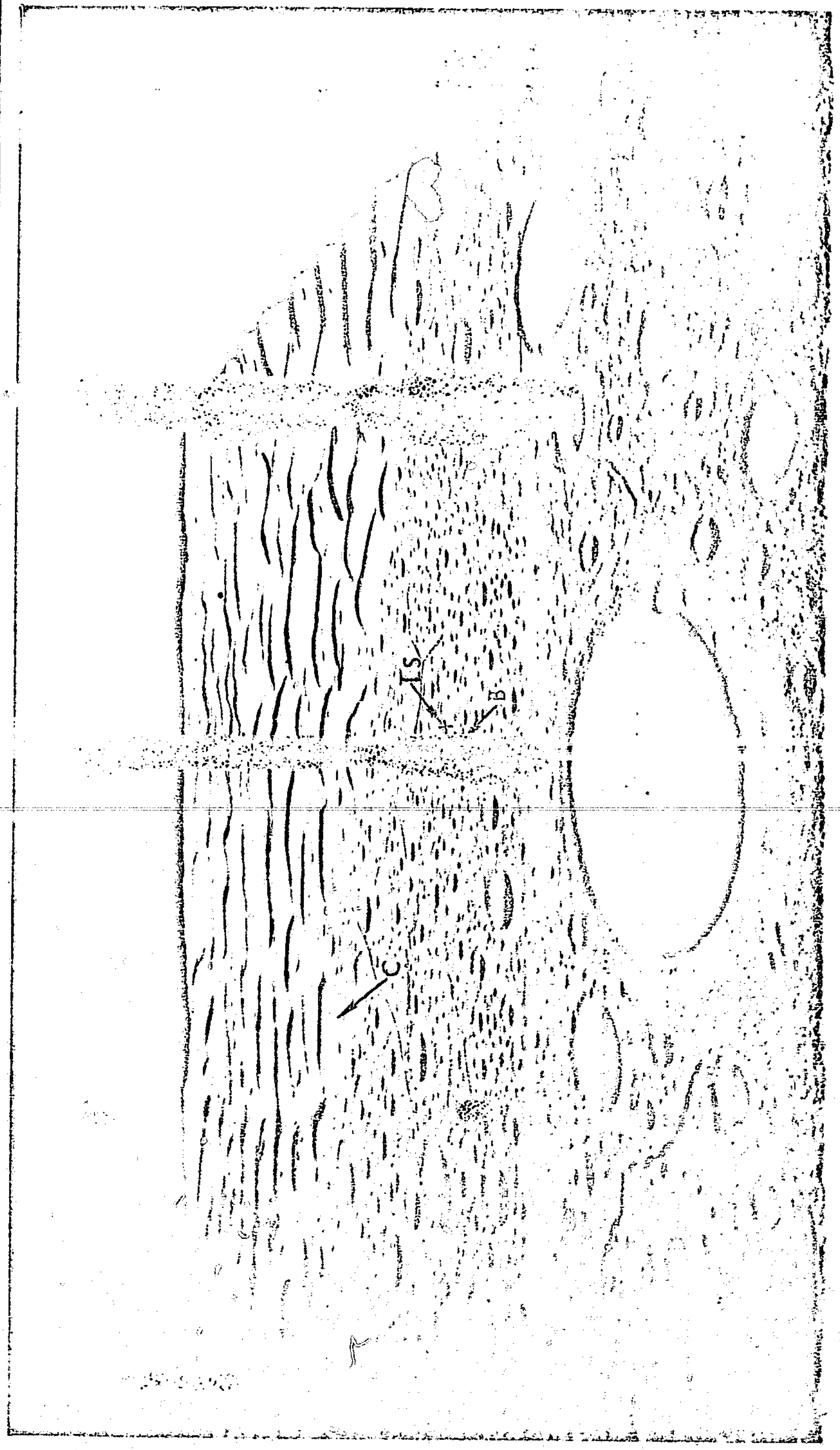

Figure III-6 MODEL 588R

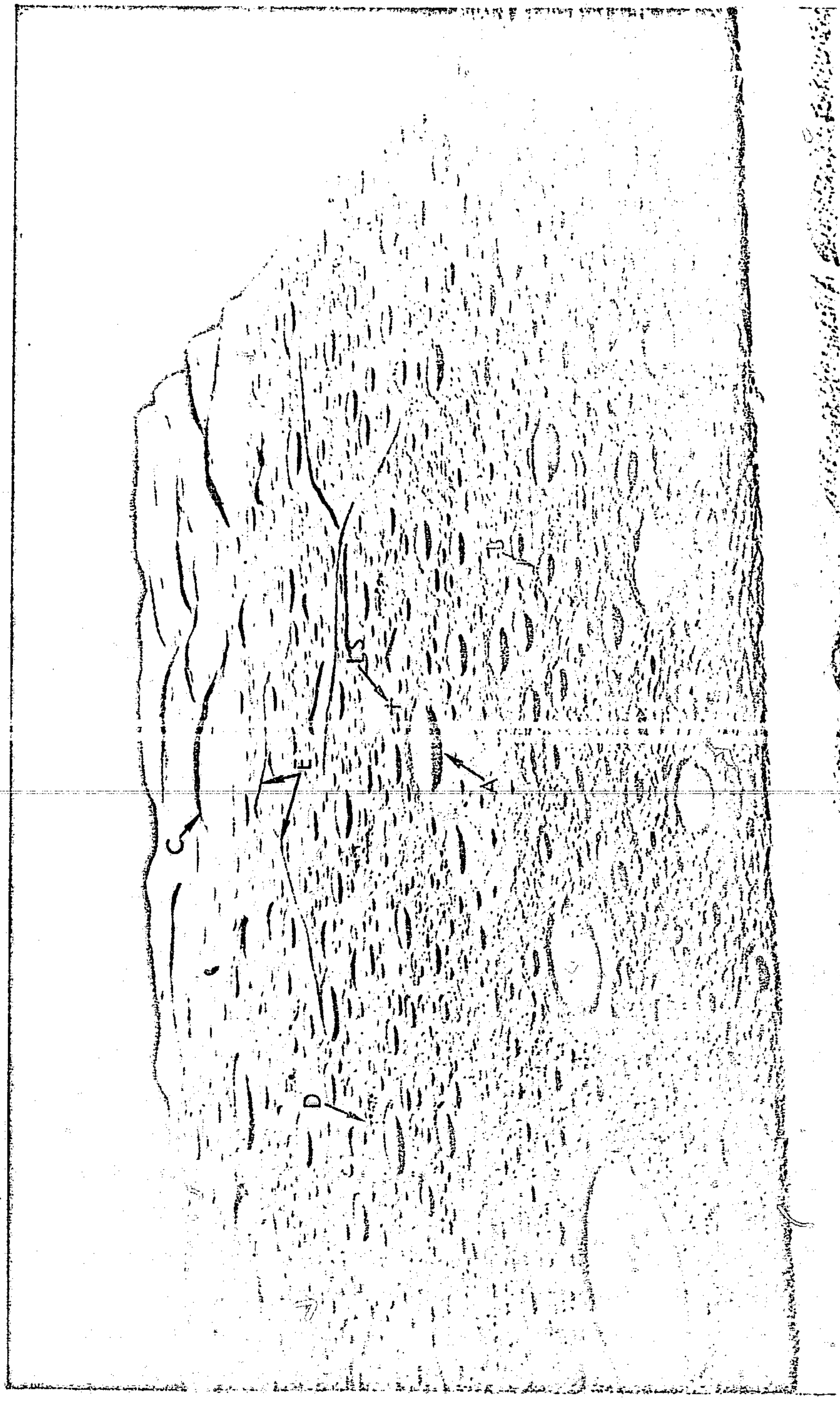

Figure III-7 MODEL 210R

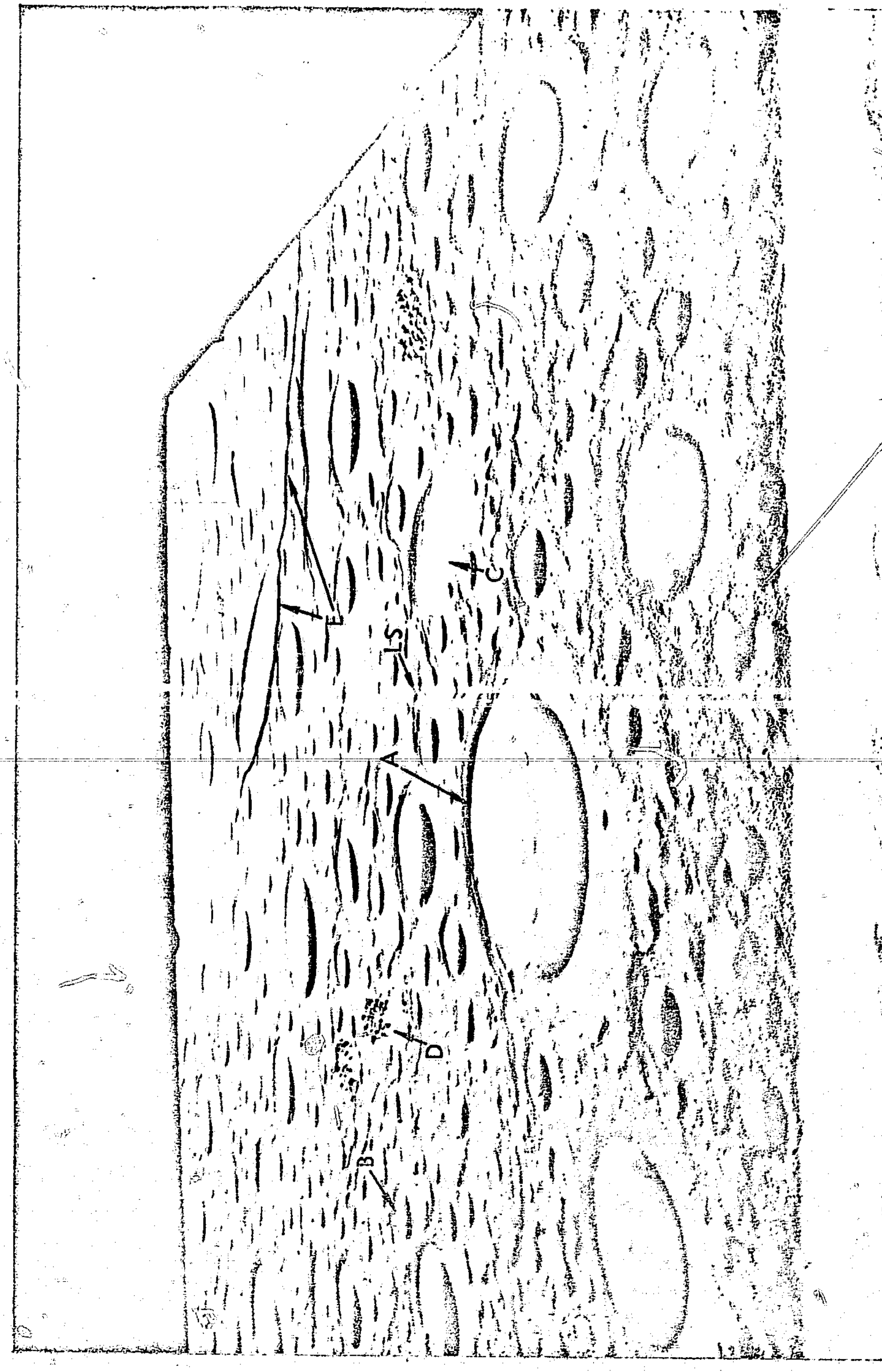

Figure III-8 MODEL 75R

Figure III-9 MODEL 588S

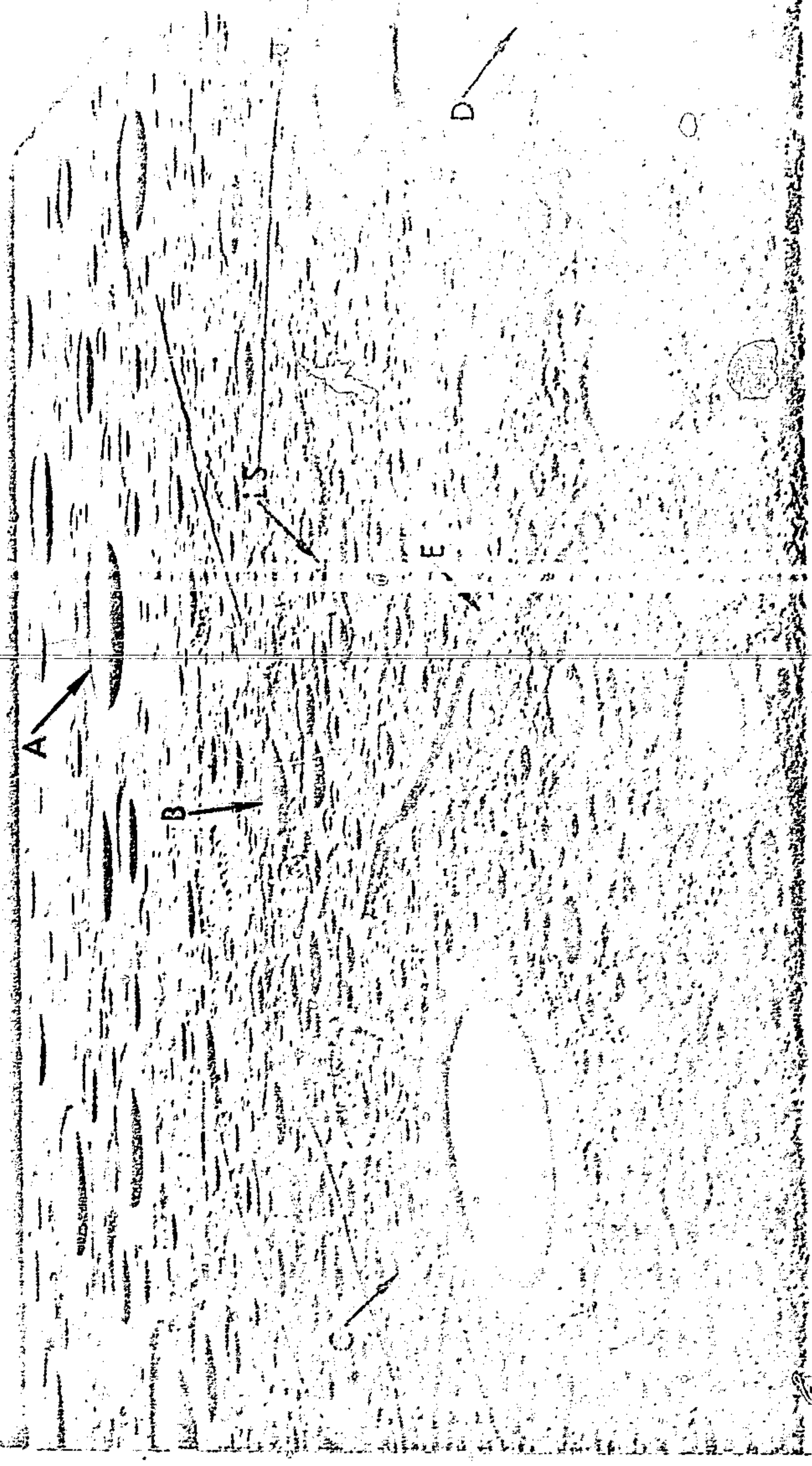

Figure III-10 MODEL 210S

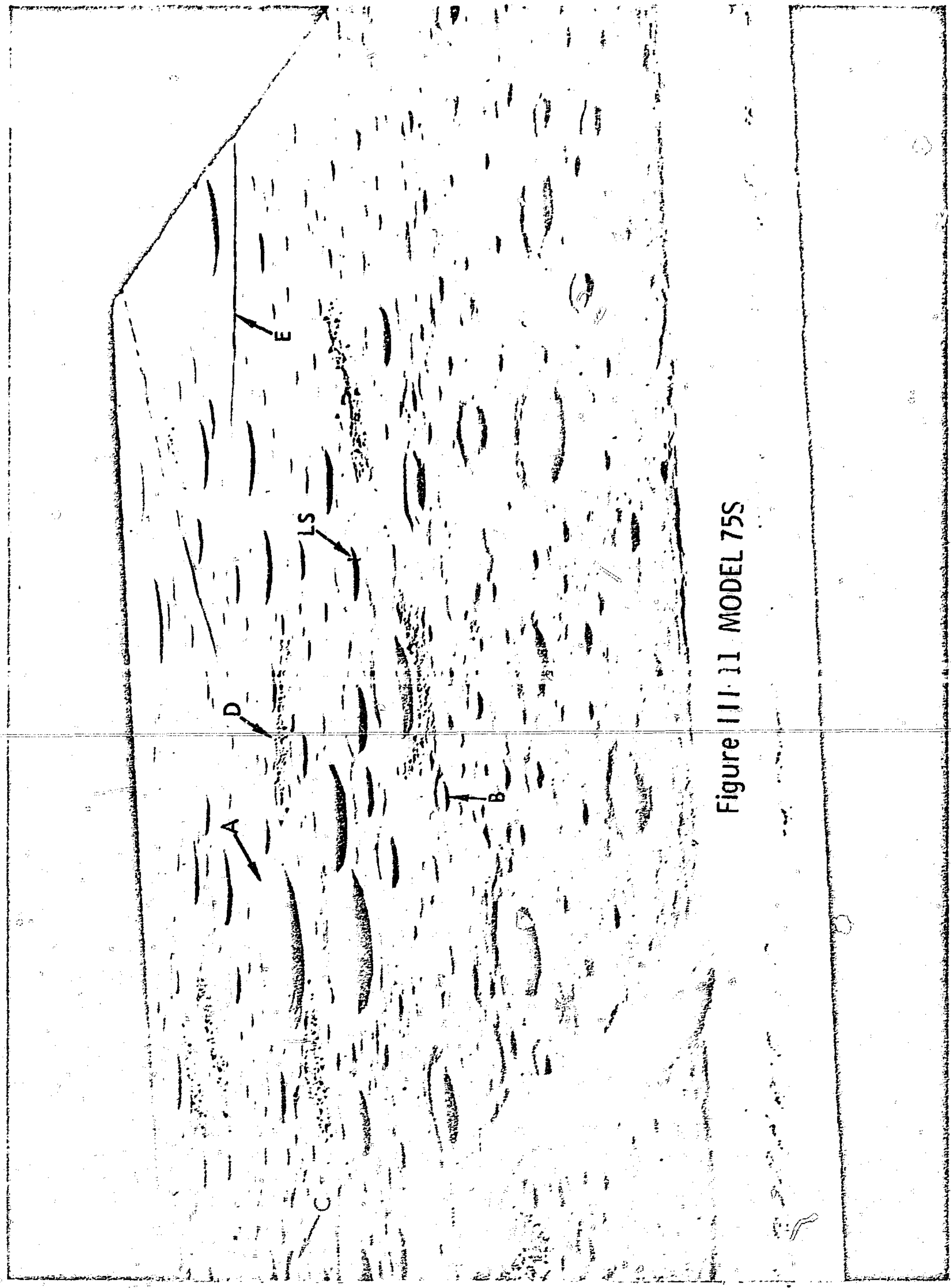

Figure III-11 MODEL 755

simulated trajectory 64 inches from the landing site for a trajectory angle of 19° and a sun angle of 7°. This point lies at approximately the start of the trajectory for each model and was selected in order to avoid shadows from the camera. Photography with illumination by the half-silvered mirror was not used at the time these photographs were taken due to incomplete fabrication of the mirror mounts. Features marked are typical, and are dimensioned in Table III-1.

The relative arrangement of the equipment is shown in Figure III-12. The model turret supports the six lunar models vertically and in a fashion such that by rotating the turret, any one of the six models can be positioned before the camera. Position of the turret is controlled by computer and rotation is motor-driven making the system completely automatic. Positional accuracy for each model is ± 3 minutes of arc.

The back stop model, prepared like the others, but without distinguishable terrain features, fills in the space between the back edge of each of the six models and the average lunar horizon. It must be hinged out of position each time that the turret is rotated to change models.

The camera carriage provides six degrees of motion freedom to the TV camera, each degree of freedom being servo driven and controlled from the computer. Carriage servo system characteristics are given in Figure III-13.

The half-silvered mirror is 8 feet high and 9 feet across and consists of four mirrors each 4 feet x 4-1/2 feet. It is used to reflect light rays from the light source on to the surface of the model. Since it is mounted in front of the TV camera, the camera must look through the mirror, thus the requirement that the mirror be of the beam splitter type. The mirror assembly is mounted

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Table III-1.

DIMENSIONING OF LUNAR FEATURES

MODEL	FEATURE	TYPE	MODEL DIMENSION	SCALE DIMENSION
75R	A*	LARGE CRATER	9.75" DIA	731' DIA
	B	SMALL CRATER	2.0" DIA	150' DIA
	C	HILL	7" x 4" x .5"HIGH	525' x 300' x 37'HIGH
	D	DEBRIS PILE	4.5" x 2"	337' x 150'
	E	RILL	38"L x 2.35"W x .5" DEEP	2850'L x 176'W x 37' DEEP
210R	A*	LARGE CRATER	3.48" DIA	731' DIA
	B	SMALL CRATER	.88" DIA	185' DIA
	C	HILL	14" x 8" x 1" HIGH	2940' x 1680' x 210' HIGH
	D	DEBRIS PILE	1.5" x 1.36"	315' x 286'
	E	RILL	33"L x .88"W x .25"DEEP	6930'L x 185'W x 53' DEEP
588R	A*	LARGE CRATER	5.0" DIA	2940' DIA
	B	SMALL CRATER	1.24" DIA	731' DIA
	C	HILL	5.5" x 3.25" x .37" HIGH	3234' x 1911' x 218' HIGH
	D	DEBRIS PILE	1.0" x 1.0"	588' x 588'
	E	RILL	12.5" L x .31" W x .12" D	7350' L x 182' W x 71' DEEP

*THIS IS THE SAME CRATER SHOWN ON ALL THREE MODELS.

Table III-1 (cont.)

DIMENSIONING OF LUNAR FEATURES

MODEL	FEATURE	TYPE	MODEL DIMENSION	SCALE DIMENSION
75S	A*	LARGE CRATER	8.75" DIA	656' DIA
	B	SMALL CRATER	1.0" DIA	75' DIA
	C	HILL	2.5" x 1.0" x .25" HIGH	188' x 75' x 19' HIGH
	D	DEBRIS PILE	9" x 3"	675' x 225'
	E	RILL	17" LONG x .75"W x .32"D	1275'L x 56' W x 24' DEEP
210S	A*	LARGE CRATER	8.5" DIA	1785' DIA
	B	SMALL CRATER	3.125" DIA	656' DIA
	C	HILL	.8" x .17" HIGH	168' x 36' HIGH
	D	DEBRIS PILE	3.12" x 1.5"	655' x 316'
	E	RILL	19.5" L x .75" W x .19" D	4095'L x 158' W x 40' DEEP
588S	A*	LARGE CRATER	7.75" DIA	4557' DIA
	B	SMALL CRATER	1.12" DIA	656' DIA
	C	HILL	.6" x .25" x .07" HIGH	353' x 147' x 41' HIGH
	D	DEBRIS PILE	.55" x .30"	323' x 176'
	E	RILL	6.2" L x .38" W x .09" D	3646' L x 223' W x 53' DEEP

*THIS IS THE SAME CRATER SHOWN ON ALL THREE MODELS.

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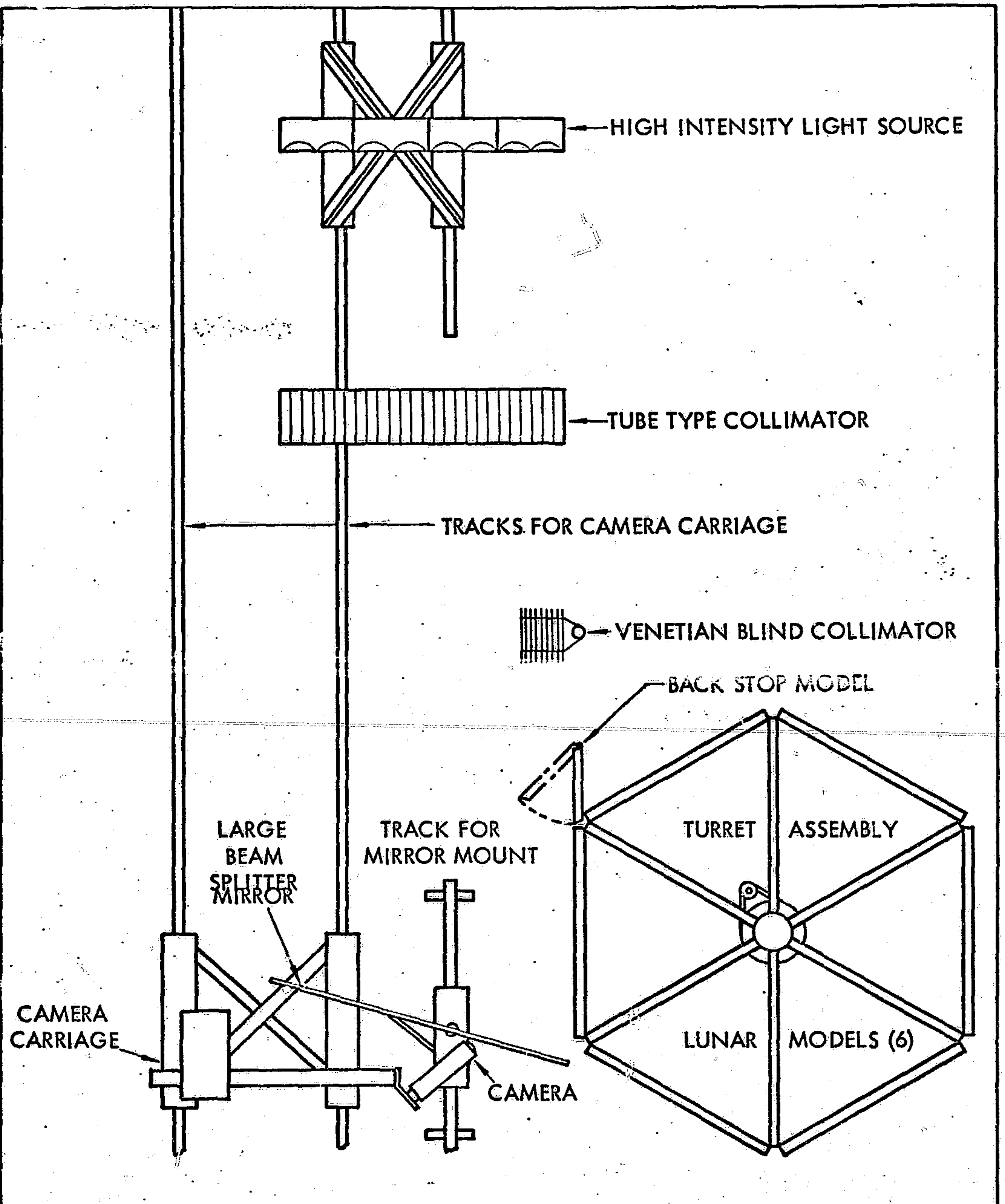

Figure III-12 MODEL ROOM LAYOUT

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CAMERA SERVO SYSTEM CHARACTERISTICS

ANGULAR SYSTEMS	ROLL	PITCH	YAW
Acceleration	Up to $60°/sec^2$	Up to $60°/sec^2$	Up to $60°/sec^2$
Rate	Up to 120°/sec	Up to 60°/sec	Up to 60°/sec
Position Accuracy	To ±4 min	To ±4 min	To ±4 min
Position Resolution	±1.3 min	±1.3 min	±1.3 min
Maximum Travel	No limit	No limit	No limit

LINEAR SYSTEMS	DOWNRANGE AXIS	CROSSRANGE AXIS	VERTICAL AXIS
Acceleration	Up to $4\ in/sec^2$	Up to $4\ in/sec^2$	Up to $4\ in/sec^2$
Rate	Up to 10 in/sec	Up to 4 in/sec	Up to 4 in/sec
Position Accuracy	To ±0.004 in	To ±0.004 in	To ±0.004 in
Position Resolution	±0.001 in	±0.001 in	±0.001 in
Maximum Travel	88 ft	34 in	63 in

Figure III-13

partly on the TV camera carriage and partly on its own track and wheels. It moves downrange with the carriage, but is independent of camera movement except in the downrange direction.

The half-silvered mirror was purchased from Liberty Mirror Division, Libbey-Owens-Ford Glass Company. The Hi-efficiency Coating No. 401 was chosen from the several coatings available because it gave the best integrated vidicon response for quartz-iodine lamps and the red lunar model dust. The transmission and reflection are given in Figure III-14. To adjust the lighting angles, as required, the mirror is tilted about a vertical axis, this axis located approximately 6 inches off the surface of the model. For a 7 degree sun angle the mirror is tilted forward 3-1/2 degrees. This procedure is followed for all the sun angles through 30°.

The high intensity collimated light source consists of 780 separate lamps and reflectors so arranged in an array to cover an area 8 x 8 ft. with collimated light. The entire array can be moved up or down, rolled along the floor, tilted and rotated in azimuth to obtain the proper pointing angle. The lamps are Sylvania quartz-iodine, tungsten filament, each rated at 75 watts, with a color temperature of 3000° K and 1600 lumens. Each lamp was focused for maximum intensity. Figure III-15 is a photograph of the 8' x 8' light source.

In order to reduce stray light and improve the collimation of the light source, the light was filtered through a black honeycomb "collimator."

The venetian blind collimator was mounted near the surface of the lunar model and used to improve collimation in the plane parallel to the model surface at the expense of collimation in the vertical plane. It was required to minimize

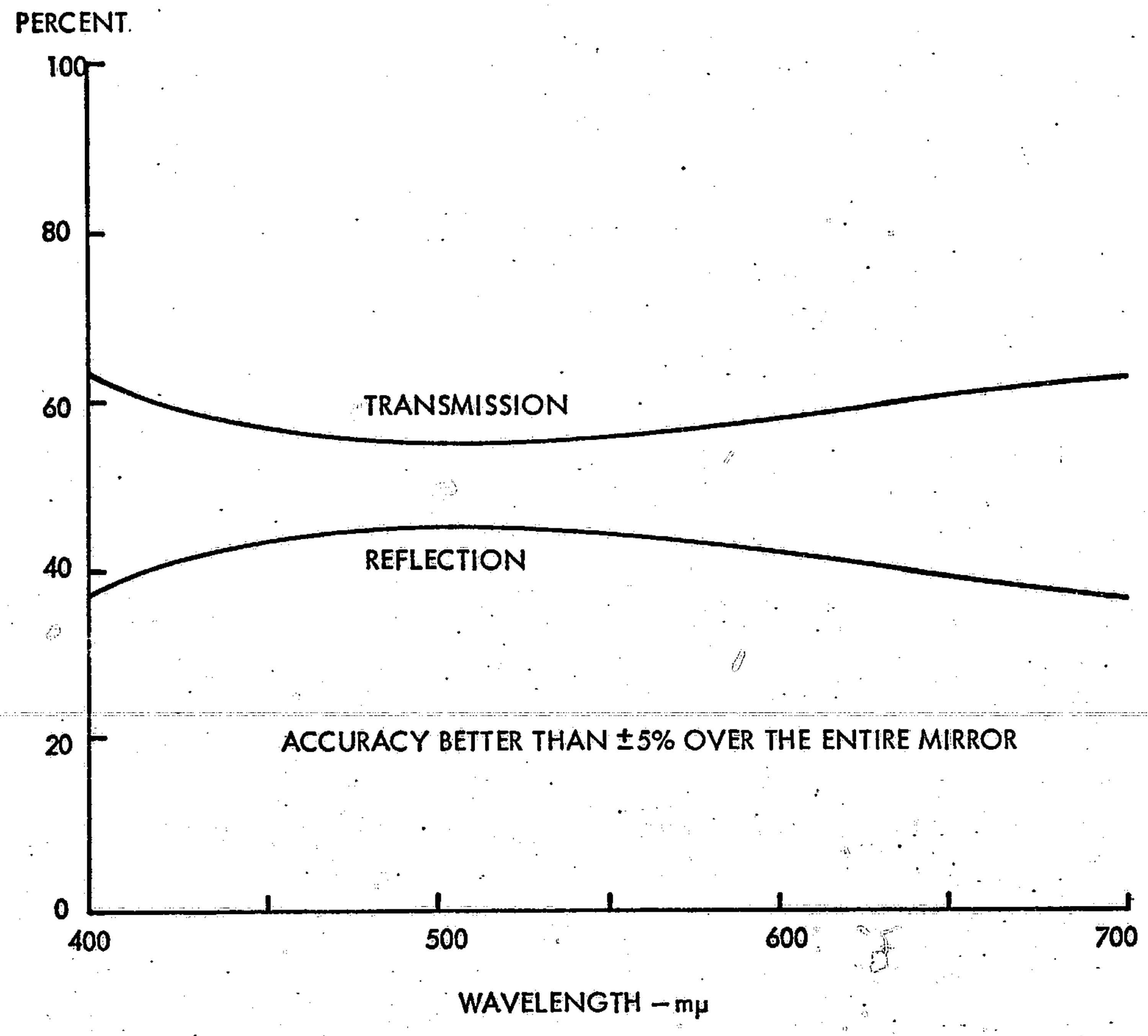

Figure III-14 SPECTRAL RESPONSE OF HI - EFFICIENCY COATING No. 401

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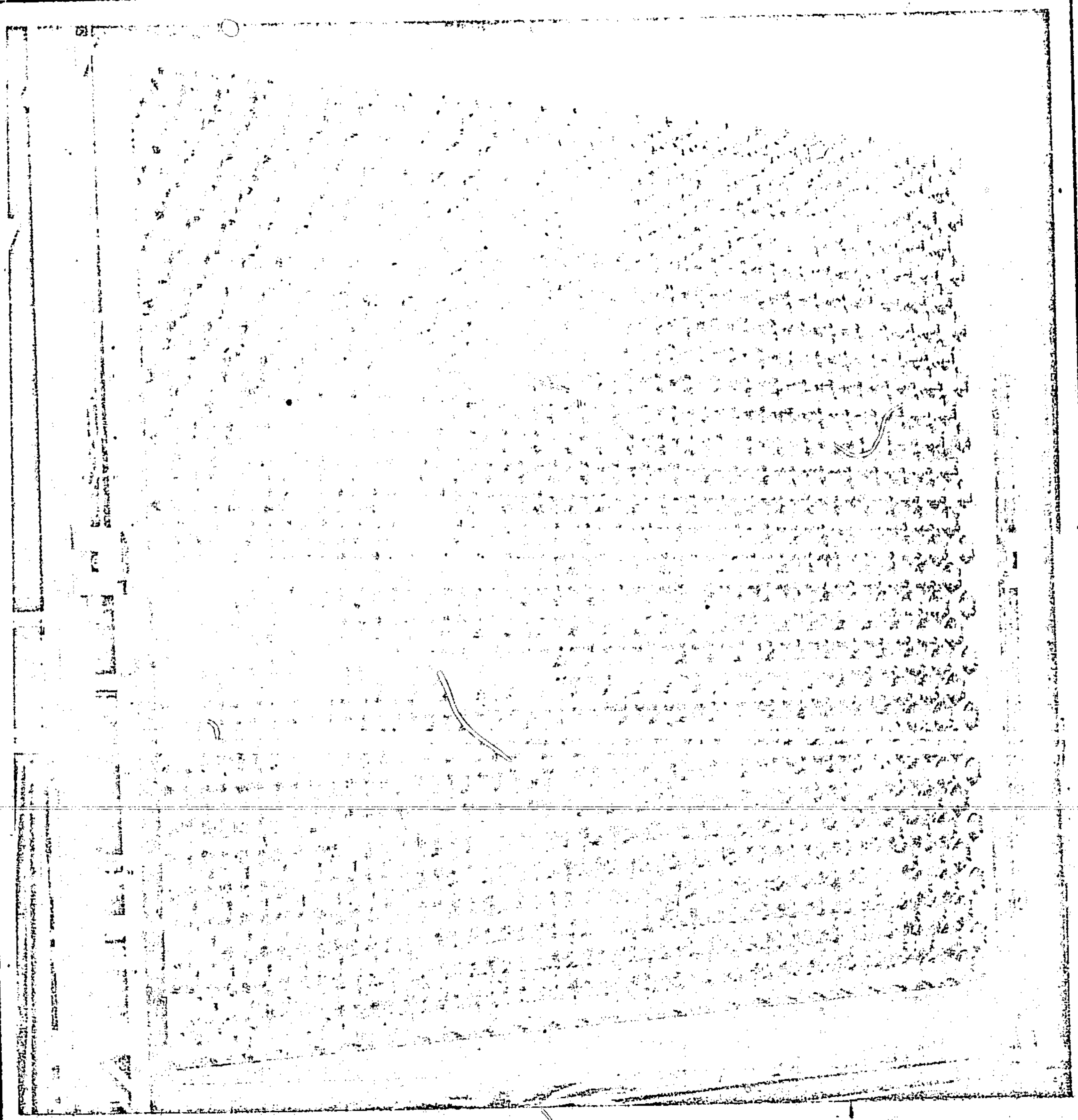

Figure III-15 SUN SOURCE

unwanted front lighting of high points on the models.

Figure III-16 shows the 75S model illuminated by the high intensity light source at a 10° sun angle. Figure III-17 shows this same model in the down-sun position. Note that all the terrain features are washed out.

4.0 COMPUTER ROOM

The computer room contains the SDS 930 digital computer with peripheral equipment, the TV control console and a magnetic tape voice recorder. Figure III-18 is a block diagram of the computer system and Figure III-19 is a block diagram of the TV system. Figure III-20 shows the sequence of events for a typical simulation run over the three models of a set (rough or smooth) and the initial and final conditions. The computer analysis for the Parametric Vision Simulation analysis was based on the graphical trajectory data provided by NASA, and shown in Figures III-21 through 26. Three models were used in flying each trajectory. Thus, a given trajectory was flown in three segments, each segment corresponding to one model. A continuous flight would have been possible by constructing a 45 foot long single model. The increased cost of such a model, plus the associated lighting problems, did not warrant this approach. The six trajectory parameters, slant range, altitude, pitch (θ), look angle, flight path angle and velocity, were split into segments corresponding to the model and time of flight. Curve fitting polynomials, as functions of time, were then generated using the method of least squares. A total of forty-eight functions were determined, varying in degree from second to fifth.

All parameters are functions of time only; however, the three axis controller inputs were used to modify the appropriate angles. This modification in no way affected the flight path. Response to controller inputs was dictated by simulation hardware constraints.

The program was written to evaluate the six polynomials. Different trajectories were obtained by altering the coefficients of the polynomials, reading the data into the computer from cards by means of the standard Space Flight Simulator card reader program.

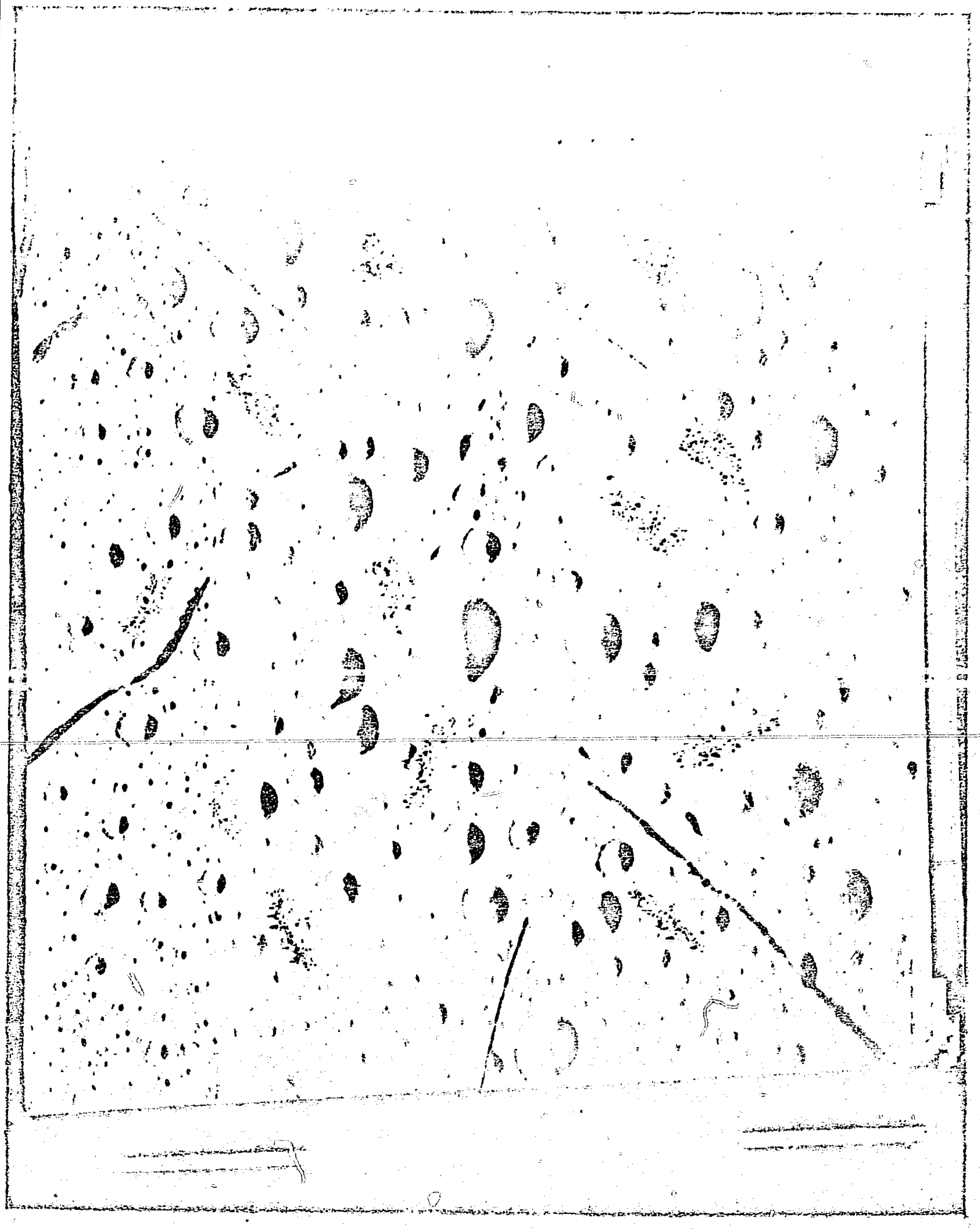

Figure III-16 10^0 SUN ANGLE, 90^0 LOOK ANGLE PHOTO OF MOON MODEL 75S

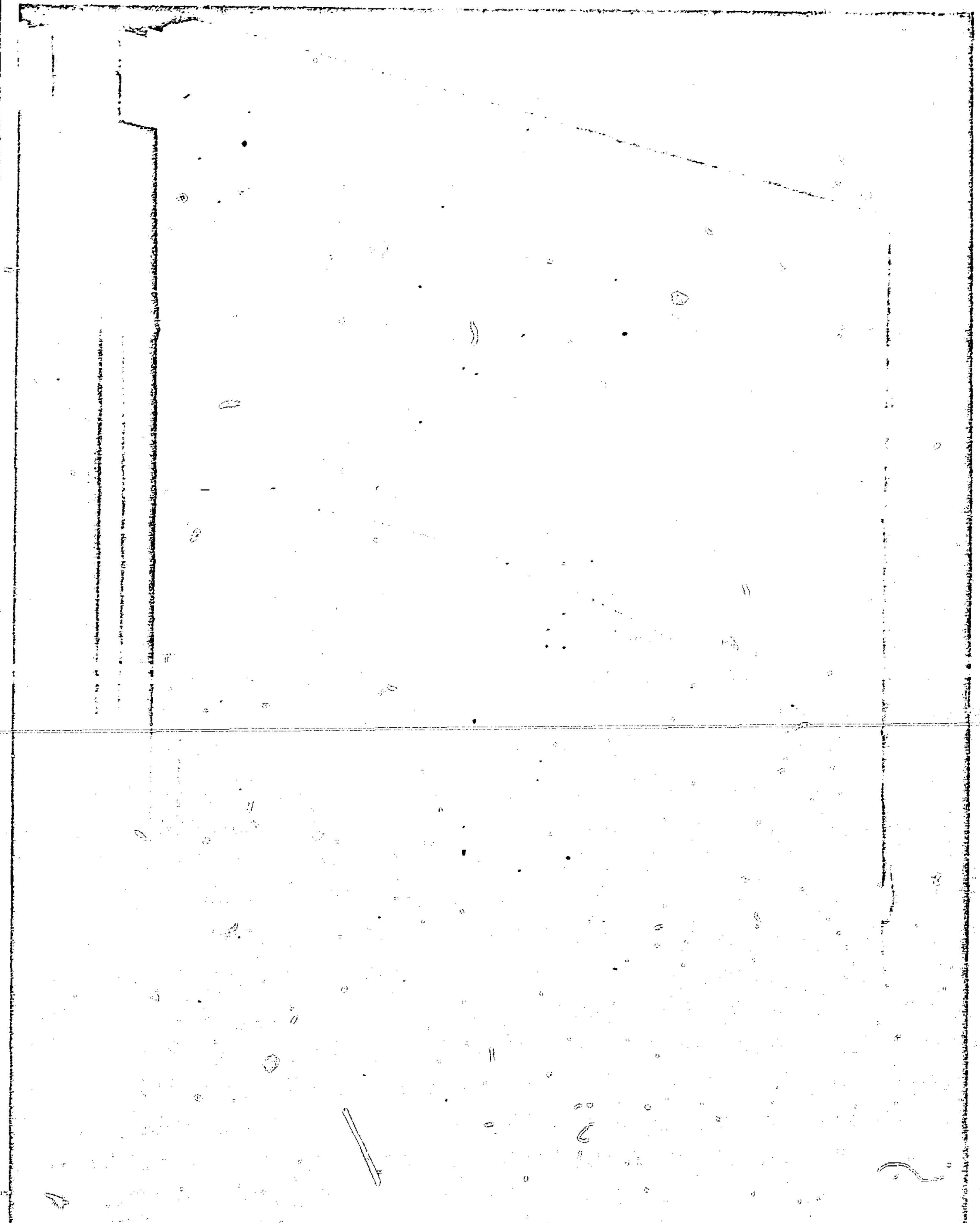

Figure III-17 DOWN-SUN PHOTO OF MOON MODEL 75S

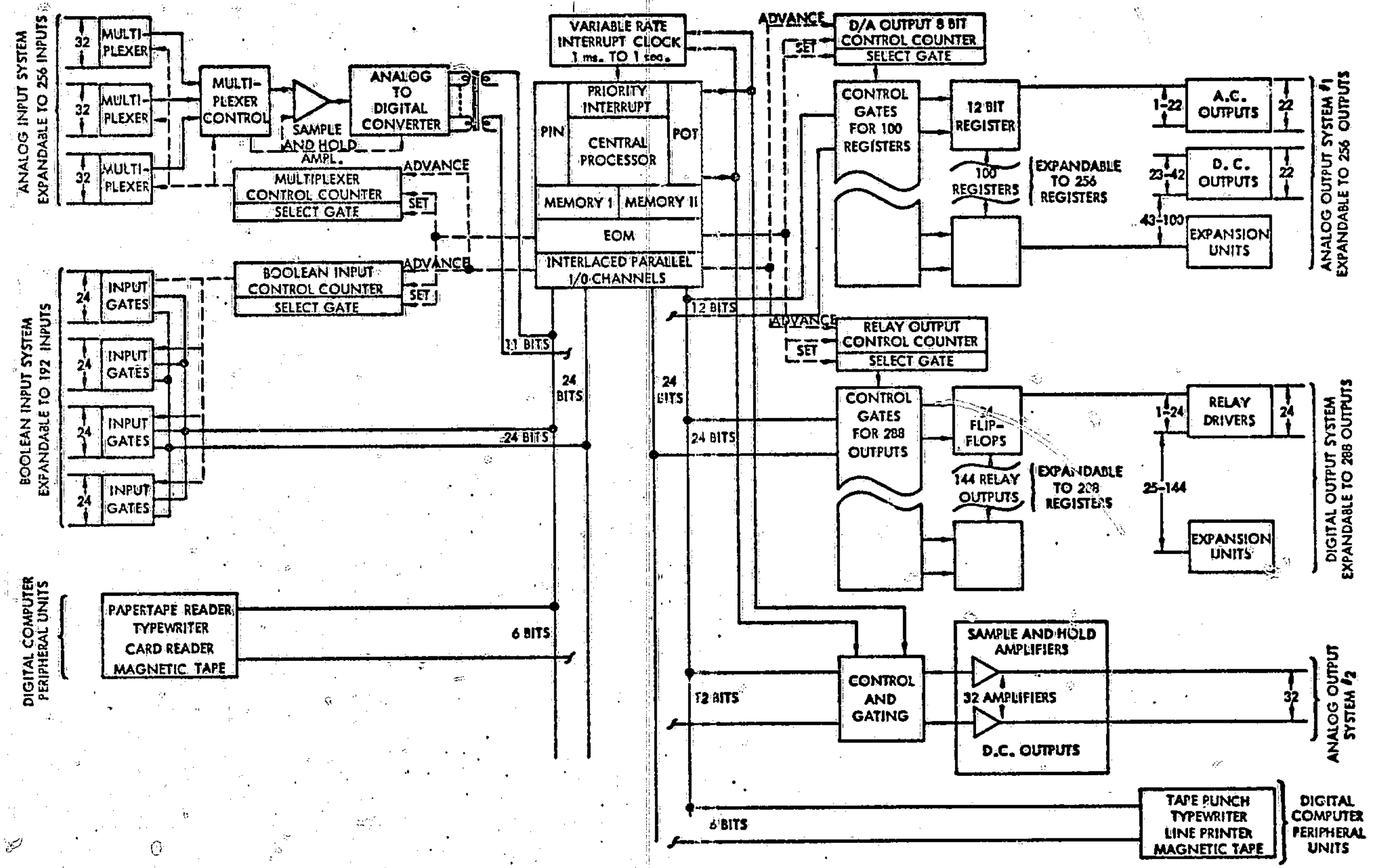

Figure III-18 SPACE FLIGHT SIMULATOR DIGITAL COMPUTOR SYSTEM

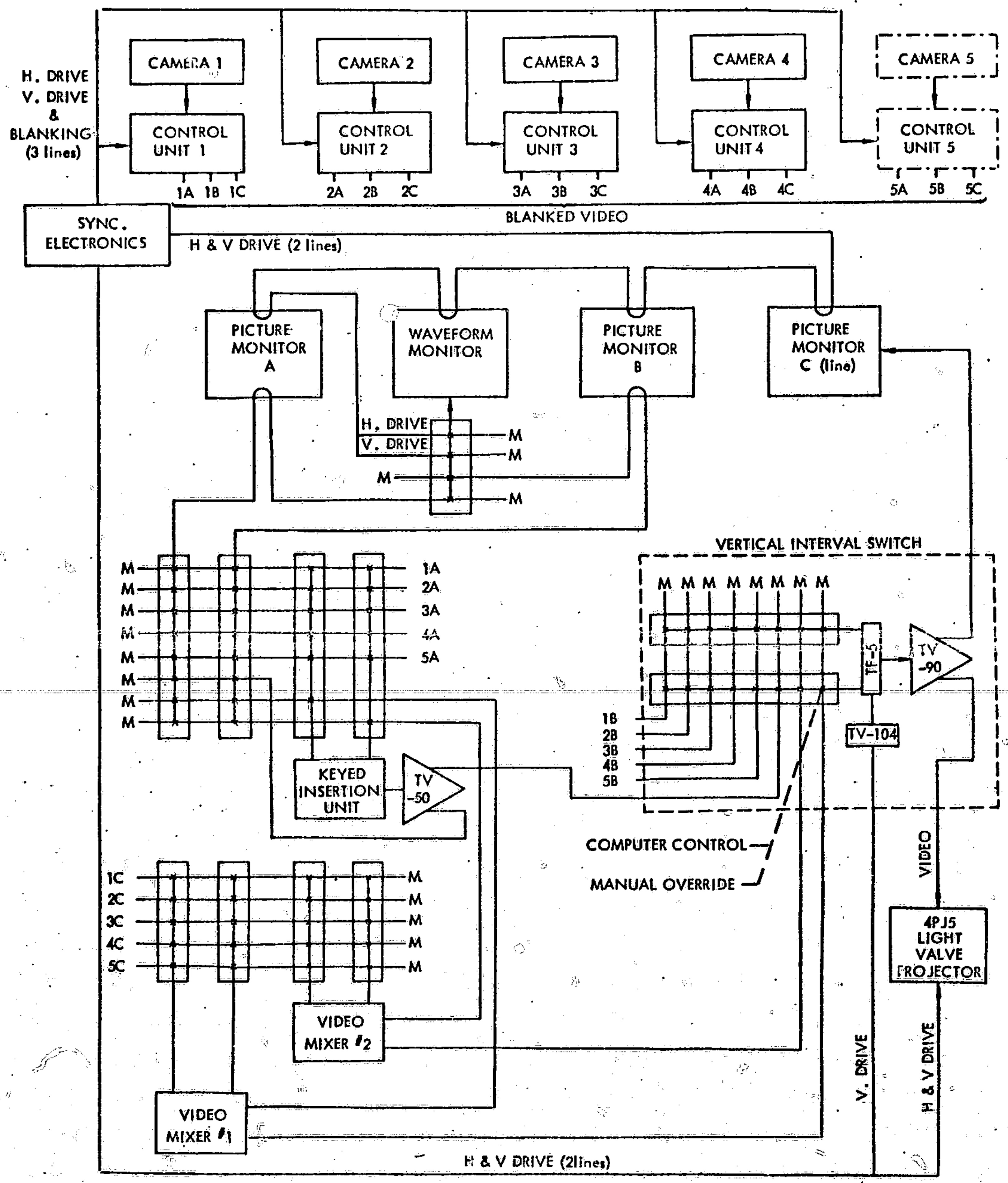

Figure III-19 SPACE FLIGHT SIMULATOR TELEVISION SYSTEM

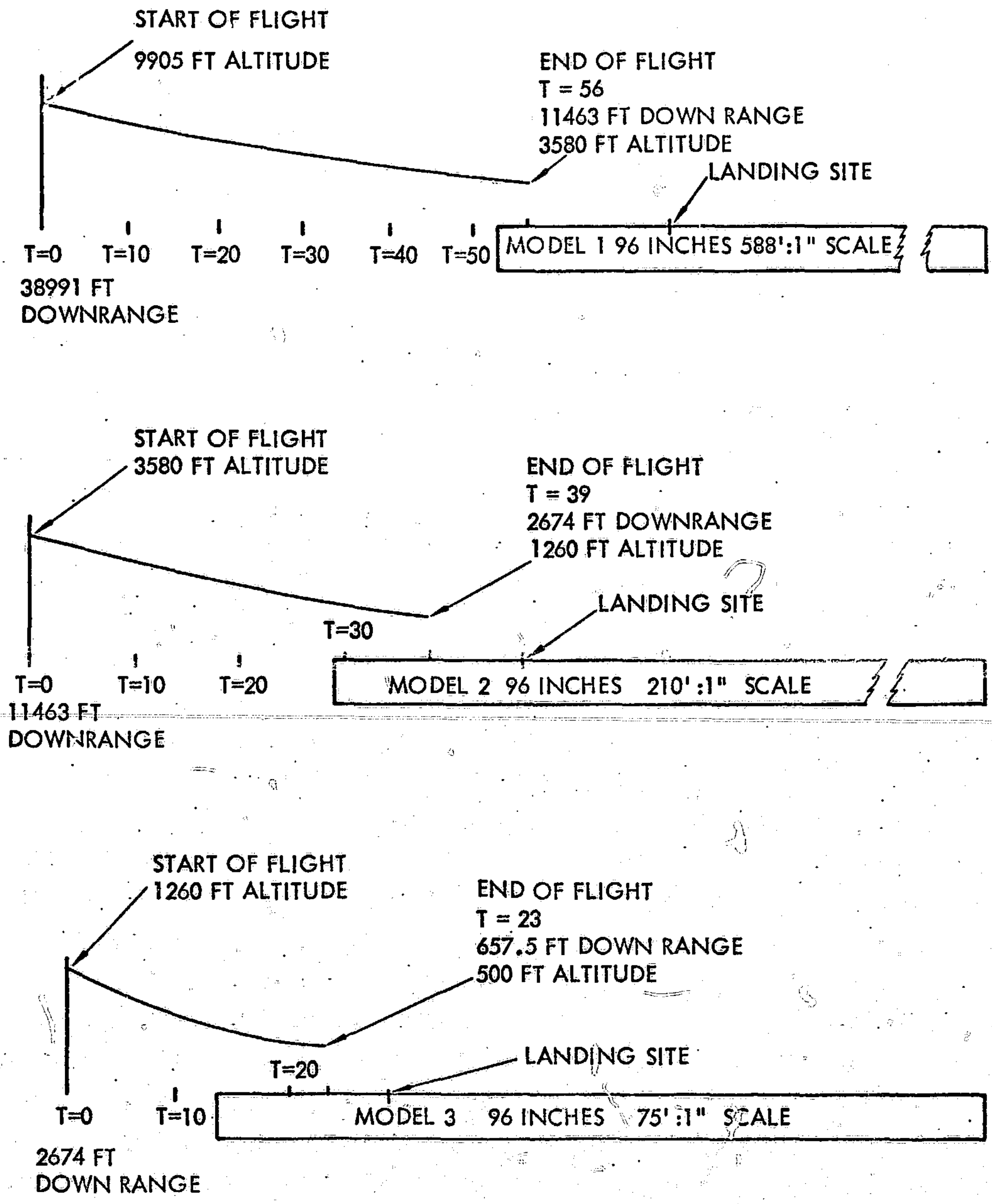

Figure III-20 SEQUENCE OF EVENTS FOR TYPICAL SIMULATION RUN

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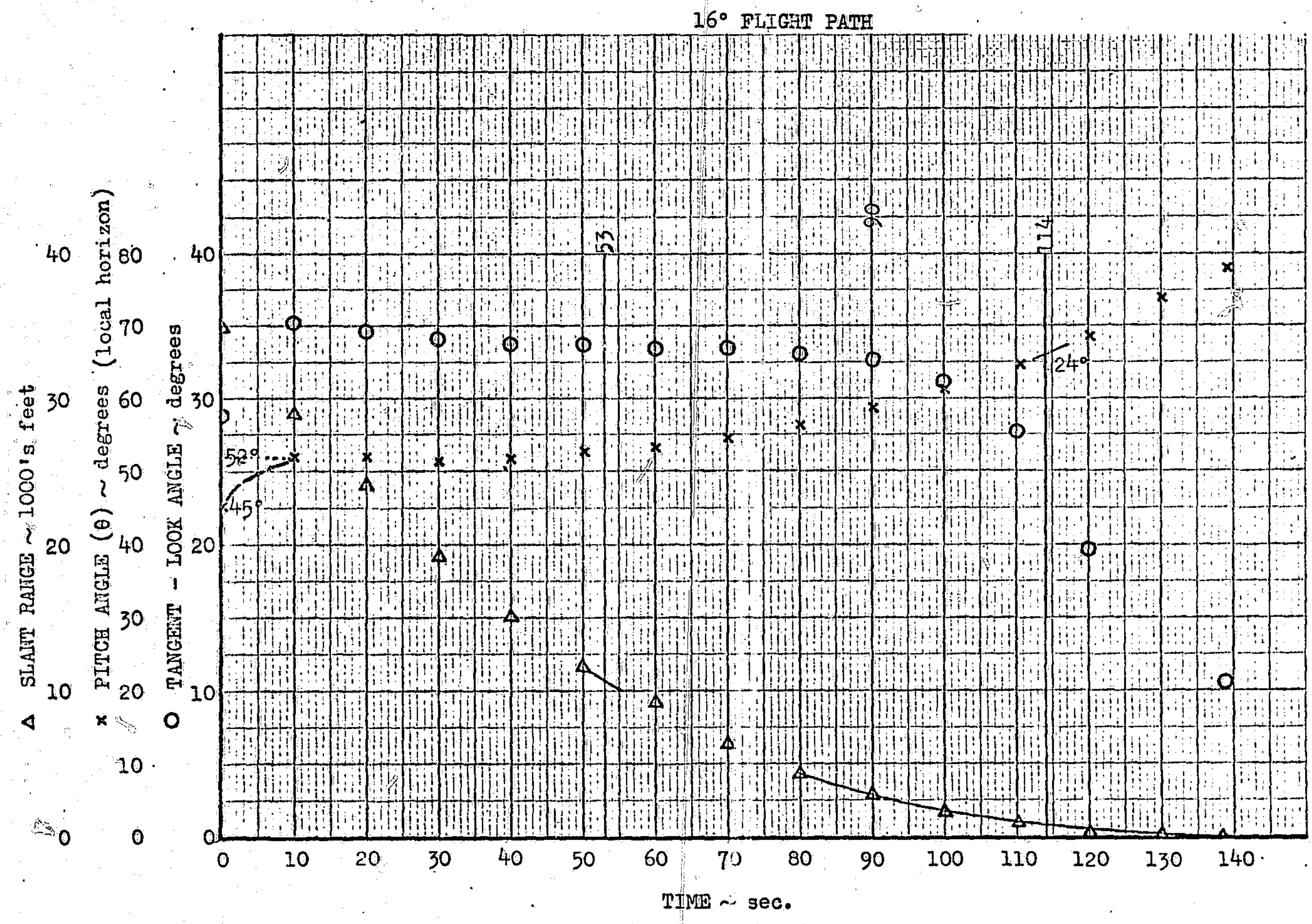

Figure III-21 TRAJECTORY DATA

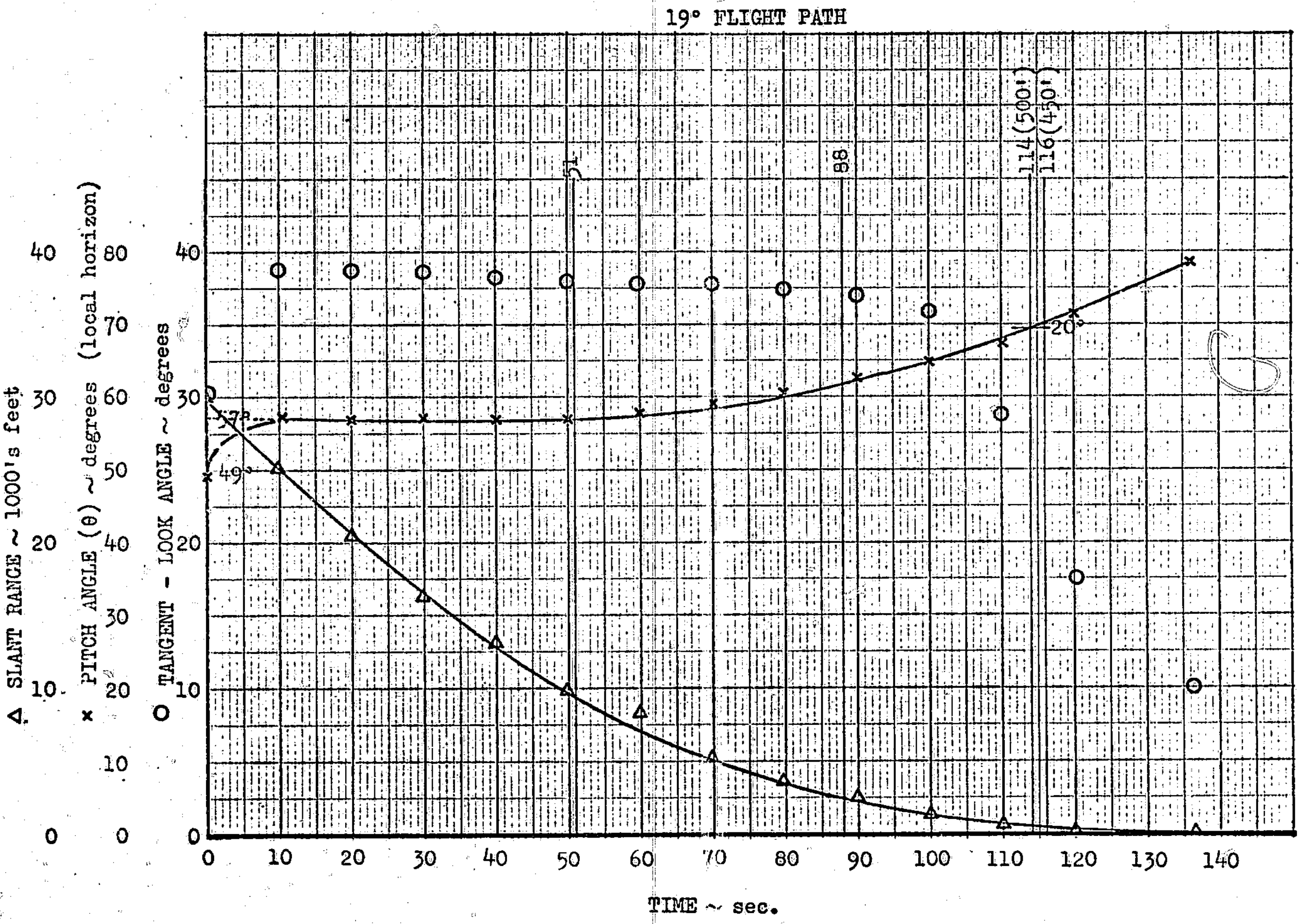

Figure III-22 TRAJECTORY DATA

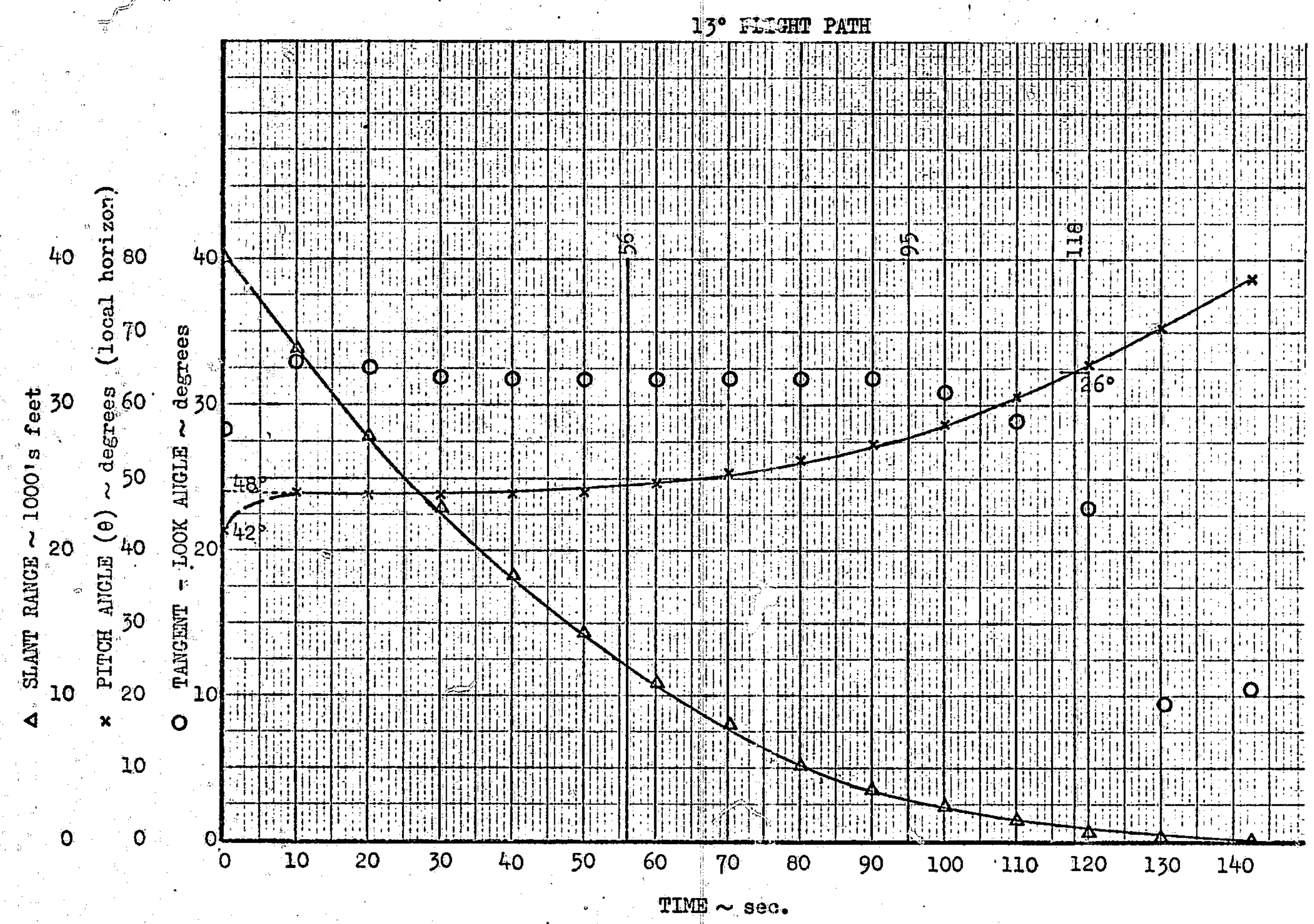

Figure III-23 TRAJECTORY DATA

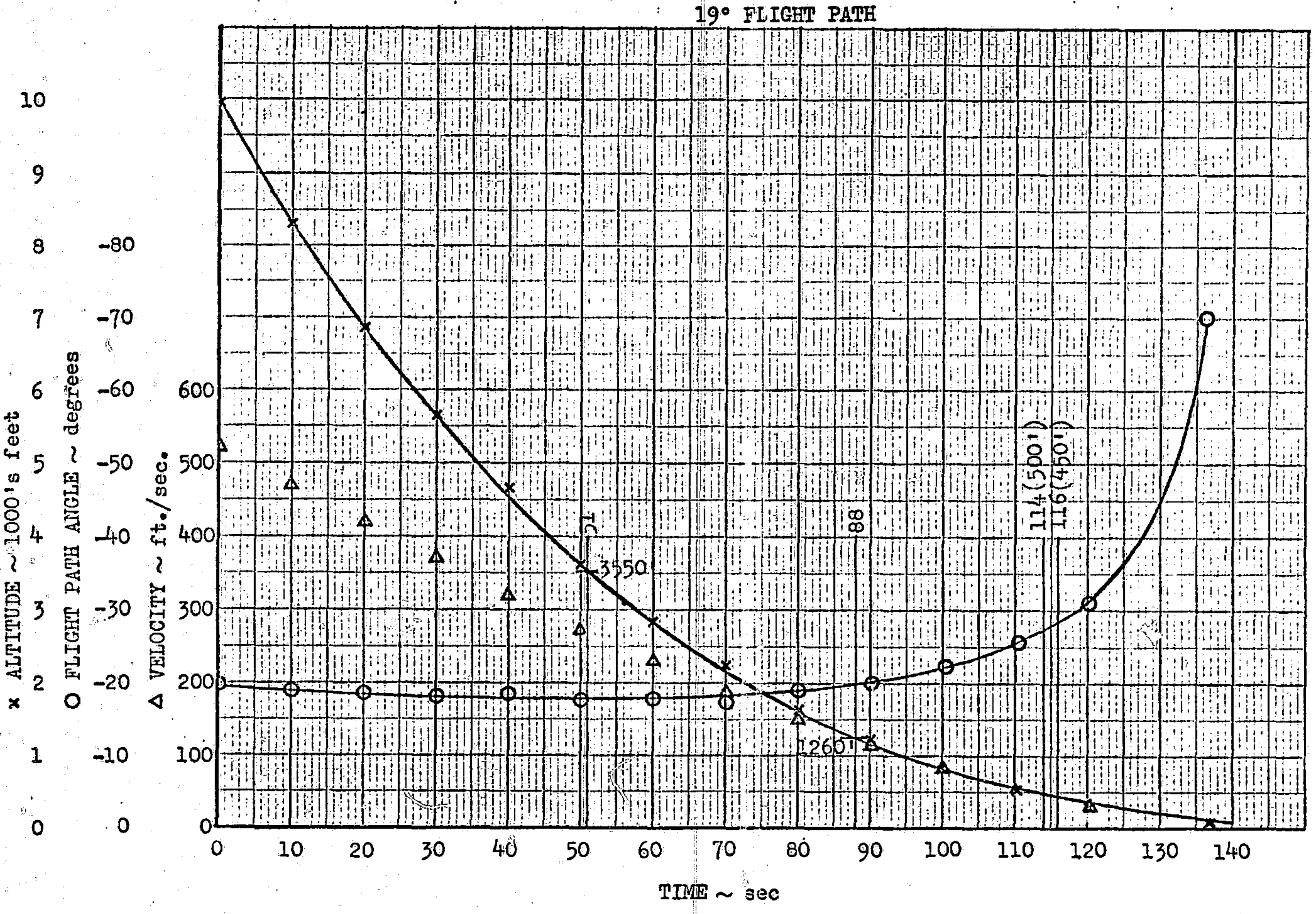

Figure III-24 TRAJECTORY DATA

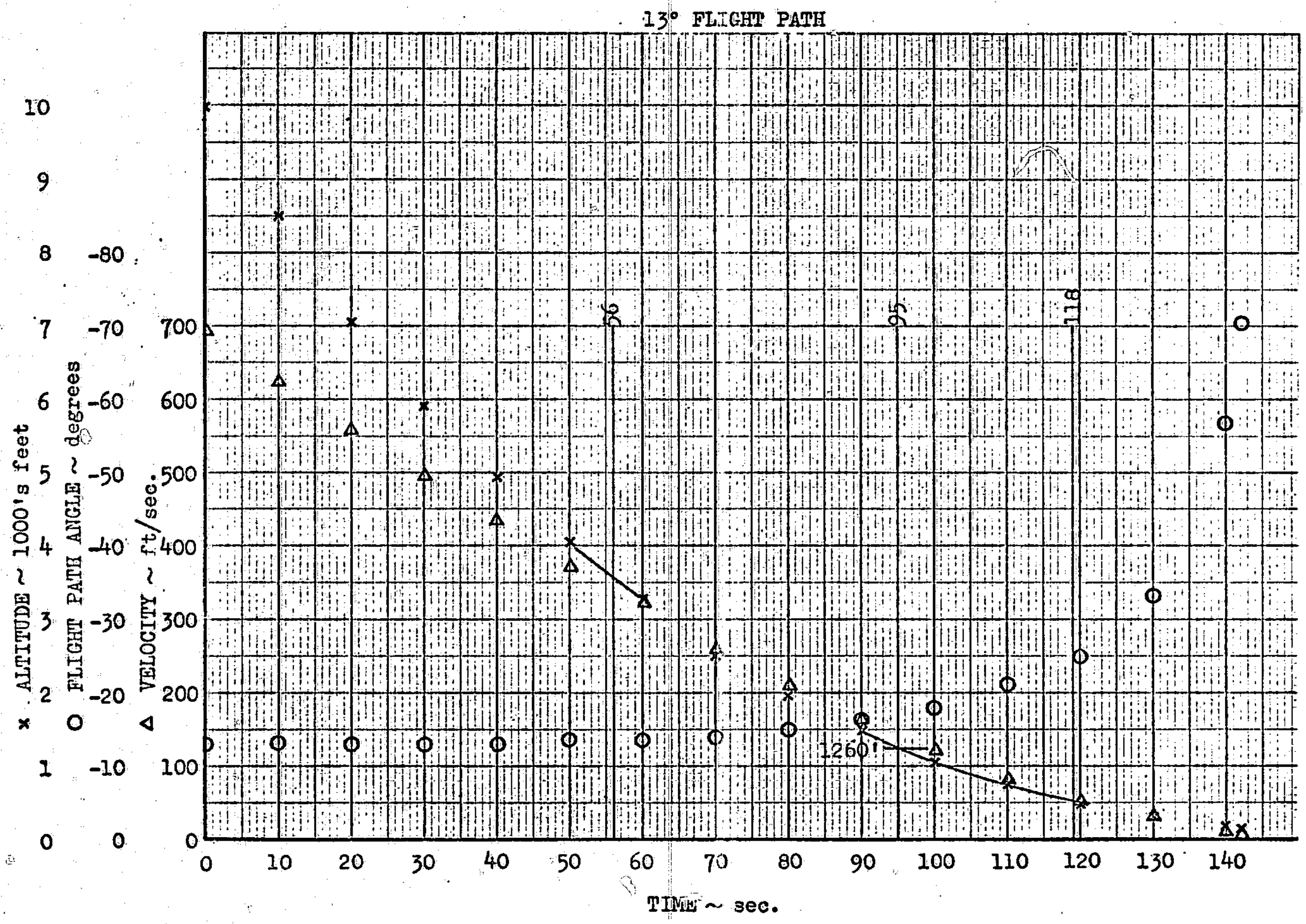

Figure III-25 TRAJECTORY DATA

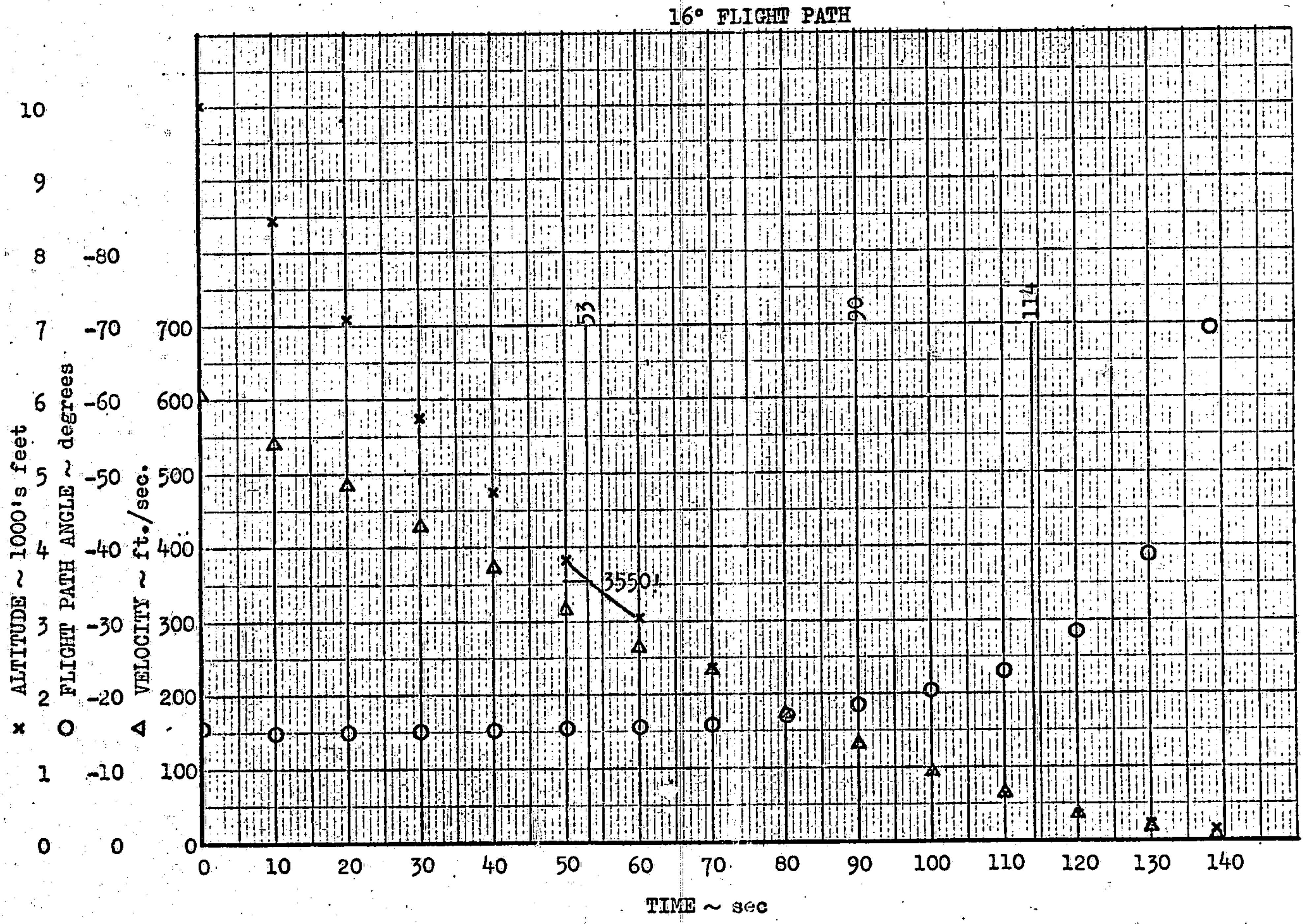

Figure III-26 TRAJECTORY DATA

APPENDIX IV - TELEVISION AND ILLUMINATION SYSTEM TESTS AND TEST RESULTS

Television System Resolution

In accord with Exhibit A of the Statement of Work, results of television system resolution, brightness and uniformity tests were reported in the Presimulation Report, Document D2-114040-1.

Angular Resolution data included in that report exceeded the specification requirement of 20 arc minutes or less. It was noted that superior angular resolution had been measured prior to contract award and that these tests would be repeated before the simulation tests began. Resolution and grey scale measurements of the entire TV system were made immediately prior to the simulation with the following results:

1) Angular resolution was measured by means of the following equipment:

   7.2" x 9.6" EIA Resolution Chart Transparency
   Light Box
   TV Camera, with 120° lens, S/N 549, installed
   TV Projector, with 120° lens installed

   Measurements were made by locating the resolution chart exactly 6" from the nodal point of the camera lens. Values of center and corner resolution were recorded. Readings obtained from projected display.

   The measured test results were:

   Center:

Horizontal	14.4 arc minutes
Vertical	19.6 arc minutes
Average	17.0 arc minutes

Corner:

Horizontal	16.4 arc minutes
Vertical	20.8 arc minutes
Average	18.6 arc minutes

2) Gray scale measurements were made with the following test equipment:

EIA Linear Gray Scale Chart

TV Camera, with 120° lens, S/N 549, installed

TV Projector, with 120° lens installed

The measurements were made by placing the gray scale chart before the camera and counting the number of visible gray shades in the projected display. Nine gray shades were visible.

Model Illumination

Fabrication of the light collimators had not been completed when the Presimulation Report was released. Accordingly model illumination data for the operational set-up could not be reported.

Model surface brightness measurements were made with the light source, mirror and dusted model in their operational positions. Results are shown in Figure IV-1. These measurements were obtained on a flat dusted lunar model to eliminate non-uniformities due to terrain features.

The uniformity does not meet the specification in the contract that any point on the model shall be within 40% of the average inminance. The major contribution to non-uniformity is attributed to an accidental break in the beam splitter mirror. Fortunately, the area of interest (i.e., the upper right quadrant where the landing site is located) is in a region of better than 40% uniform illumination, and the areas beyond and to the far left of the landing site are in the non-uniformly lit

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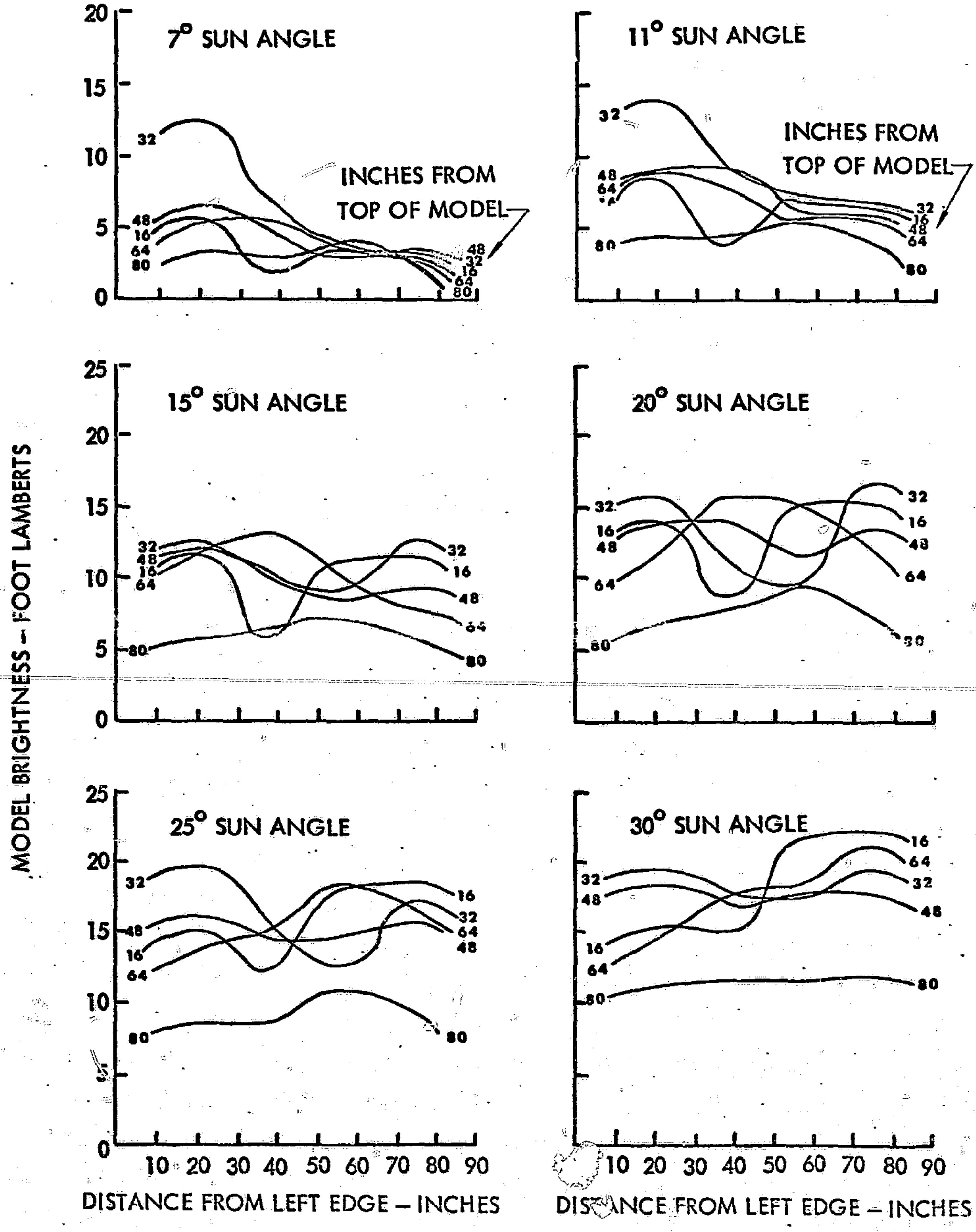

Figure IV-1 MODEL SURFACE BRIGHTNESS IN OPERATIONAL POSITION portions of the mode. These areas would be "washed-out" in the visual display because of the photometric properties of the surface. Visibility is, within rather broad limits, strictly a function of the photometric properties of the surface and not a function of surface brightness so that lack of uniformity did not detract from simulation results.

System Brightness Uniformity

The techn[illegible]ring brightness uniformity was as follows: Place the target board at the left edge of the camera view field, on a horizontal centerline passing through the camera and projector optical axis. Provide a constant-velocity command to the camera gimbal yaw servo, such that the target moves horizontally through the display at a rate of 5 or 10 degrees per second.

Track the target movement across the display field manually, using the photometer telescopic sight. The potentiometer output is to be connected to the X-axis [illegible] and calibrated in degrees. The vertical axis of the plotter will be driven by the photometer output. The resultant chart will be a plot of brightness vs. horizontal display angle for a fixed elevation angle of 0°.

Repeat the foregoing procedure at elevation angles of -20°, -40°, and +20°.

The demonstrated brightness variation, excluding the area within 5° of the left edge, is ±29.7%. (This figure includes the entire television system, and the pickup and projection optical systems.) The television system performance meets or exceeds all contract specifications.

Comparison with Lunar Visibility

While every effort was made to duplicate visual conditions on the lunar surface it was physically impossible to duplicate either the lunar photometric function, or the scene brightness exactly. Figure IV-2 shows the photometric function of the

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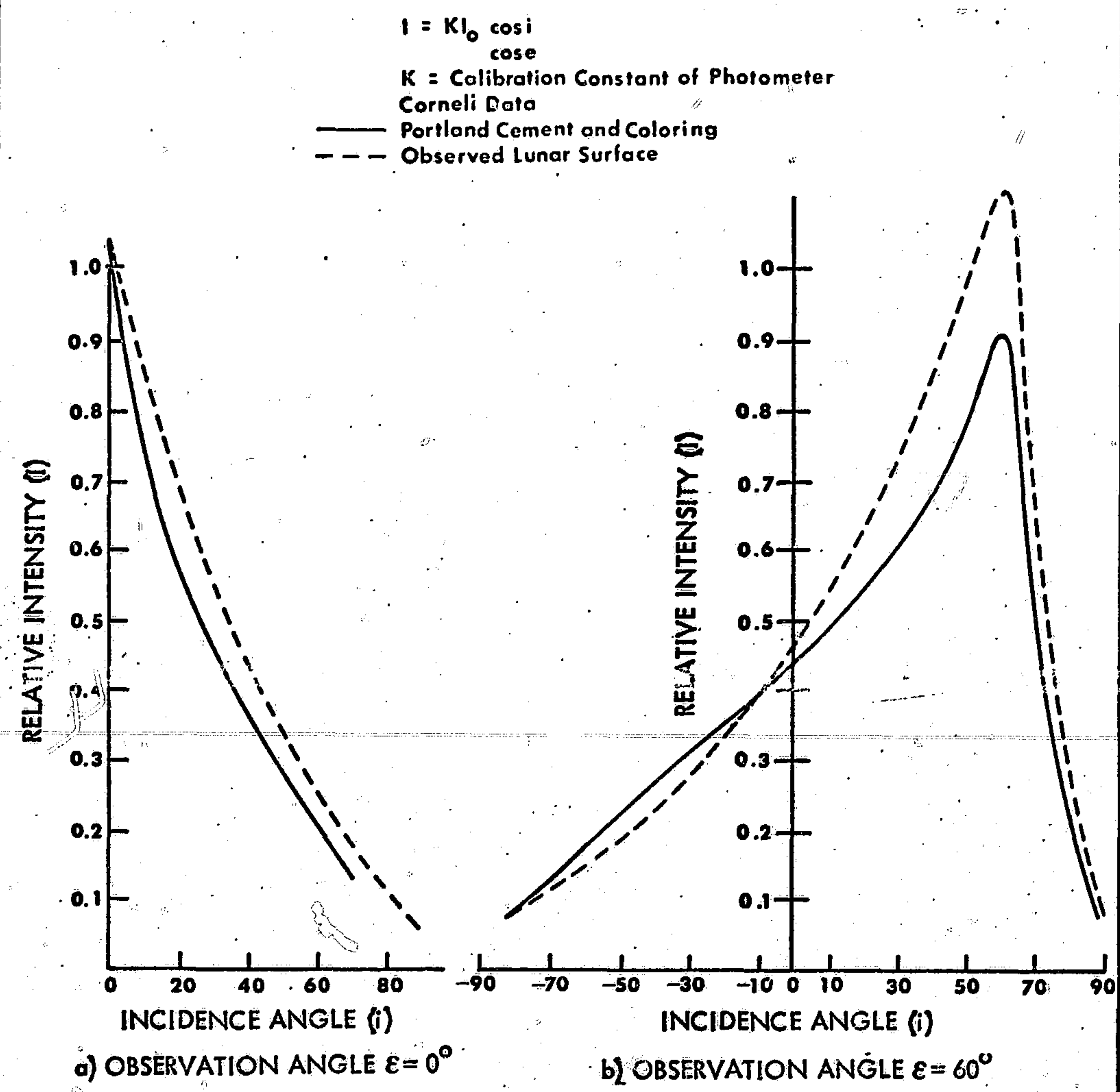

Figure IV-2 PHOTOMETRIC FUNCTION OF CEMENT MIXTURE portland cement-iron oxide mixture and the lunar photometric function. It can be seen that the cement mixture duplicates the lunar surface reasonably well though not exactly. No attempt has been made to derive a figure of merit for this material, or to assess how much the deviation affects the visual simulation. The fact that the material duplicates the gross condition on the lunar surface has already been shown in Figures III-16 and -17.

Figure IV-3 shows the difference in scene brightness between the simulator screen and lunar surface superimposed on curves showing what the human eye can be expected to see. The figure shows that while the scene brightness of the simulator screen is considerably less than that of the lunar surface, the difference has only a small effect on visibility. The human eye could detect almost as much detail on the simulator screen as on the lunar surface. Actually, the TV projector limits the resolution to something considerably less than the capability of the human eye and no increase in brightness can compensate for this limitation.

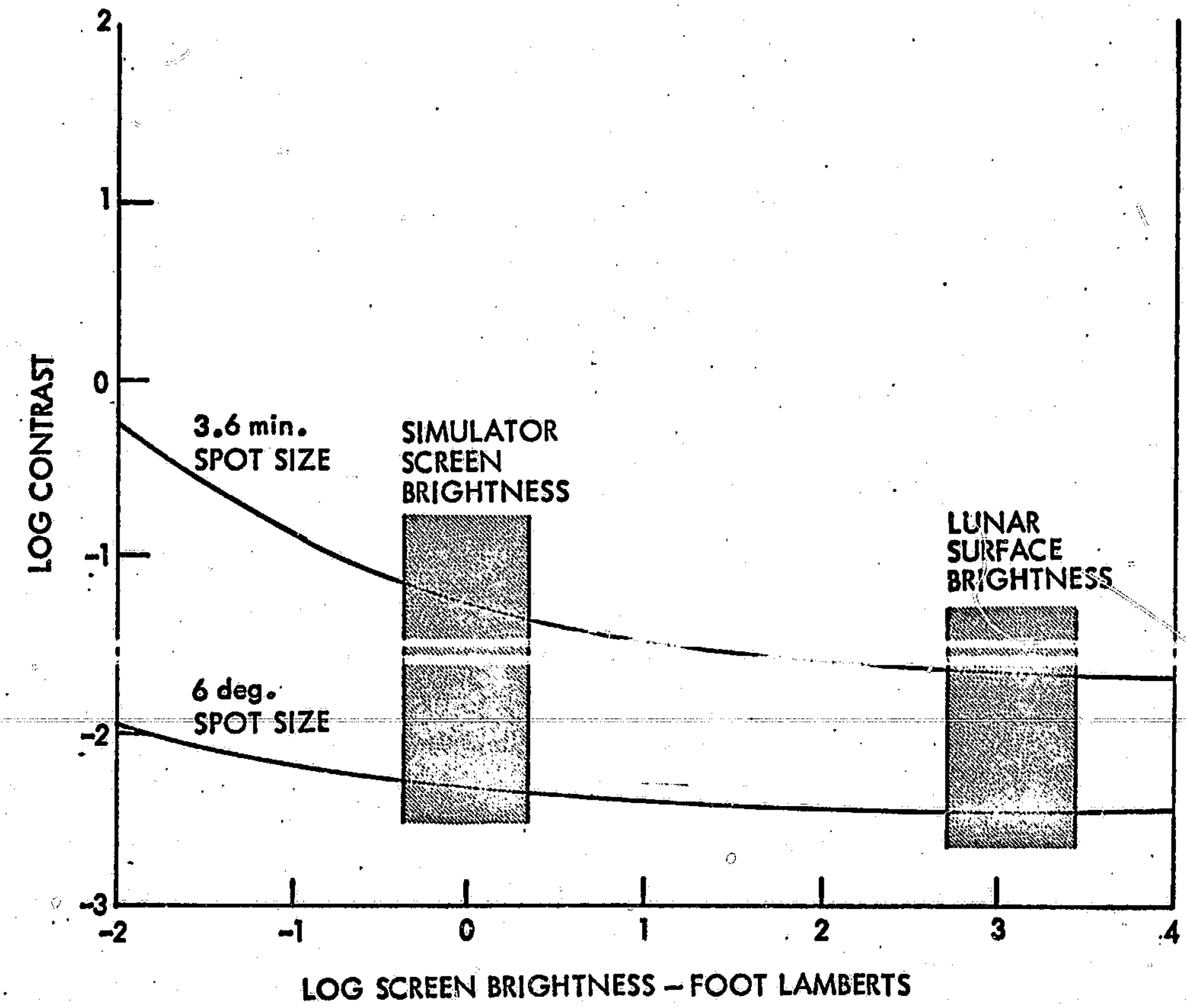

Figure IV-3 THRESHOLD OF BRIGHTNESS – CONTRAST FOR 50% DETECTION FOR TWO SPOT SIZES