UNIVERSITY OF CALIFORNIA, SAN DIEGO
SCRIPPS INSTITUTION OF OCEANOGRAPHY
VISIBILITY LABORATORY
SAN DIEGO, CALIFORNIA 92152

AN EXAMPLE OF AN EARLY TECHNIQUE FOR VISIBILITY CALCULATIONS

Jacqueline I. Gordon, Peggy V. Church

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

SIO Ref. 68-13
June 1968

Naval Ship Systems Command
Contract NObs-84075
Assignment 9

Approved:

S. Q. Duntley

Seibert Q. Duntley, Director
Visibility Laboratory

Approved for Distribution:

William A. Nierenberg

William A. Nierenberg, Director
Scripps Institution of Oceanography

Contents

FOREWORD

This is the fifth report issued under Assignment 9 of Contract NObs-84075. This report contains results of visibility calculations made using the atmospheric optical data and terrain and background data issued in the first two of the reports under Assignment 9, SIO Refs. 64-3 and 64-5. The contents of these two reports have been published in Applied Optics. The atmospheric and lighting conditions documented in the two reports and used herein were those which prevailed at the time of Visibility Laboratory research flight 74 (medium high sun).

AN EXAMPLE OF AN EARLY TECHNIQUE FOR VISIBILITY CALCULATIONS

Jacqueline I. Gordon and Peggy V. Church

I. INTRODUCTION

A hitherto unreported calculation study of the visual detection and recognition of a complex object lighted by the sun and sky and screened by the real atmosphere was completed in the spring of 1957 as an exercise in developing what was, at that time, a new technique for making visibility calculations. The object chosen was a toy clearly different from any real vehicle. Although the 1957 technique has been superseded (e.g., see "Visibility", Applied Optics 3, 549-599 (1964)) there have been recurrent external inquiries about the early work. This report is issued, therefore, chiefly for historical purposes. It is not regarded as an example of the current technique.

The model used was a toy tank arithmetically scaled up to a length of 23 feet. Its shape differed from that of any known tank used by this country or any other country. The toy possessed few details; it was judged, therefore, to have the right degree of complexity for use in developing what was then a new technique for handling non-uniform objects. The toy was coated with an olive paint, the directional reflectance of which has been published.[1]

The visibility computations were made for a clear day with the sun at a zenith angle of 41.5°.[2] The attenuation length at ground level was 4.6 nautical miles, and there was a heavy haze layer from 1 000 to 2 000 feet altitude, although from the ground this was described as a clear day. The sky luminance distribution[3] was assumed to be symmetrical with respect to the azimuth of the sun.

---

[1]The luminous directional reflectance measurements for various portions of the model have been reported previously as Item 4 of Table IV of Ref. 1.

[2]The atmospheric data for computing contrast attenuation has been previously reported in Sec. 6 of Ref. 2.

[3]The sky luminance distribution was presented in Fig. 1 of Ref. 1.

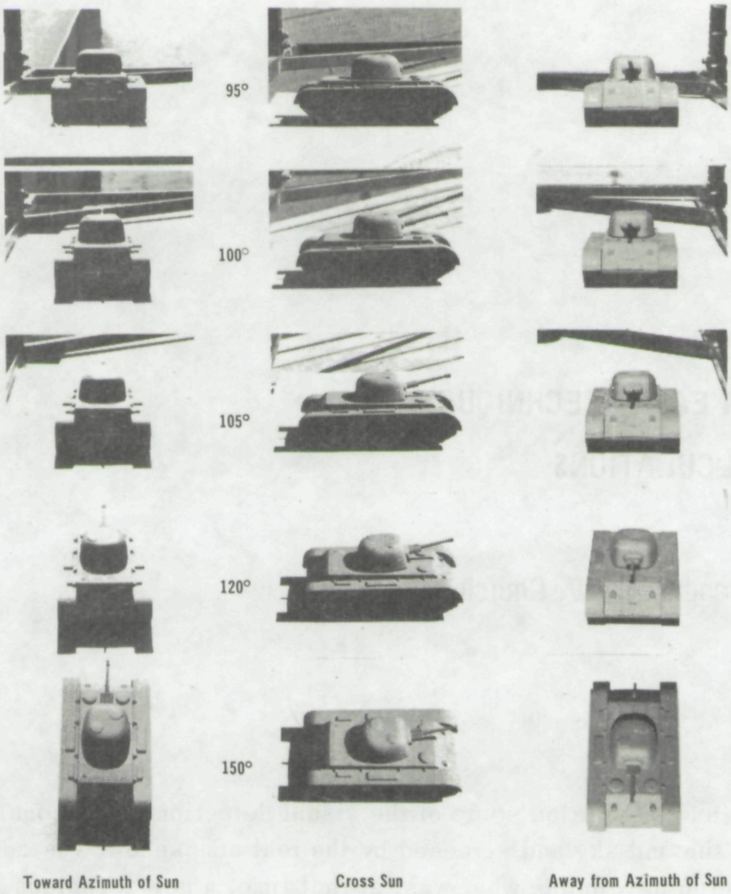


Fig. 1

Two model positions were used. In one case the model was headed parallel to the azimuth of the sun and in the second case, perpendicular to the azimuth of the sun. In both cases the observer was heading toward the model using three approaches: 1) toward the azimuth of the sun, 2) cross sun, and 3) away from the sun. Photographs of the model from the three approach directions for both model headings are presented in Figs. 1 and 2. The upper pictures depict the appearance of the model at long slant ranges when the path of sight is at a zenith angle of 95° (depressed 5° below the horizontal). The vertical column of pictures represents the changing appearance of the model as the distance between object and observer is shortened and the path of sight increases in zenith angle.

The model was assumed to be on or at the side of a road. Two types of roads were used: 1) a hard-packed yellow dirt road, and 2) an old macadam road. The model at the edge of the road was on freshly growing green grass.[4]

---

[4]The luminous directional reflectance measurements for the three backgrounds have been reported previously as Items 6 through 8 in Table 3.2 of Ref. 2.

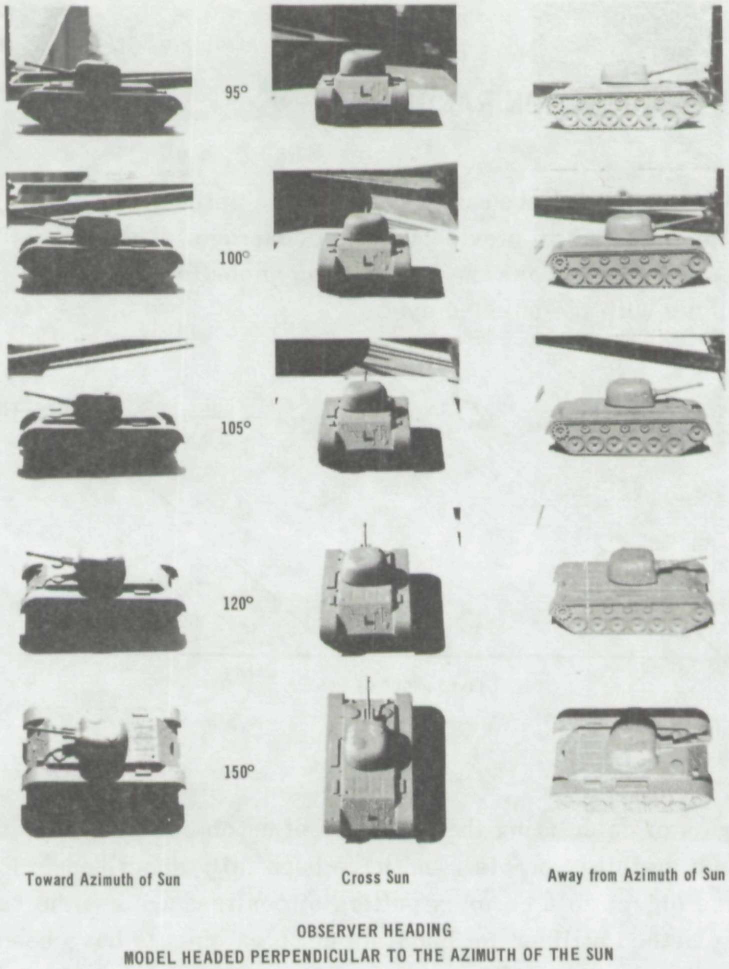


Fig. 2

The observation aircraft was assumed to be flying straight and level down the road at one of two speeds, 250 knots or 500 knots.

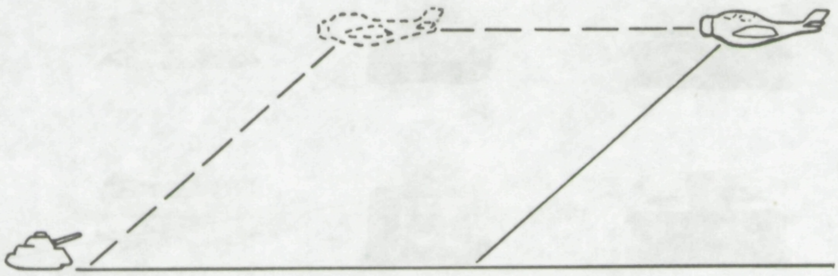
In Sec. II are presented the results of the study for search of the road accomplished by fixating at the optimal angle of sight and allowing the forward movement of the plane to provide area coverage. All cases noted above were evaluated.

In Sec. III are presented the results of the effects of using other flight patterns, of using visual aids, and of having positional information on the object. The search method is the same static eye method described in Sec. II. Two cases were selected as examples to depict the results.

Finally, presented in Sec. IV are sample results of searching for the object using discrete fixations on the terrain.

II. DETECTION AND RECOGNITION RANGES

Search of the road was accomplished by fixating at the optimal angle of sight and allowing the forward movement of the plane to provide the area coverage. This manner of search is illustrated in Fig. 3. The observer was assumed to have an unobstructed view in the direction of the object and to be searching with the unaided eye.



FIXED ANGLE OF SIGHT

Fig. 3

The basic techniques of calculating the detection of an object for this method of search were developed for a previous visibility problem and have been fully described in Ref. 3. The difference lies in treating the object as a complex pattern of contrast against the background. The basic ideas behind the method utilized for handling complex objects have been described in Ref. 4.

After detection of the object on the road or beside the road, the observer was assumed to continue to maintain straight and level flight, to continue to search the road but, in addition, to return to the previously detected object for brief, steady views. It was assumed that both sufficient information on the nature of the object should be discernible and a necessary minimum length of time should elapse after detection, before information concerning the object could be accumulated by the brain and a threshold of recognition achieved. The detection of the presence of a turret was assumed to be necessary before recognition could occur, and a 2.7 second (Ref. 5) time lapse was assumed to be a minimum time interval between detection and recognition.

The results are presented graphically in the following 37 figures. The figures comprise two main groups. The first group, Figs. 4 through 22, are for the model headed parallel to the azimuth of the sun; the second group, Figs. 23 through 40, are for the model headed perpendicular to the azimuth of the sun. Each of these groups is divided into three sub-groups classified by background: dirt road, macadam road, and grass.

Each figure presents results for one heading of the observer with respect to the azimuth of the sun for one observer speed. The horizontal distance from observer to object for observer altitudes up to 18,000 feet is depicted, one curve for detection and one for recognition. The grid is 1 : 1 in feet, although the horizontal scale is marked in nautical miles for convenience.

II.1 Model Headed Parallel to Azimuth of the Sun

The model is headed toward the sun as depicted in Fig. 1.

DIRT ROAD. The model is on a hard-packed yellow dirt road.

Low Speed. The aircraft is headed toward the sun in Fig. 4, flying at a speed of 250 knots. Aircraft headings of cross-sun and away from the sun are shown in Figs. 5 and 6.

High Speed. The aircraft is flying at a speed of 500 knots on three headings relative to the sun in Figs. 7 through 9.

Another manner of presenting the results is illustrated in Fig. 10. The data are shown on a polar graph with the sun on the zero azimuth. The detection distances are for an observer altitude of 6 000 ft. and are from the curves in Figs. 4 through 9. Zero detection distance represents the point directly above the object at 6 000 ft. altitude. The model is headed parallel to the azimuth of the sun. Since the sky luminance distribution was assumed to be symmetrical with respect to the azimuth of the sun, the detection distances are also symmetrical with respect to the azimuth of the sun. There are three observer approaches relative to the azimuth of the sun. Each approach path converges radially on the target. The graph shows a suggested interpolation for other approach paths.

Note that the detection data for the aircraft heading toward the sun, Figs. 4 and 7, are plotted at azimuth 180° from the sun.

MACADAM ROAD. The model is headed toward the sun on a macadam road.

Low Speed. The aircraft is flying at a speed of 250 knots on three headings in Figs. 11 through 13.

High Speed. The aircraft is flying at a speed of 500 knots on three headings in Figs. 14 through 16.

GRASS BESIDE ROAD. The model is headed toward the sun beside a road on verdant green grass.

Low Speed. The aircraft is flying at a speed of 250 knots on three headings relative to the sun in Figs. 17 through 19.

High Speed. The aircraft is flying at a speed of 500 knots on three headings relative to the sun in Figs. 20 through 22.

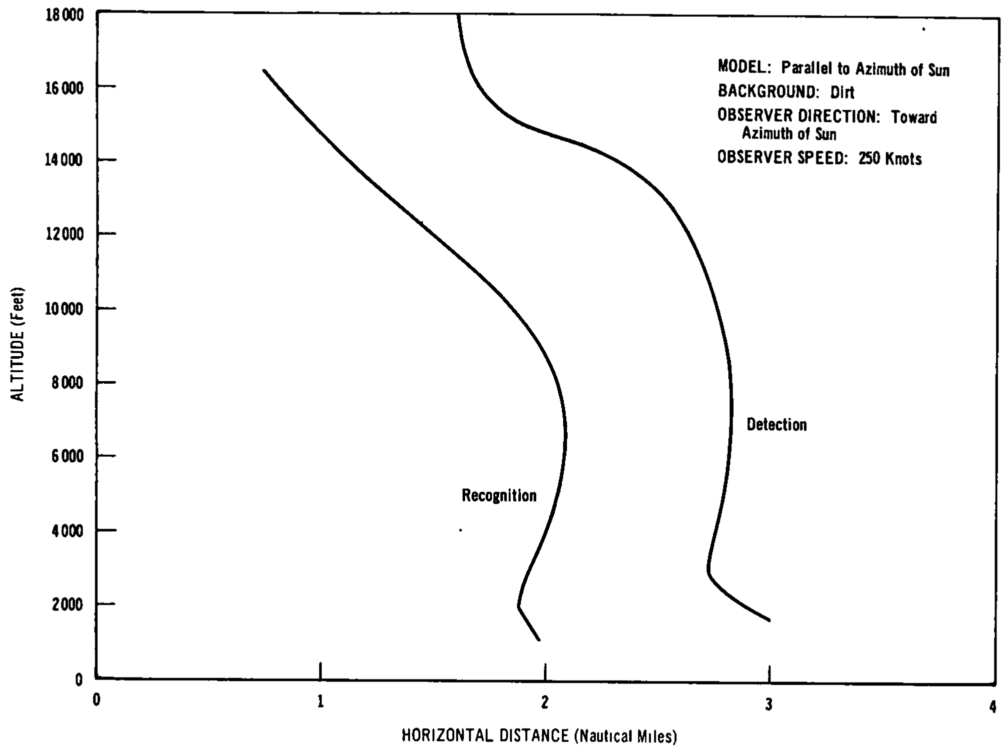

MODEL: Parallel to Azimuth of Sun
BACKGROUND: Dirt
OBSERVER DIRECTION: Toward Azimuth of Sun
OBSERVER SPEED: 250 Knots
Detection
Recognition
ALTITUDE (Feet)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 4

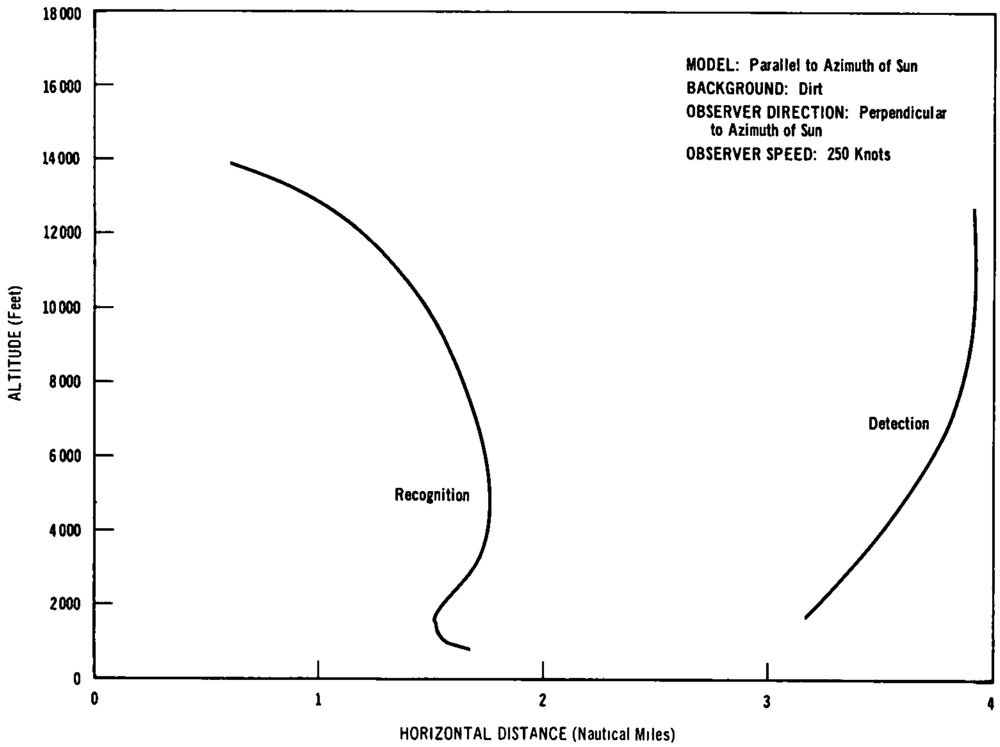

MODEL: Parallel to Azimuth of Sun
BACKGROUND: Dirt
OBSERVER DIRECTION: Perpendicular to Azimuth of Sun
OBSERVER SPEED: 250 Knots
Detection
Recognition
ALTITUDE (Feet)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 5

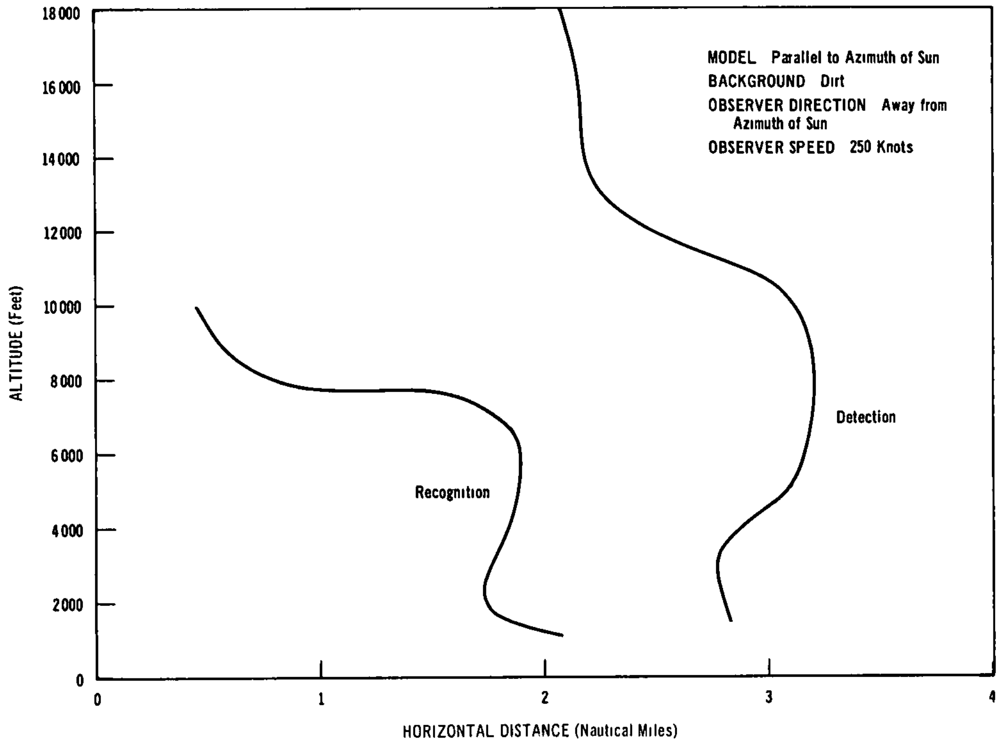

MODEL Parallel to Azimuth of Sun
BACKGROUND Dirt
OBSERVER DIRECTION Away from Azimuth of Sun
OBSERVER SPEED 250 Knots
Detection
Recognition
ALTITUDE (Feet)
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 6

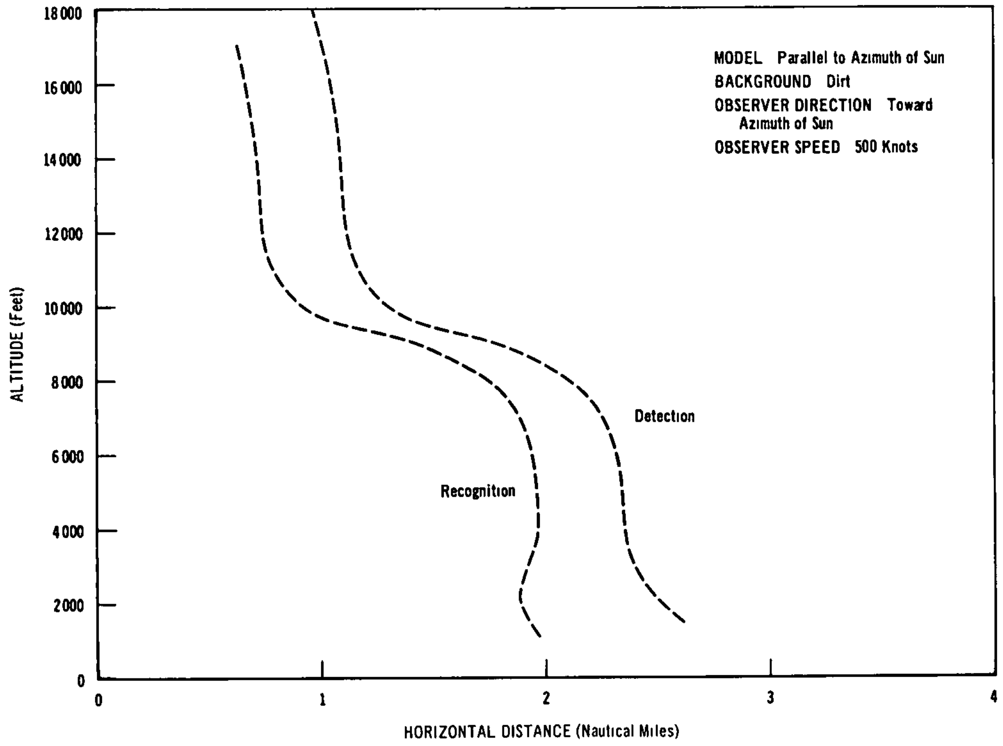

MODEL Parallel to Azimuth of Sun
BACKGROUND Dirt
OBSERVER DIRECTION Toward Azimuth of Sun
OBSERVER SPEED 500 Knots
Detection
Recognition
ALTITUDE (Feet)
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 7

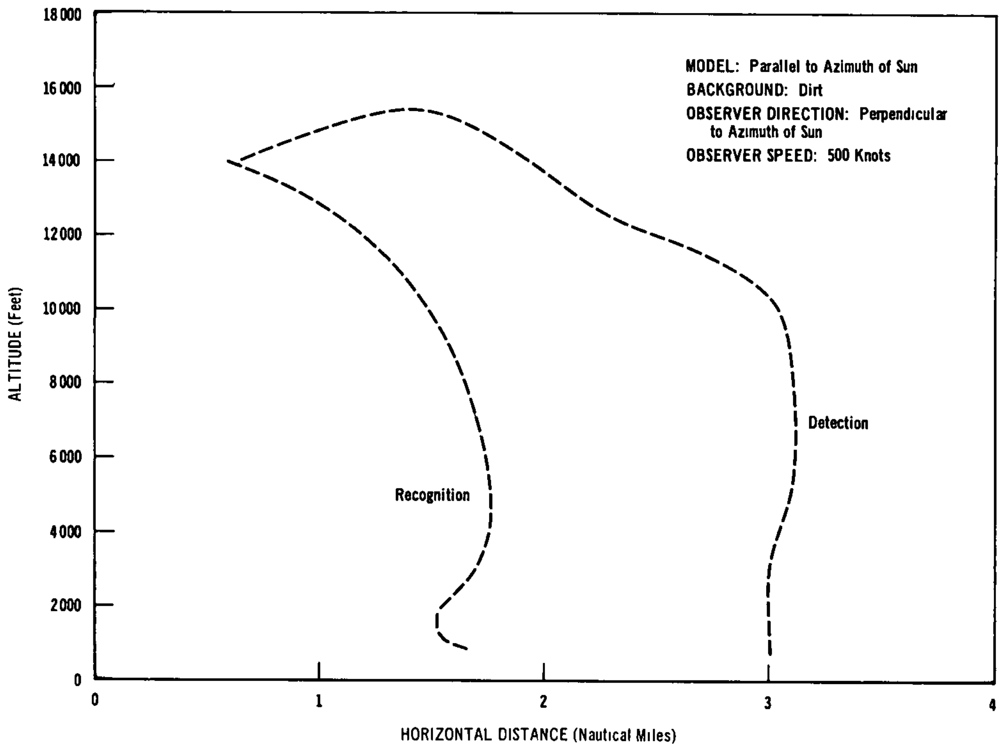

MODEL: Parallel to Azimuth of Sun
BACKGROUND: Dirt
OBSERVER DIRECTION: Perpendicular to Azimuth of Sun
OBSERVER SPEED: 500 Knots
Detection
Recognition
ALTITUDE (Feet)
HORIZONTAL DISTANCE (Nautical Miles)
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2 000
0
0
1
2
3
4

Fig. 8

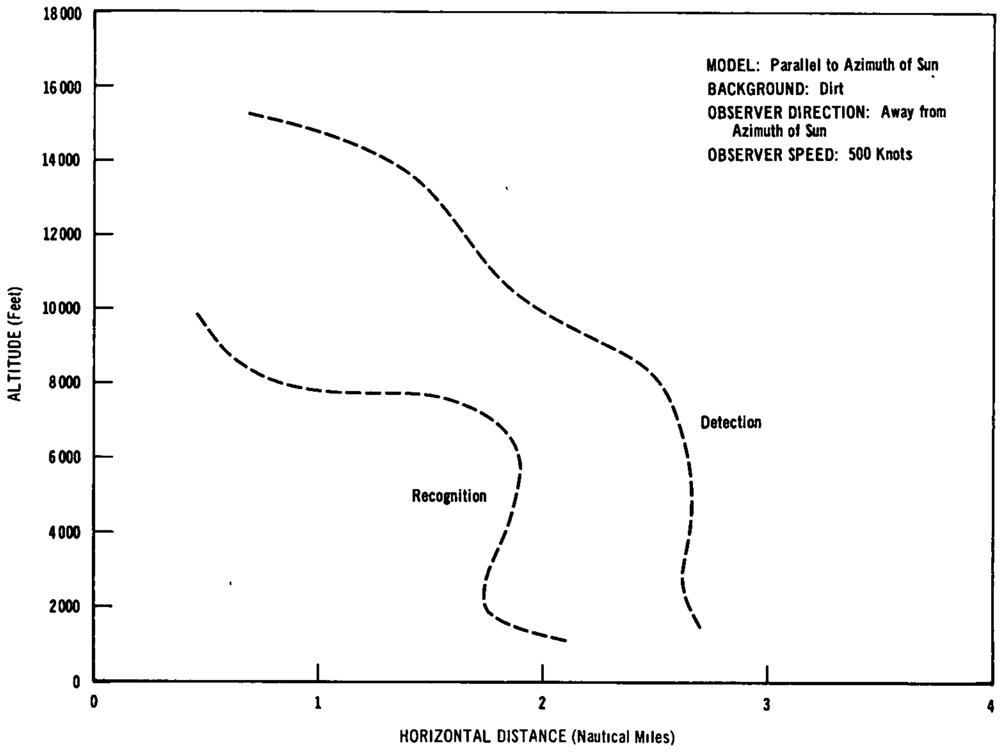

MODEL: Parallel to Azimuth of Sun
BACKGROUND: Dirt
OBSERVER DIRECTION: Away from Azimuth of Sun
OBSERVER SPEED: 500 Knots
Detection
Recognition
ALTITUDE (Feet)
HORIZONTAL DISTANCE (Nautical Miles)
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2 000
0
0
1
2
3
4

Fig. 9

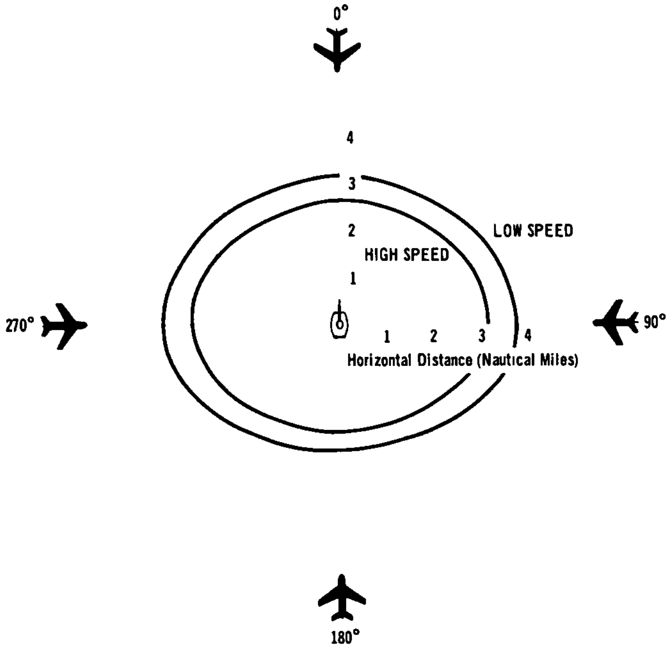


Fig. 10. Detection by observer in aircraft at 6000 ft. altitude, of model headed parallel to the azimuth of the sun, on a dirt road.

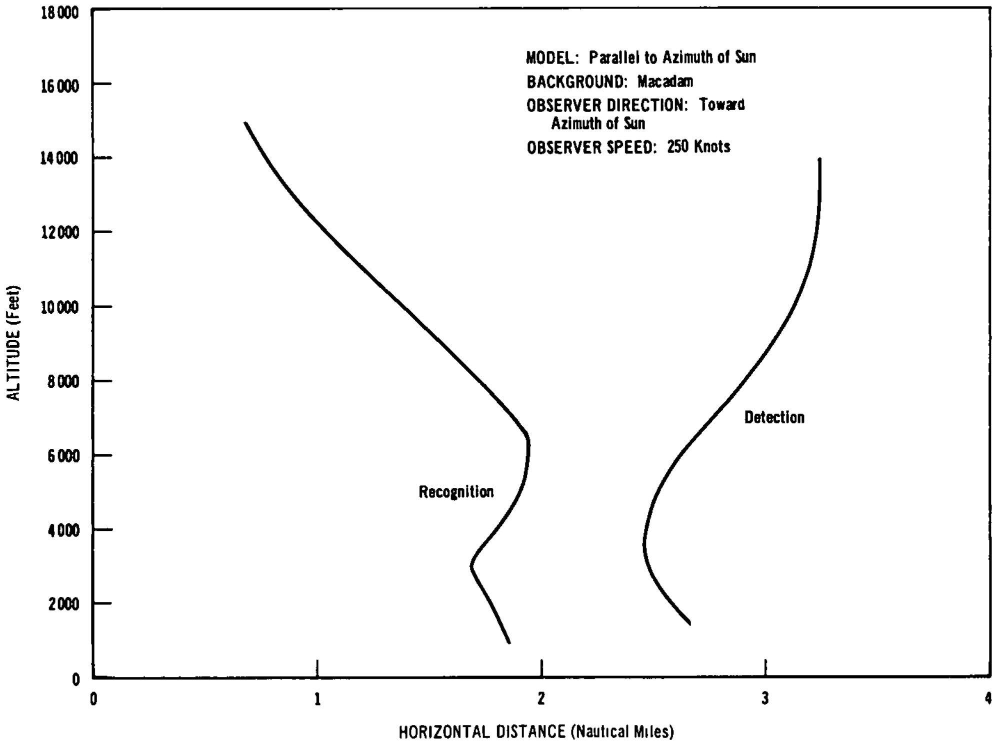


Fig. 11

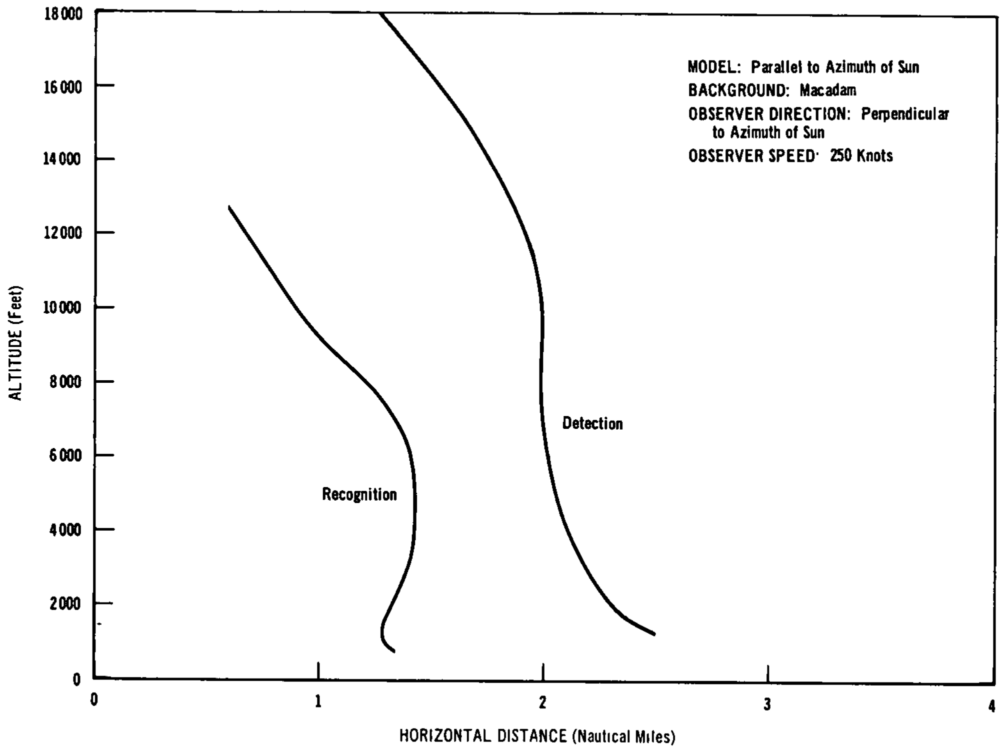

MODEL: Parallel to Azimuth of Sun
BACKGROUND: Macadam
OBSERVER DIRECTION: Perpendicular to Azimuth of Sun
OBSERVER SPEED· 250 Knots
Detection
Recognition
ALTITUDE (Feet)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 12

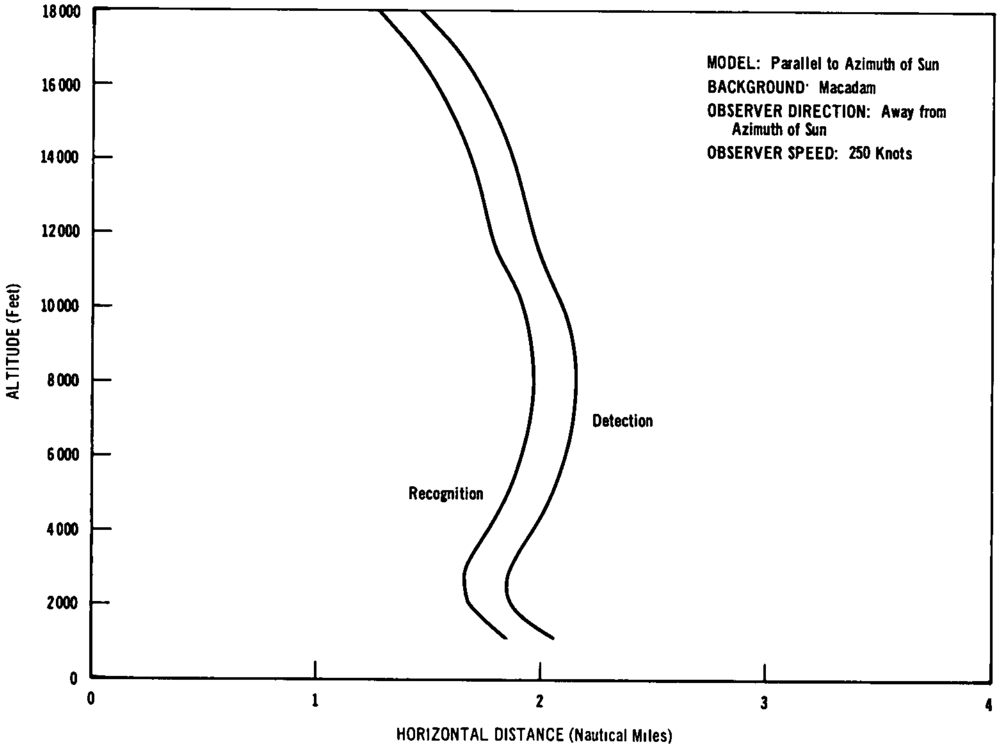
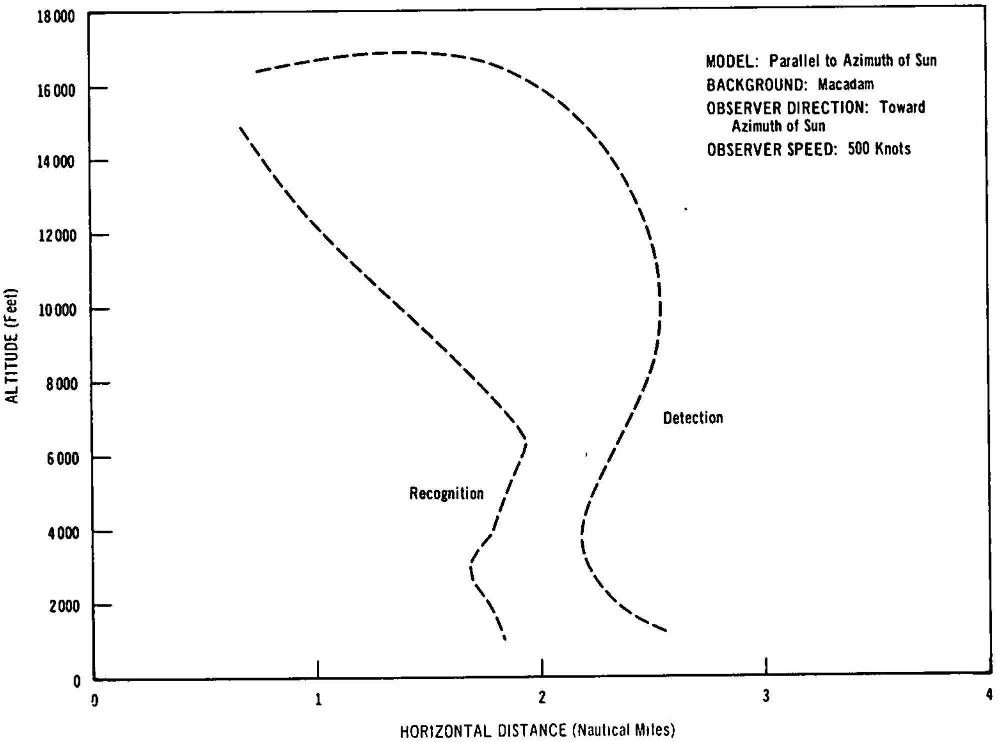
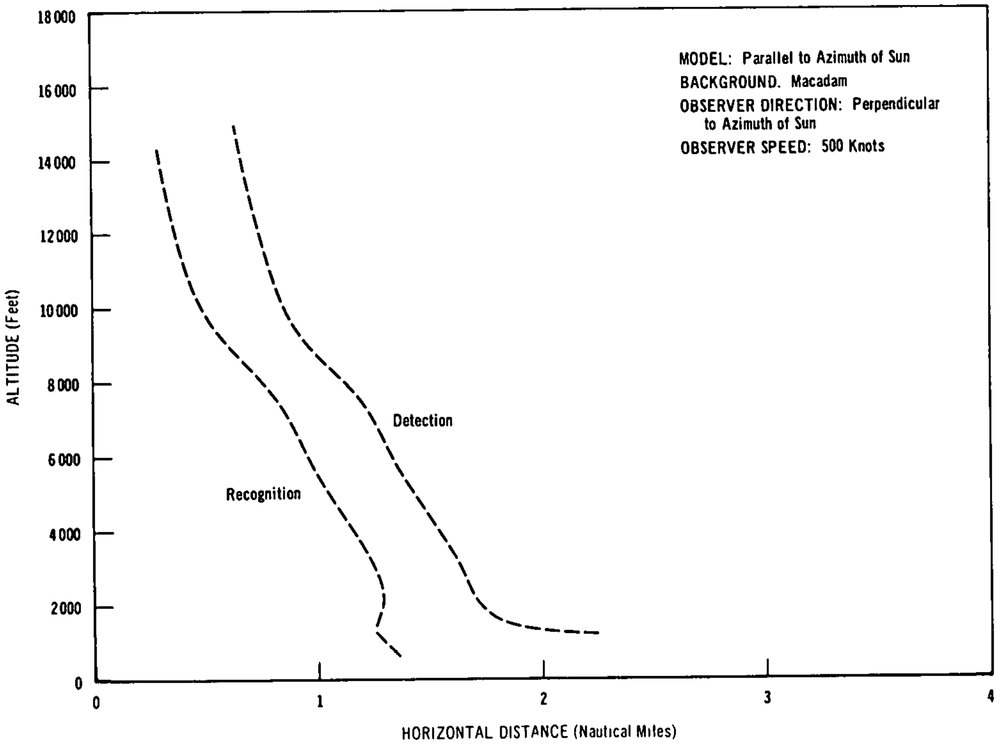

MODEL: Parallel to Azimuth of Sun
BACKGROUND· Macadam
OBSERVER DIRECTION: Away from Azimuth of Sun
OBSERVER SPEED: 250 Knots
Detection
Recognition
ALTITUDE (Feet)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 13



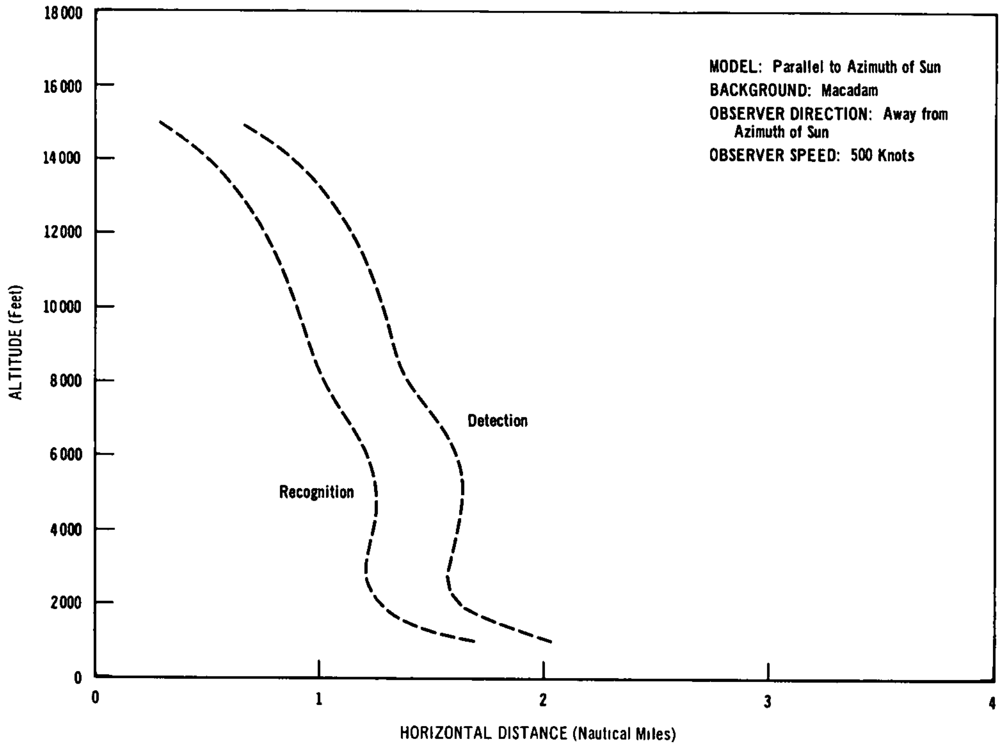
MODEL: Parallel to Azimuth of Sun
BACKGROUND: Macadam
OBSERVER DIRECTION: Toward Azimuth of Sun
OBSERVER SPEED: 500 Knots
Detection
Recognition
ALTITUDE (Feet)
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 14



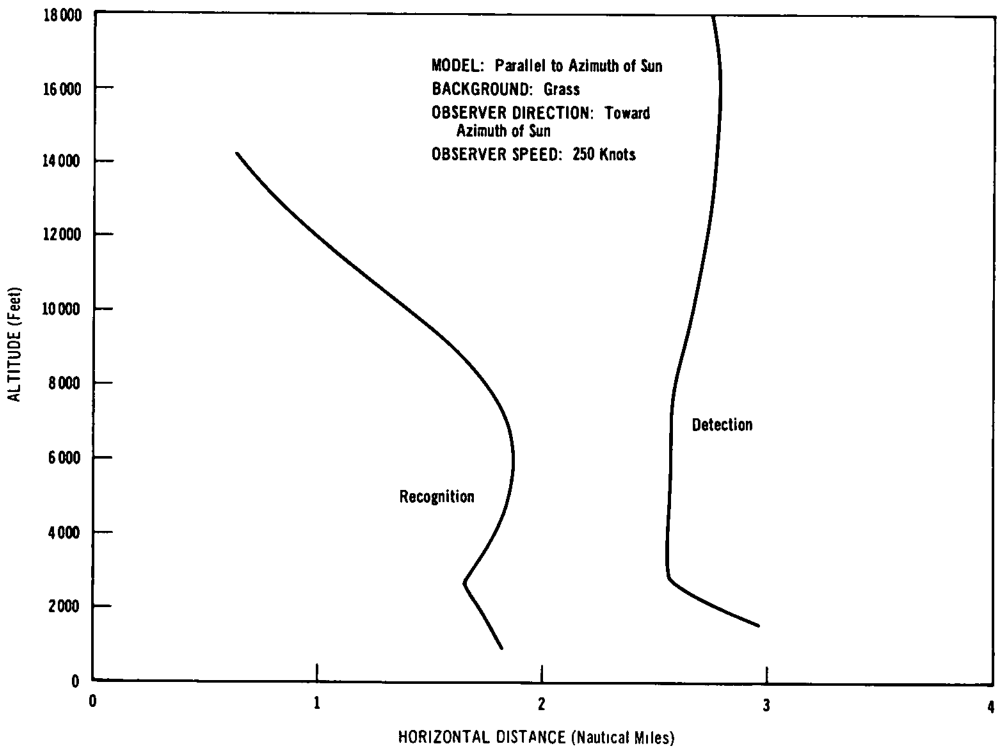
MODEL: Parallel to Azimuth of Sun
BACKGROUND. Macadam
OBSERVER DIRECTION: Perpendicular to Azimuth of Sun
OBSERVER SPEED: 500 Knots
Detection
Recognition
ALTITUDE (Feet)
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 15



18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
ALTITUDE (Feet)
MODEL: Parallel to Azimuth of Sun
BACKGROUND: Macadam
OBSERVER DIRECTION: Away from Azimuth of Sun
OBSERVER SPEED: 500 Knots
Detection
Recognition
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 16



18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
ALTITUDE (Feet)
MODEL: Parallel to Azimuth of Sun
BACKGROUND: Grass
OBSERVER DIRECTION: Toward Azimuth of Sun
OBSERVER SPEED: 250 Knots
Detection
Recognition
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 17

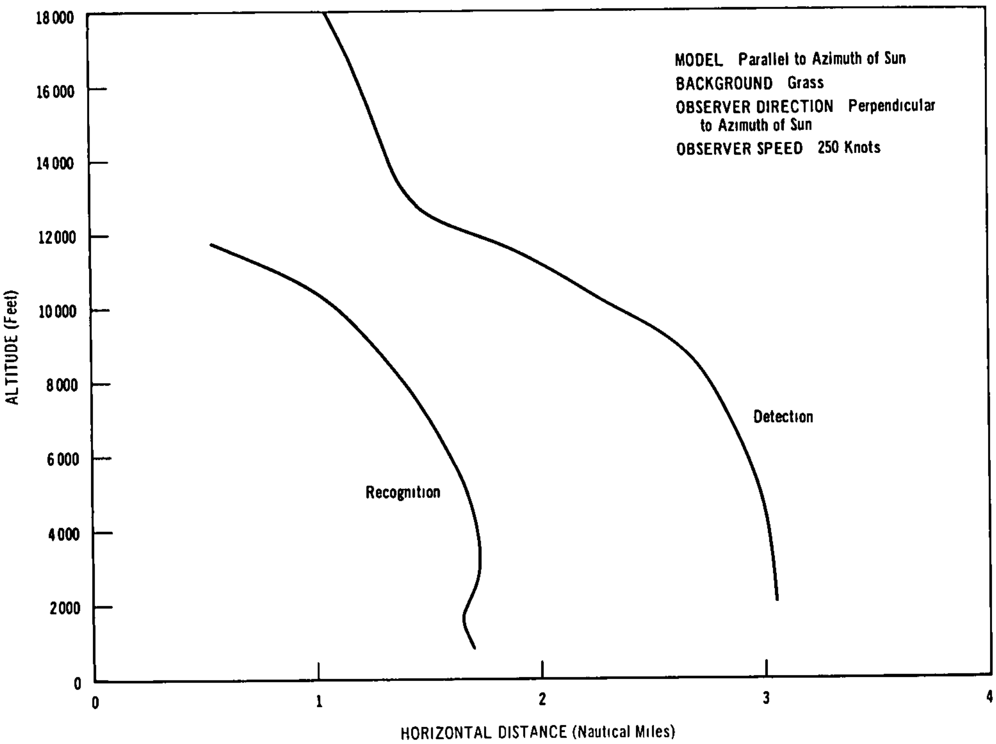

MODEL Parallel to Azimuth of Sun
BACKGROUND Grass
OBSERVER DIRECTION Perpendicular to Azimuth of Sun
OBSERVER SPEED 250 Knots
Detection
Recognition
ALTITUDE (Feet)
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 18

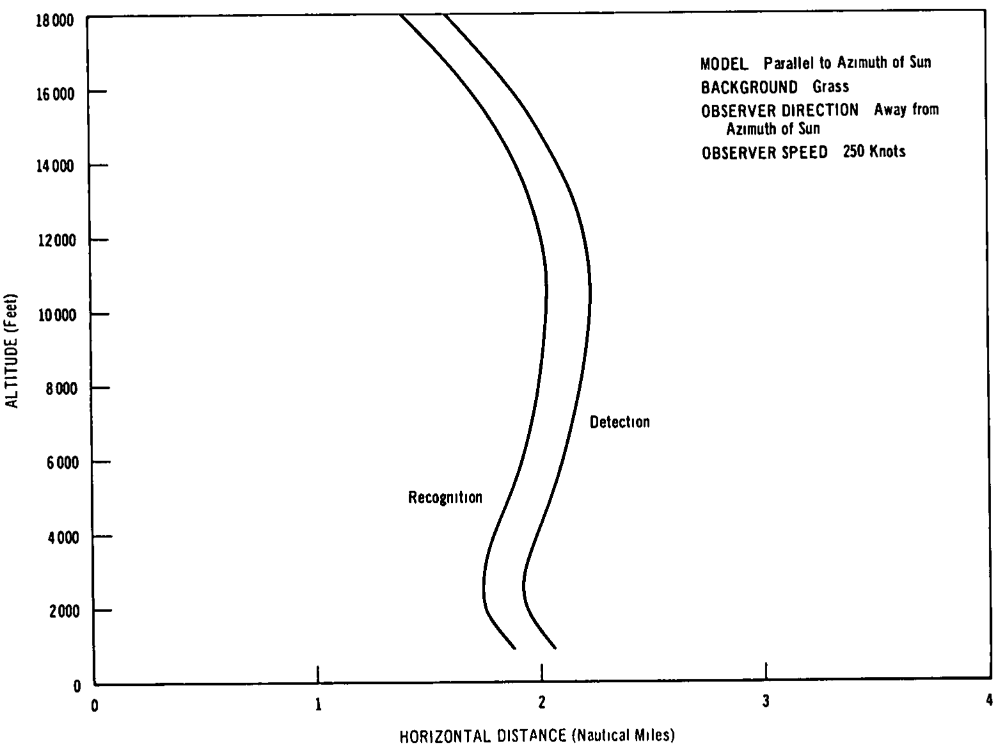

MODEL Parallel to Azimuth of Sun
BACKGROUND Grass
OBSERVER DIRECTION Away from Azimuth of Sun
OBSERVER SPEED 250 Knots
Detection
Recognition
ALTITUDE (Feet)
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 19

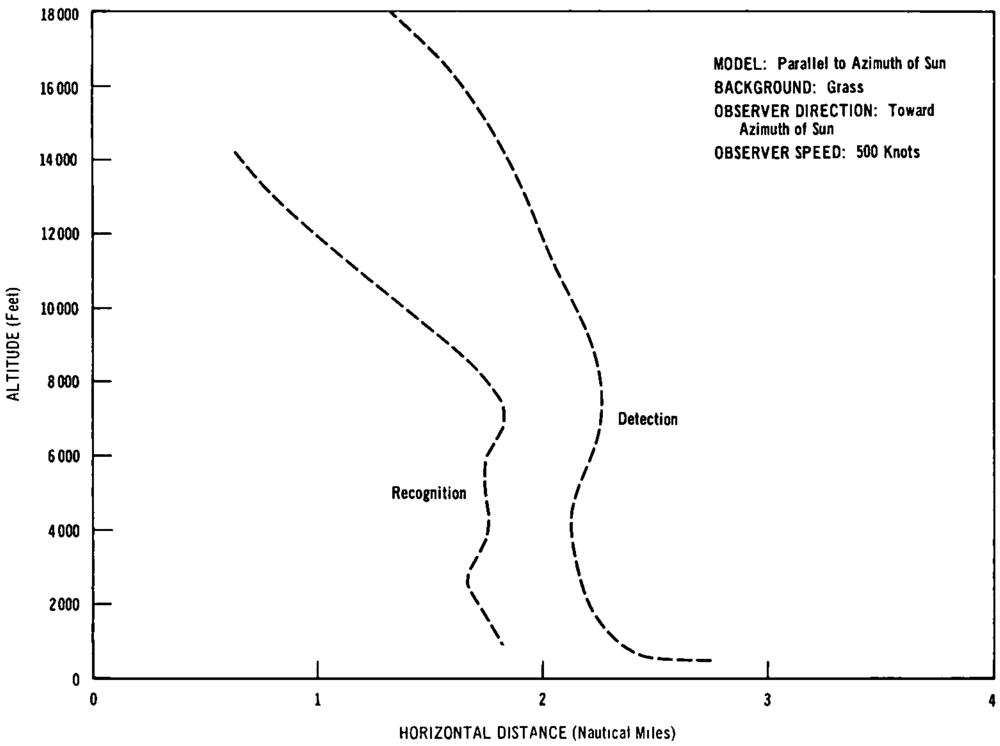

18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2 000
0
ALTITUDE (Feet)
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)
MODEL: Parallel to Azimuth of Sun
BACKGROUND: Grass
OBSERVER DIRECTION: Toward Azimuth of Sun
OBSERVER SPEED: 500 Knots
Detection
Recognition

Fig. 20

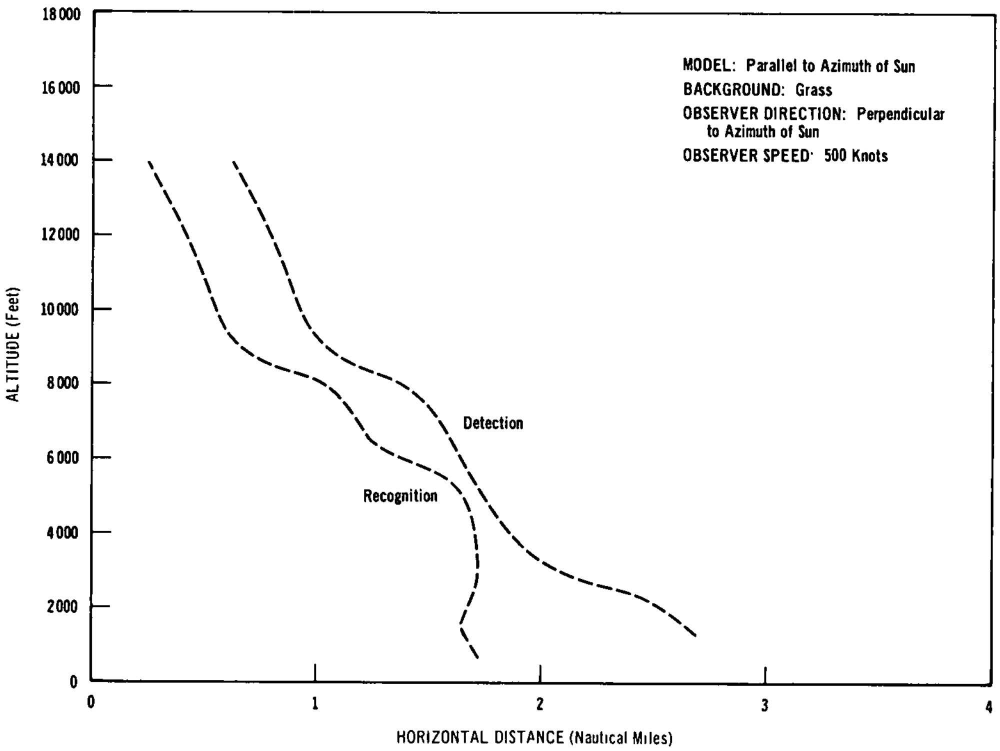

18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2 000
0
ALTITUDE (Feet)
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)
MODEL: Parallel to Azimuth of Sun
BACKGROUND: Grass
OBSERVER DIRECTION: Perpendicular to Azimuth of Sun
OBSERVER SPEED· 500 Knots
Detection
Recognition

Fig. 21

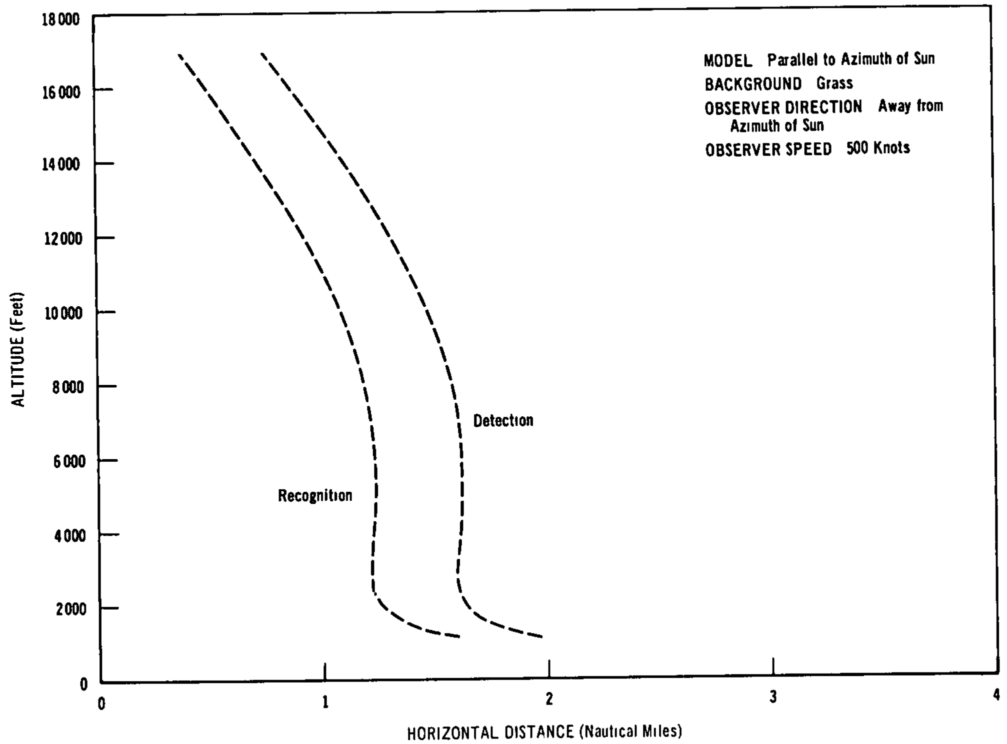


Fig. 22

II.2 Model Headed Perpendicular to the Azimuth of the Sun

The model is headed perpendicular to the azimuth of the sun as depicted in Fig. 2.

DIRT ROAD. The model is on a hard-packed yellow dirt road.

Low Speed. The aircraft is headed toward the sun in Fig. 23, flying at a speed of 250 knots. Aircraft headings of cross-sun and away from the sun are shown in Figs. 24 and 25.

High Speed. The aircraft is flying at a speed of 500 knots on three headings relative to the sun in Figs. 26 through 28.

MACADAM ROAD. The model is headed perpendicular to the azimuth of the sun on a macadam road.

Low Speed. The aircraft is flying at a speed of 250 knots on three headings in Figs. 29 through 31.

High Speed. The aircraft is flying at a speed of 500 knots on three headings in Figs. 32 through 34.

GRASS BESIDE ROAD. The model is headed perpendicular to the azimuth of the sun beside a road on verdant green grass.

Low Speed. The aircraft is flying at a speed of 250 knots on three headings relative to the sun in Figs. 35 through 37.

High Speed. The aircraft is flying at a speed of 500 knots on three headings relative to the sun in Figs. 38 through 40.

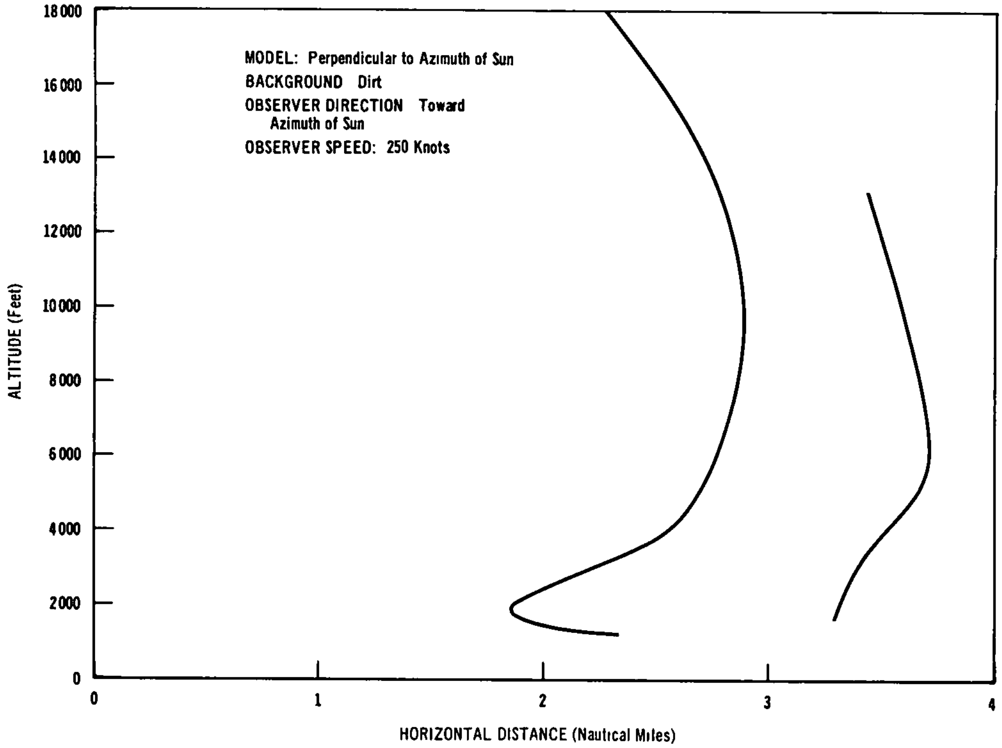


Fig. 23

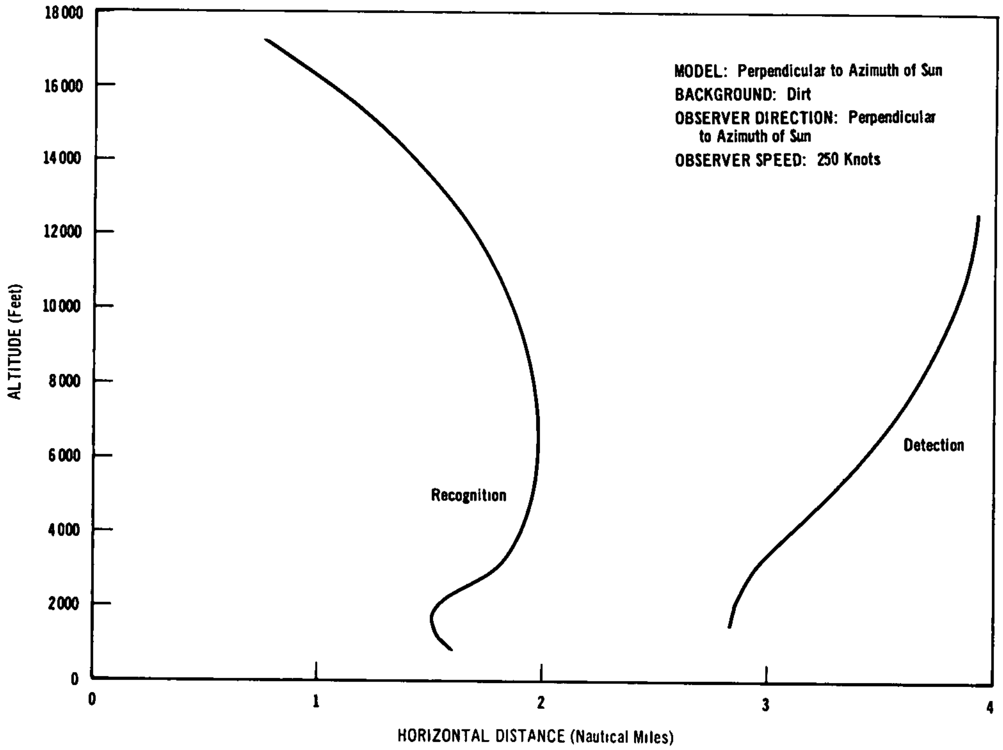


Fig. 24

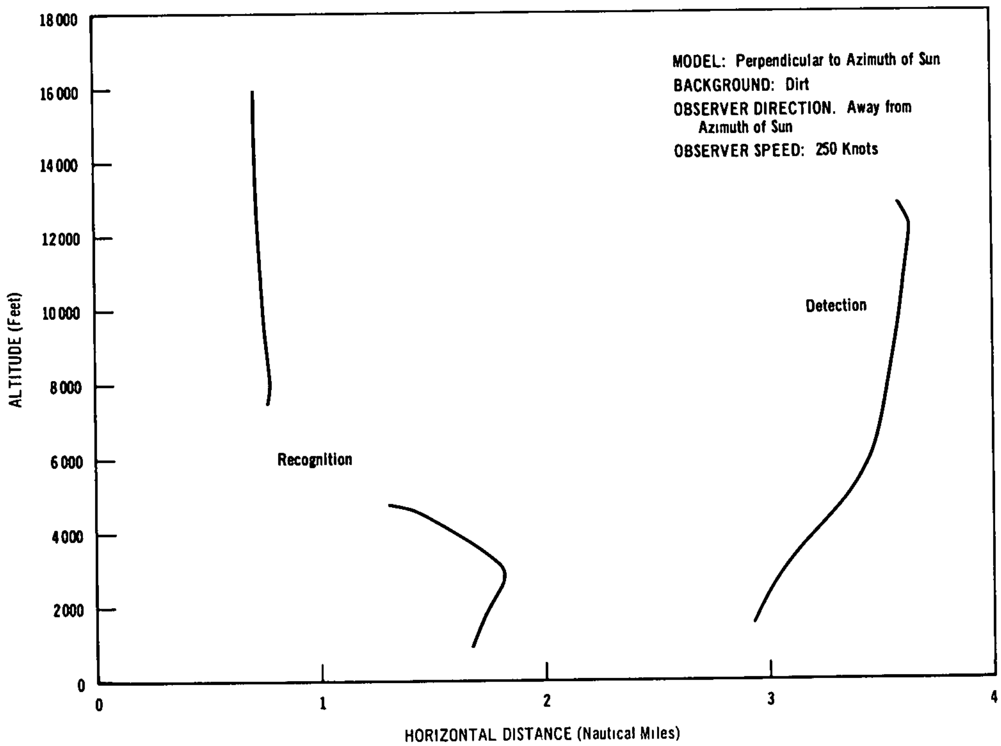

MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Dirt
OBSERVER DIRECTION. Away from Azimuth of Sun
OBSERVER SPEED: 250 Knots
Recognition
Detection
ALTITUDE (Feet)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 25

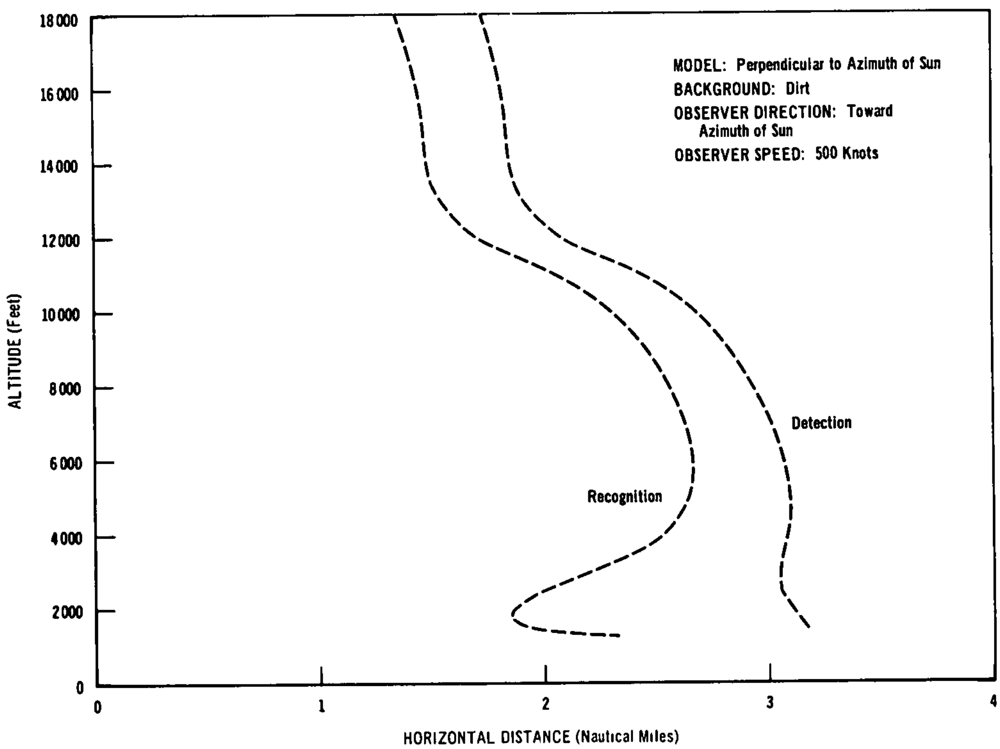
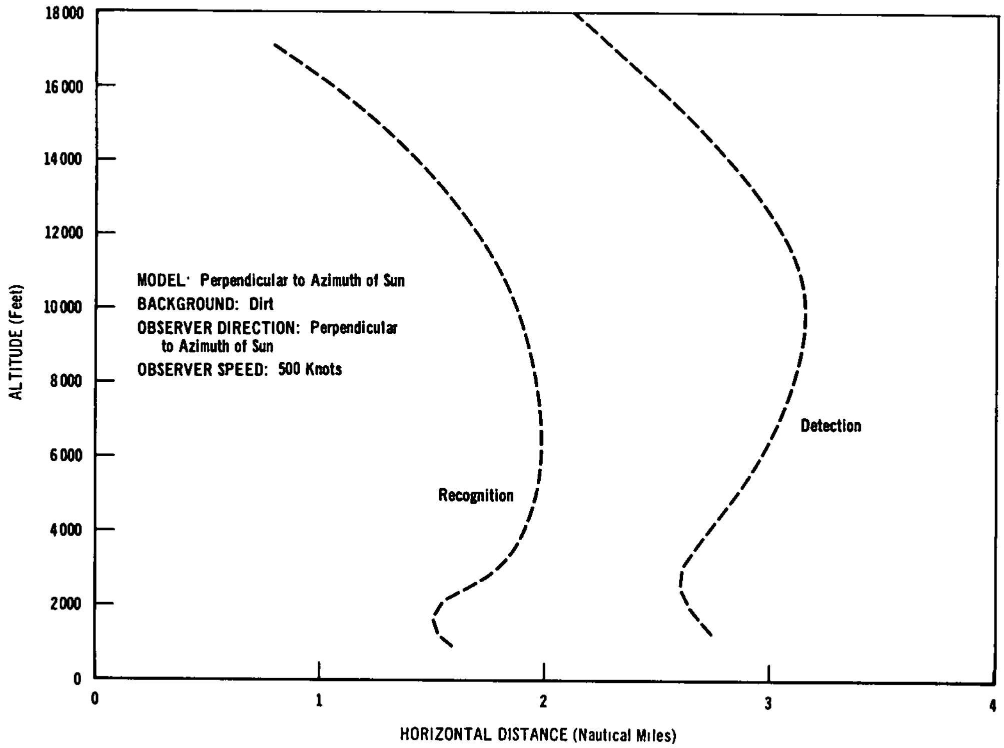
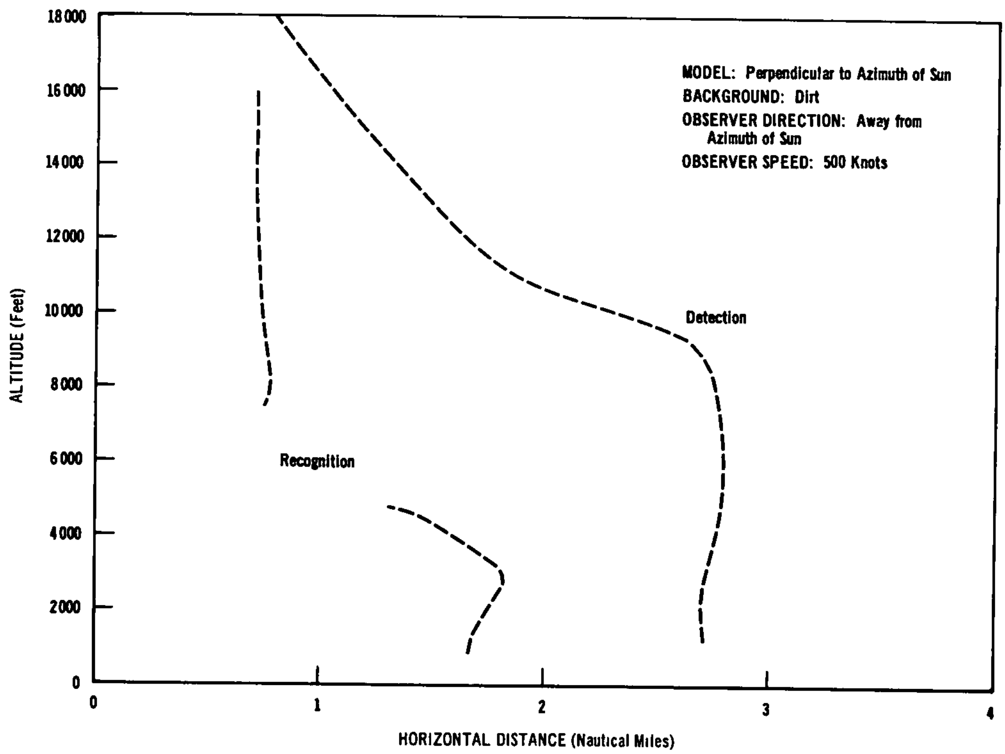

MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Dirt
OBSERVER DIRECTION: Toward Azimuth of Sun
OBSERVER SPEED: 500 Knots
Recognition
Detection
ALTITUDE (Feet)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 26



18000
16000
14000
12000
10000
8000
6000
4000
2000
0
ALTITUDE (Feet)
MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Dirt
OBSERVER DIRECTION: Perpendicular to Azimuth of Sun
OBSERVER SPEED: 500 Knots
Detection
Recognition
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 27



18000
16000
14000
12000
10000
8000
6000
4000
2000
0
ALTITUDE (Feet)
MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Dirt
OBSERVER DIRECTION: Away from Azimuth of Sun
OBSERVER SPEED: 500 Knots
Detection
Recognition
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 28

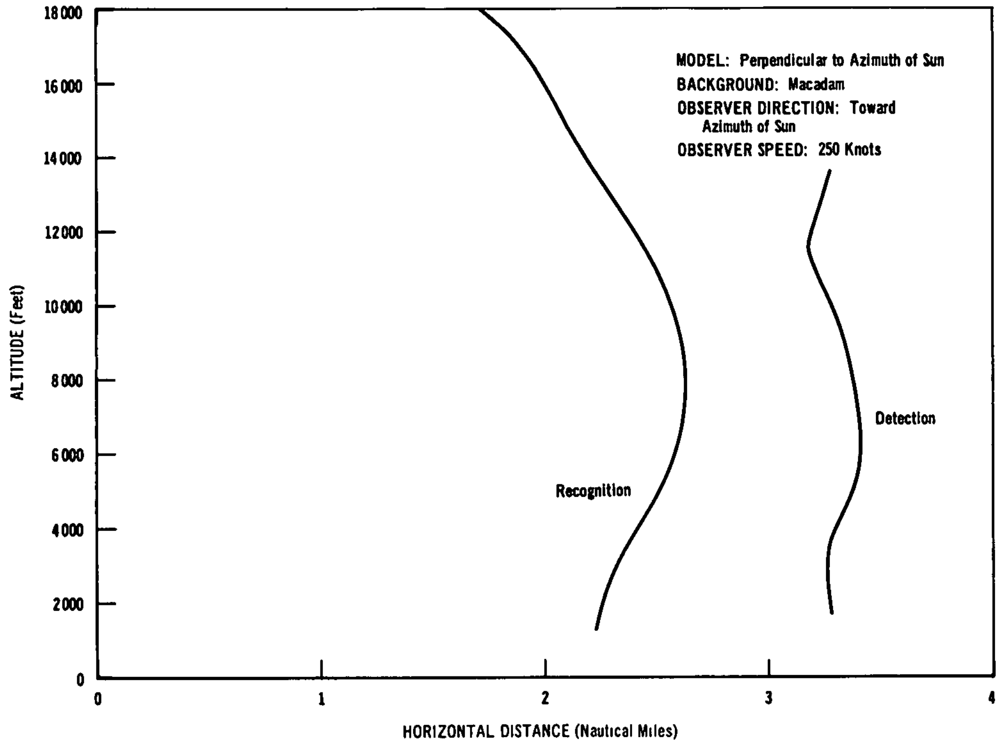

MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Macadam
OBSERVER DIRECTION: Toward Azimuth of Sun
OBSERVER SPEED: 250 Knots
Detection
Recognition
ALTITUDE (Feet)
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 29

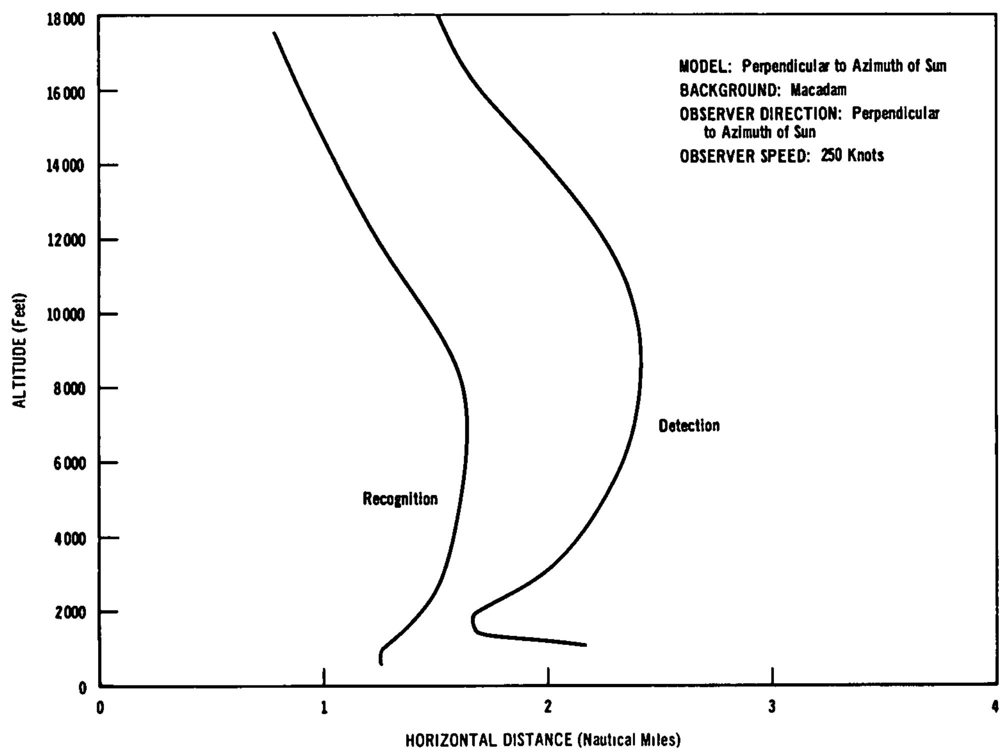

MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Macadam
OBSERVER DIRECTION: Perpendicular to Azimuth of Sun
OBSERVER SPEED: 250 Knots
Detection
Recognition
ALTITUDE (Feet)
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 30

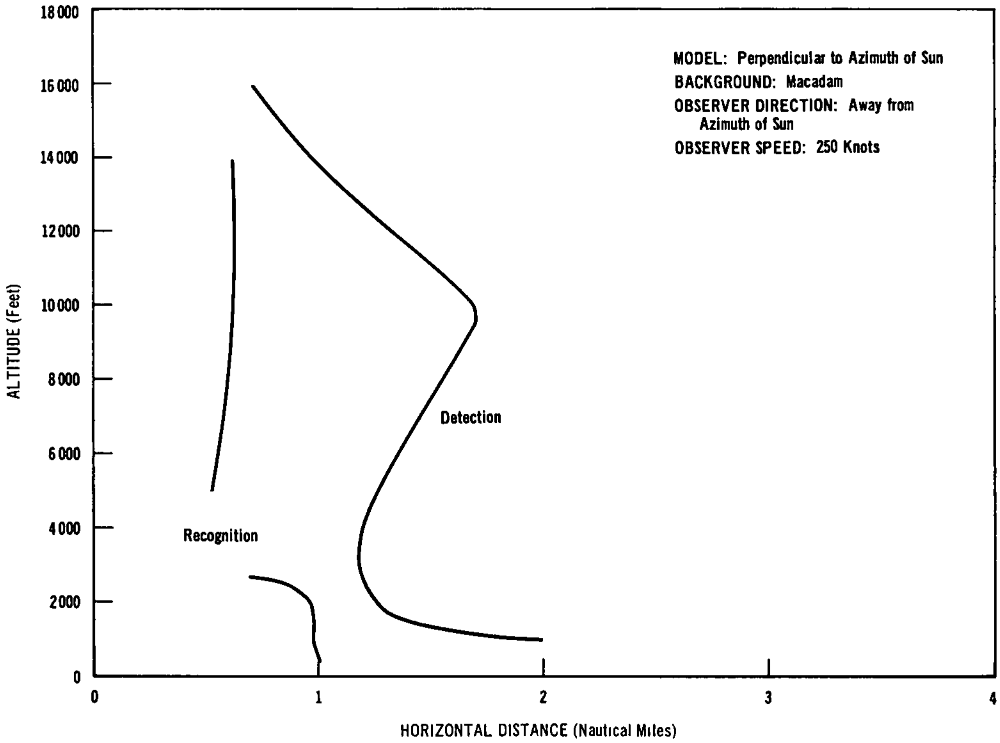

MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Macadam
OBSERVER DIRECTION: Away from Azimuth of Sun
OBSERVER SPEED: 250 Knots
Detection
Recognition
ALTITUDE (Feet)
HORIZONTAL DISTANCE (Nautical Miles)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4

Fig. 31

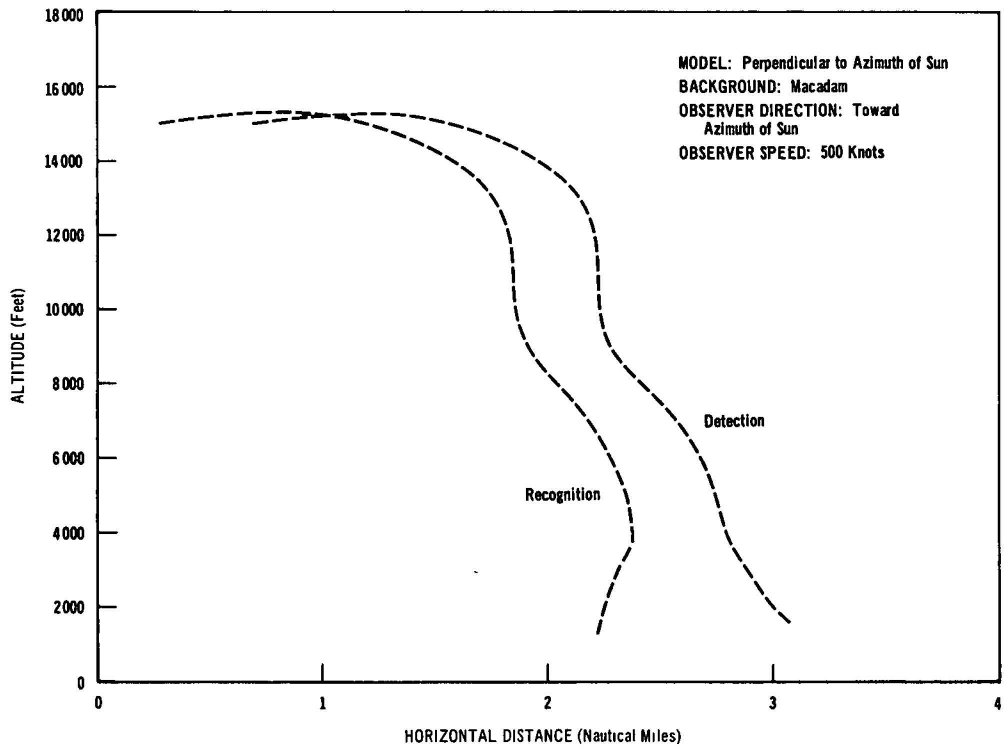

MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Macadam
OBSERVER DIRECTION: Toward Azimuth of Sun
OBSERVER SPEED: 500 Knots
Detection
Recognition
ALTITUDE (Feet)
HORIZONTAL DISTANCE (Nautical Miles)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4

Fig. 32

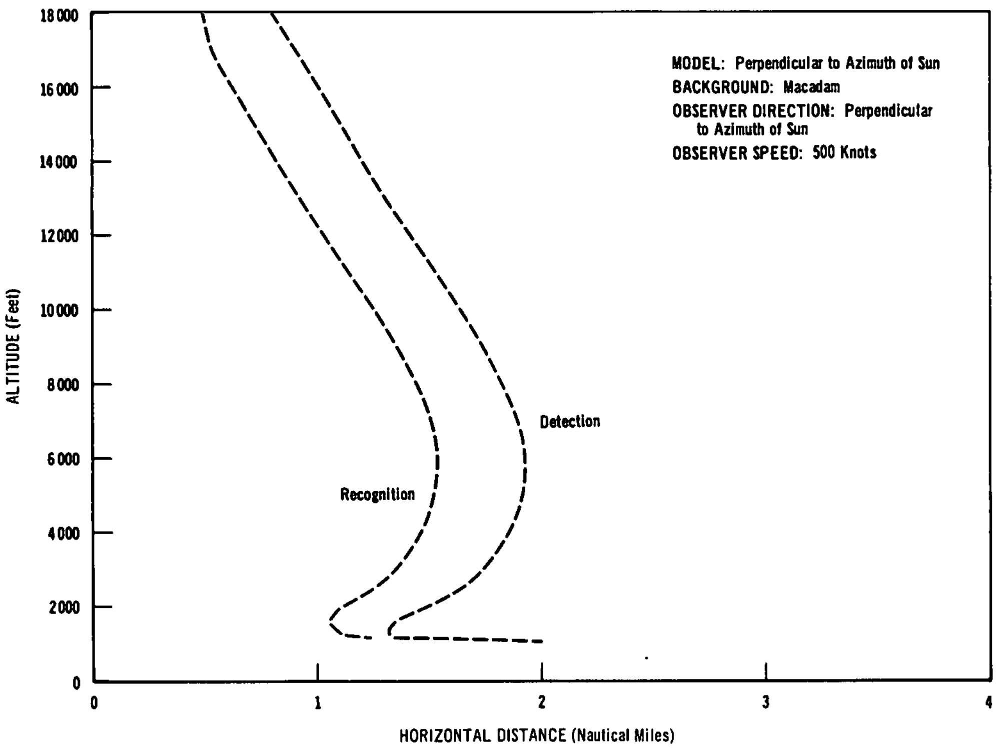

MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Macadam
OBSERVER DIRECTION: Perpendicular to Azimuth of Sun
OBSERVER SPEED: 500 Knots
Detection
Recognition
ALTITUDE (Feet)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 33

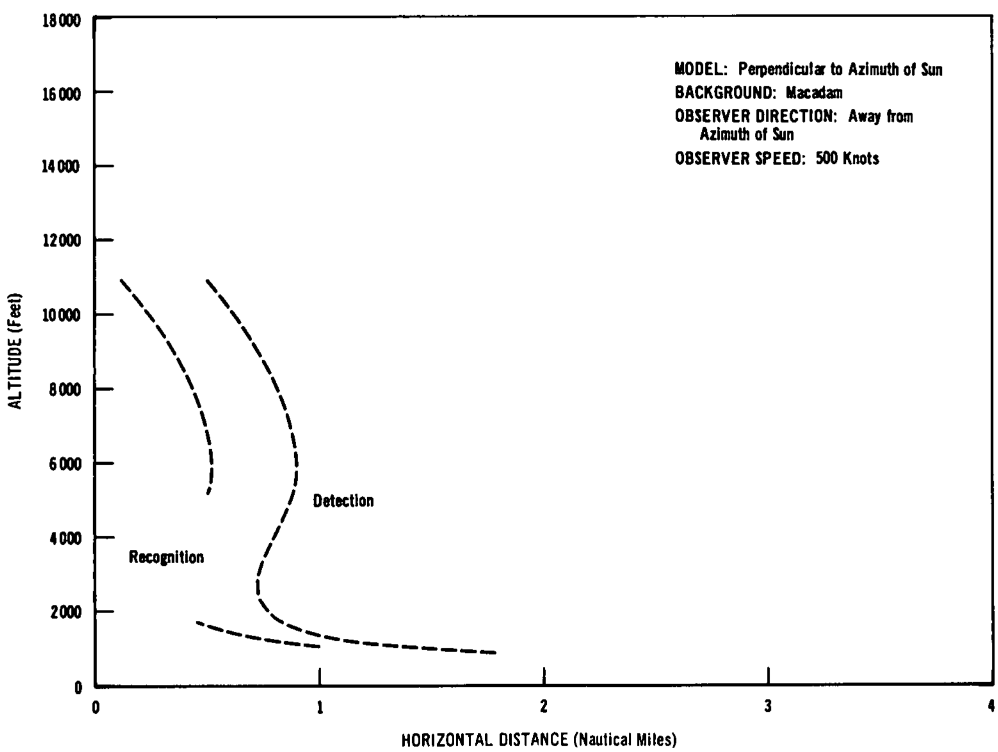

MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Macadam
OBSERVER DIRECTION: Away from Azimuth of Sun
OBSERVER SPEED: 500 Knots
Detection
Recognition
ALTITUDE (Feet)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 34

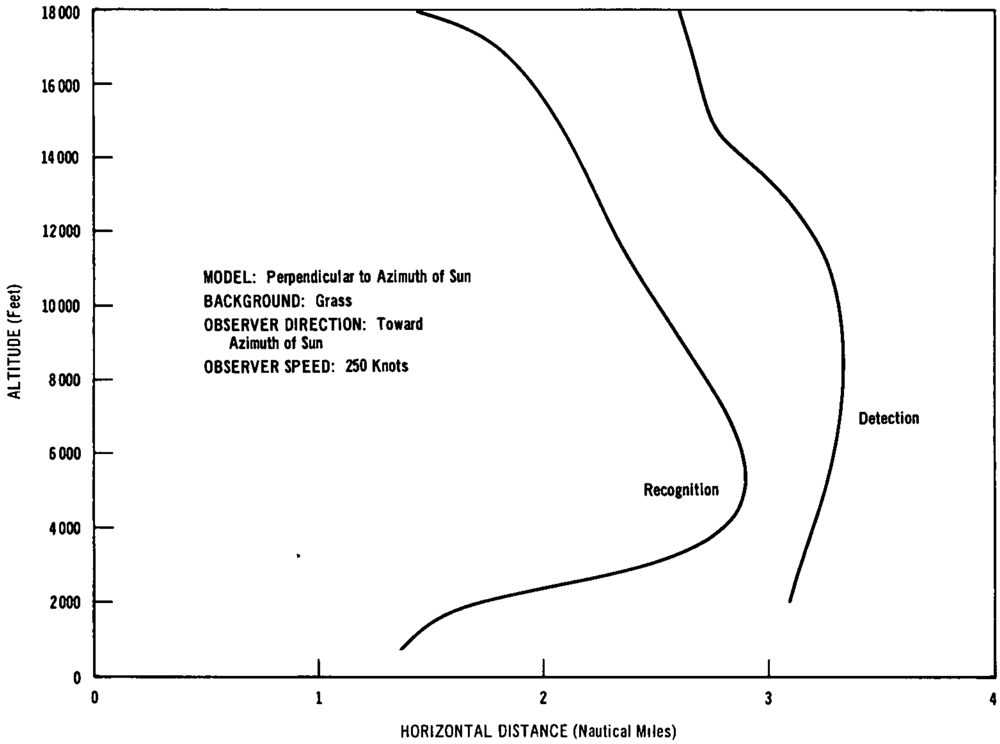

MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Grass
OBSERVER DIRECTION: Toward Azimuth of Sun
OBSERVER SPEED: 250 Knots
Detection
Recognition
ALTITUDE (Feet)
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 35

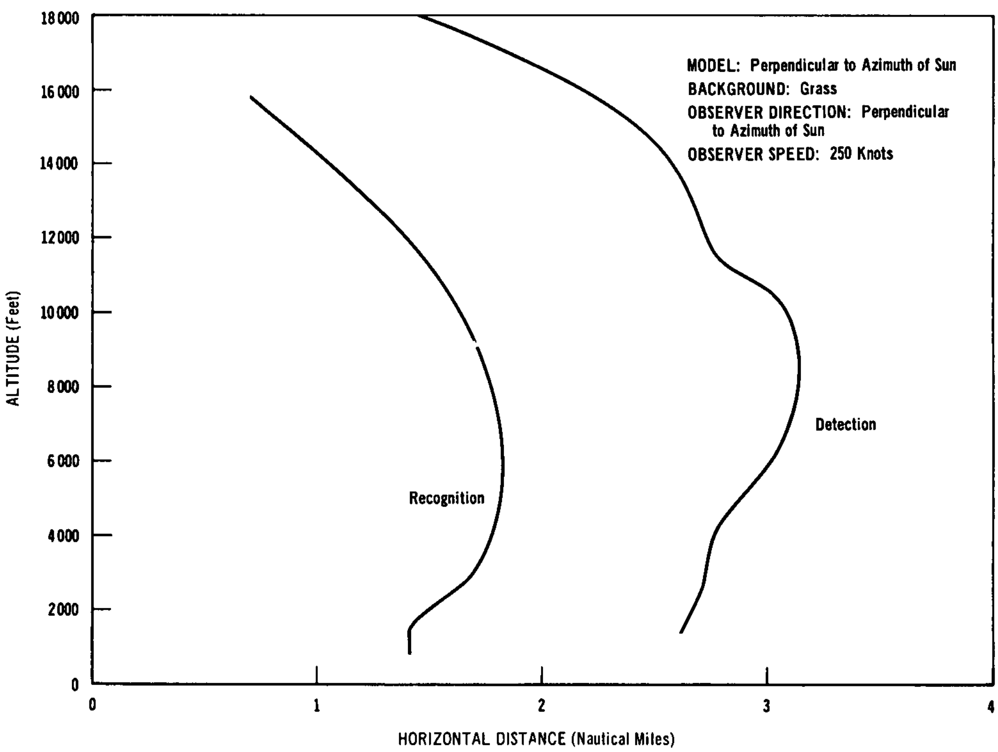

MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Grass
OBSERVER DIRECTION: Perpendicular to Azimuth of Sun
OBSERVER SPEED: 250 Knots
Detection
Recognition
ALTITUDE (Feet)
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 36

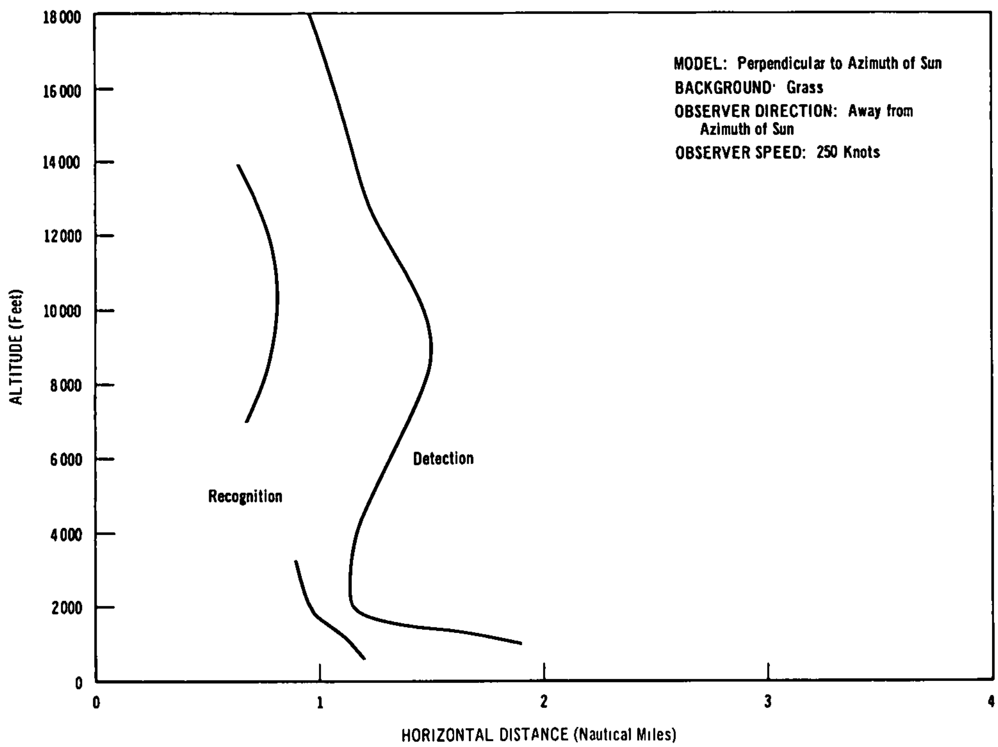

MODEL: Perpendicular to Azimuth of Sun
BACKGROUND· Grass
OBSERVER DIRECTION: Away from Azimuth of Sun
OBSERVER SPEED: 250 Knots
Detection
Recognition
ALTITUDE (Feet)
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 37

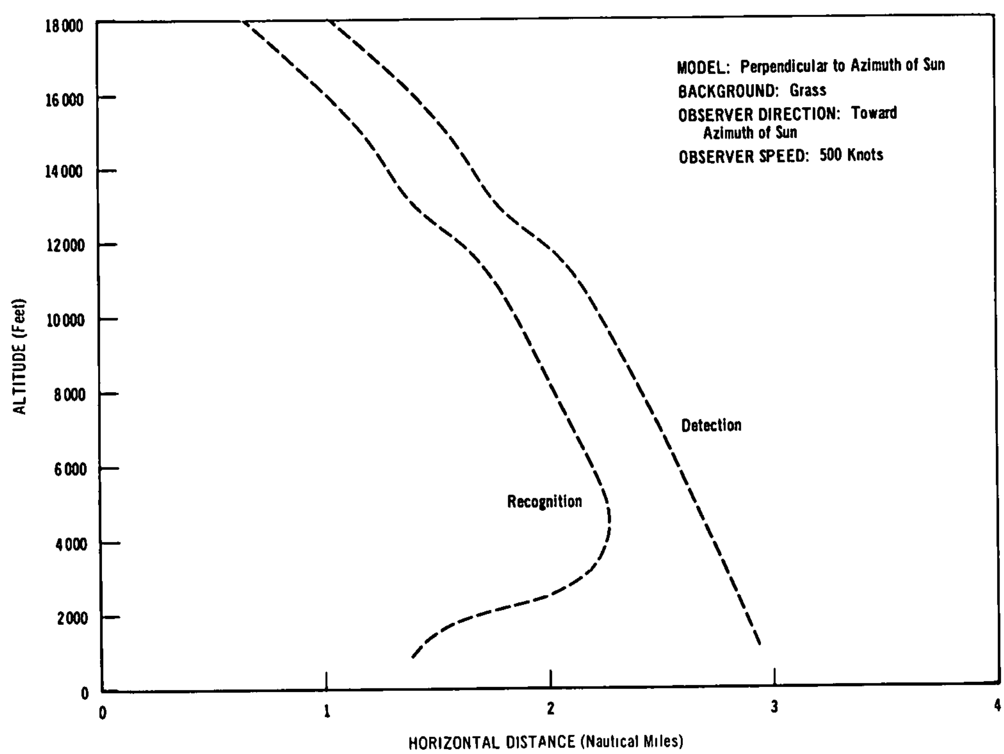

MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Grass
OBSERVER DIRECTION: Toward Azimuth of Sun
OBSERVER SPEED: 500 Knots
Detection
Recognition
ALTITUDE (Feet)
18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)

Fig. 38

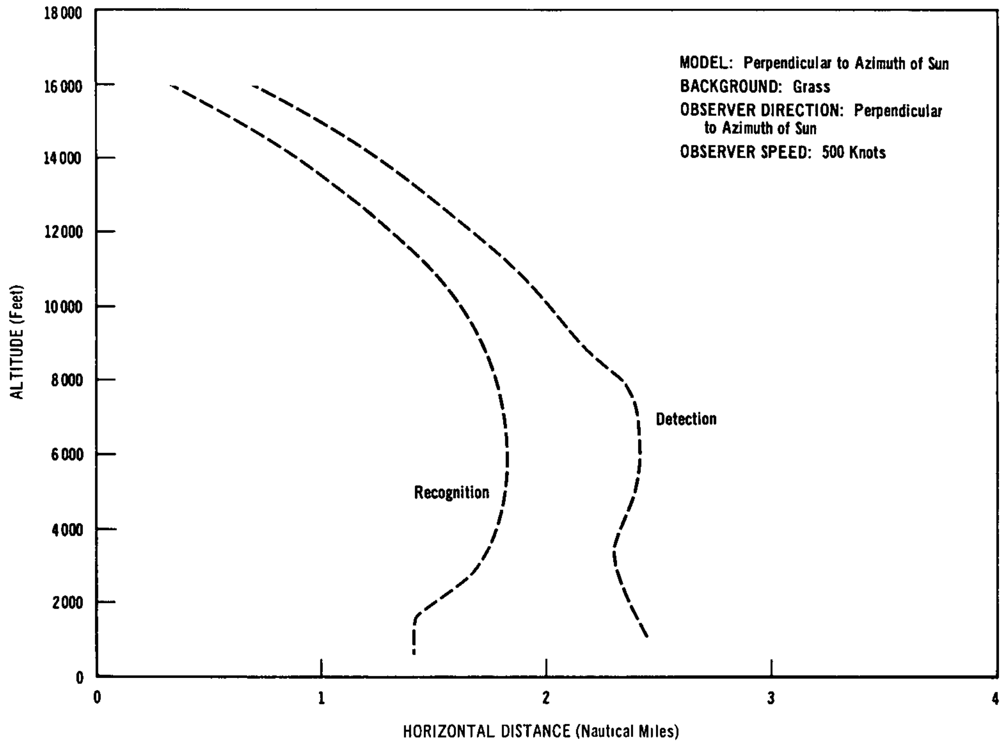

18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
ALTITUDE (Feet)
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)
MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Grass
OBSERVER DIRECTION: Perpendicular to Azimuth of Sun
OBSERVER SPEED: 500 Knots
Detection
Recognition

Fig. 39

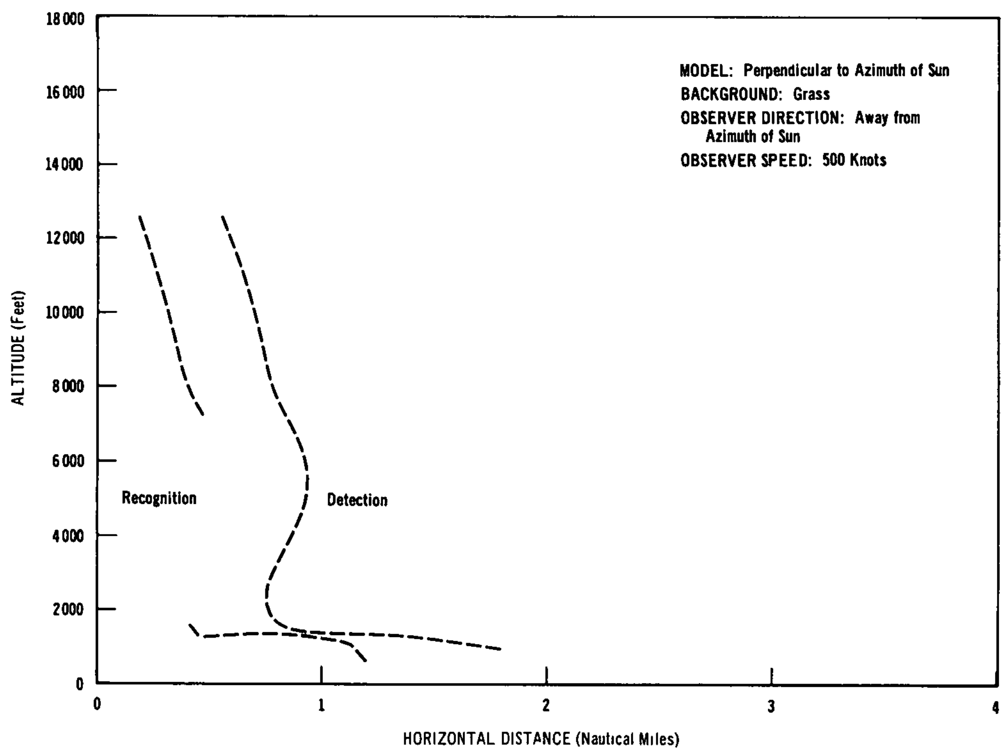

18 000
16 000
14 000
12 000
10 000
8 000
6 000
4 000
2000
0
ALTITUDE (Feet)
0
1
2
3
4
HORIZONTAL DISTANCE (Nautical Miles)
MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Grass
OBSERVER DIRECTION: Away from Azimuth of Sun
OBSERVER SPEED: 500 Knots
Recognition
Detection

Fig. 40

III. EFFECT OF OTHER FLIGHT PATTERNS, USE OF VISUAL AIDS, POSITIONAL INFORMATION ON THE OBJECT

The curves in Section II are based upon assuming straight and level flight before detection, and between the detection and recognition of the object. The observer was assumed to have an unobstructed view in the direction of the object and to be viewing with the unaided eye. The eyes of the observer are at a fixed angle of sight with the movement of the plane providing the search of the road. The model may be moving or still.

Four conditions, different from those above, were imposed on two sample cases in order to evaluate the effect of these different conditions on the detection and recognition of the object. The four conditions investigated are:

1. What is the effect on the recognition distance if the observer starts to dive after detection?

2. What is the effect on detection and/or recognition if the flight pattern is zig-zag, but level?

3. What is the effect on detection and/or recognition if the observer uses a visual aid?

4. What is the effect on detection and/or recognition if the observer is in possession of advance information on object location?

The two sample cases were chosen so as to represent the extremes in the relationship between the detection and recognition curves presented in Sec. II. Thus, all other cases should lie between these two.

The first sample case, where the recognition curve is close to the detection curve for both speeds, is for a model parallel to the azimuth of the sun, Figs. 19 and 22. The observer heading is away from the azimuth of the sun, and the model is on a grass background. The time criterion (2.7 seconds) for recognition predominates. In other words, detection of the presence of a turret is possible before the lapse of 2.7 seconds.

The second sample case, where the recognition curve is far from the detection curve and is the same for both speeds, is for a model perpendicular to the azimuth of the sun, Figs. 24 and 27. The observer heading is perpendicular to the azimuth of the sun, and the model is on a dirt road. The "sufficient detail" criterion for recognition predominates. That is to say, the turret could not be detected at a distance comparable to 2.7 seconds after detection of the model.

III.1 Diving Toward Object After Detection

What is the effect on the recognition distance if the observer starts to dive after detection?

For the first sample case, where the time criterion for recognition predominates, the problem of diving toward the object reduces to the difference in distance traveled during a dive and during level flight in 2.7 seconds. This is roughly illustrated in Fig. 41. The path is somewhat curved at the beginning of a dive, and there is some acceleration. The two (x) points noted on the dive

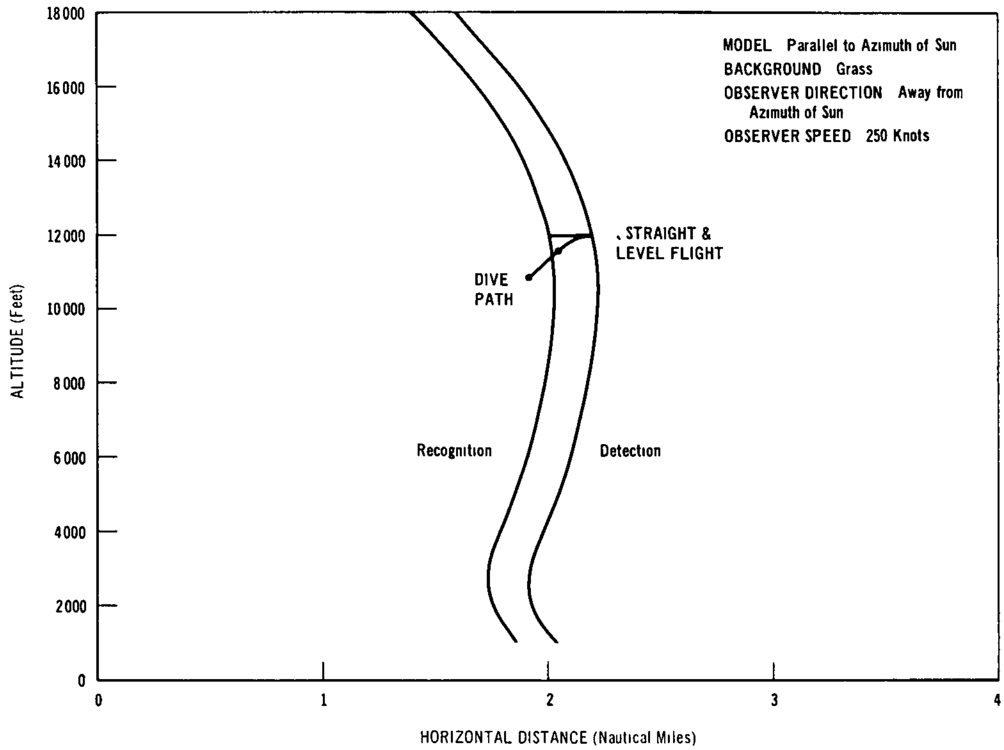


Fig. 41

path are: (1) for no acceleration and (2) for the distance traveled at twice the speed of the level flight. The answer probably lies somewhere in between, i.e.: the longer slant path between the detection and recognition curves is offset by the acceleration, and hence the effect on the recognition curve is negligible.

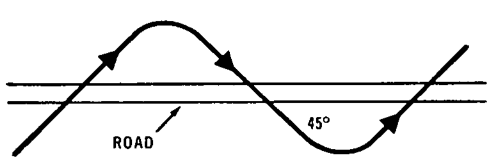
For the second sample case, time is not the deciding factor for recognition, and thus there is no difference in the recognition distances.

Therefore, all the recognition curves presented in Section 2 are applicable to straight and level flight or to diving after detection.

III.2 Zig-Zag Flight Pattern

What is the effect on detection and/or recognition if the flight pattern is zig-zag but level?

The zig-zag pattern was assumed to be as follows: to fly level across the road at a 45° angle to the road, turn, fly across at a 45° angle and repeat.



Detection

During zig-zag flight the observer was assumed to be searching the road. Thus, at the cross-over points he is looking in the direction of the road, which is the direction of the general travel of his plane for the entire pattern. Therefore, his speed relative to the road is reduced, and it will be possible for him to detect the object at slightly farther distances. This is illustrated in Fig. 42 (which utilizes the second sample case). A similar effect would be seen for sample case 1.

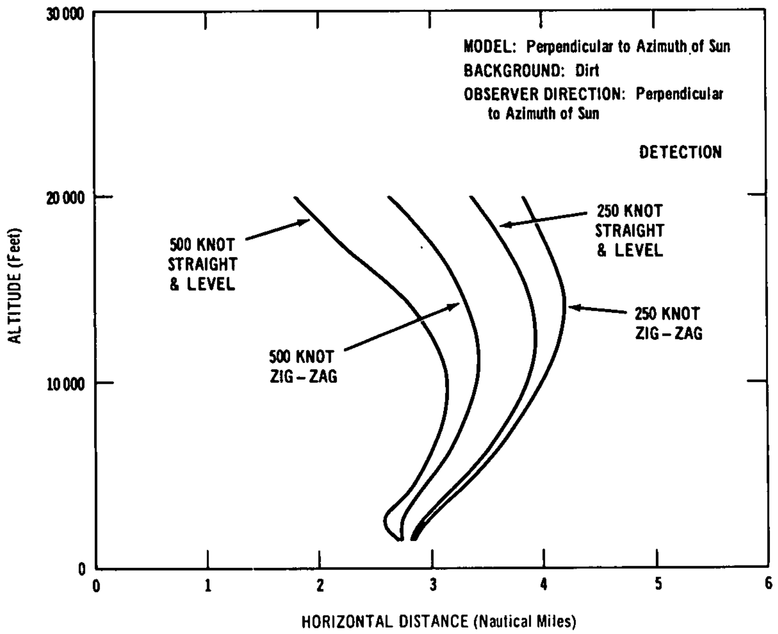


Fig. 42

Detection differences were not evaluated for other positions in the pattern, i.e., near the turn. During the actual turn it is possible that the observer cannot see the road at the most advantageous angle of sight. Thus the detection gain shown in Fig. 42 does not hold for the entire flight pattern and might actually be offset by loss in search time during the turn.

Note that the scale for this graph has been reduced to half the size of preceding ones, in order to depict the longer ranges.

Recognition

Recognition may possibly be aided by use of a zig-zag pattern by affording the observer changing views of the object, thus giving him more information.

III.3 Use of a Visual Aid

What is the effect on detection and/or recognition if the observer uses a visual aid?

The observer is assumed to use binoculars with 2X optics.

Detection

The use of a visual aid is applicable only in a constrained search situation. (The use of a visual aid in a non-constrained search situation may hinder by cutting down on the field of view.) An observer searching down a road at a fixed angle of view presents just such a constrained situation. He is assumed to know the optimum angle for search. Sample case 2 (Fig. 24) for 250 knots was chosen to illustrate the gain in detection range. As can be seen in Fig. 43, the increase varies with altitude (i.e., observer angle of view), Generally speaking, visual aids increase the maximum possible detection range at whatever speed the observer is traveling. The same general phenomenon will occur for sample case 1.

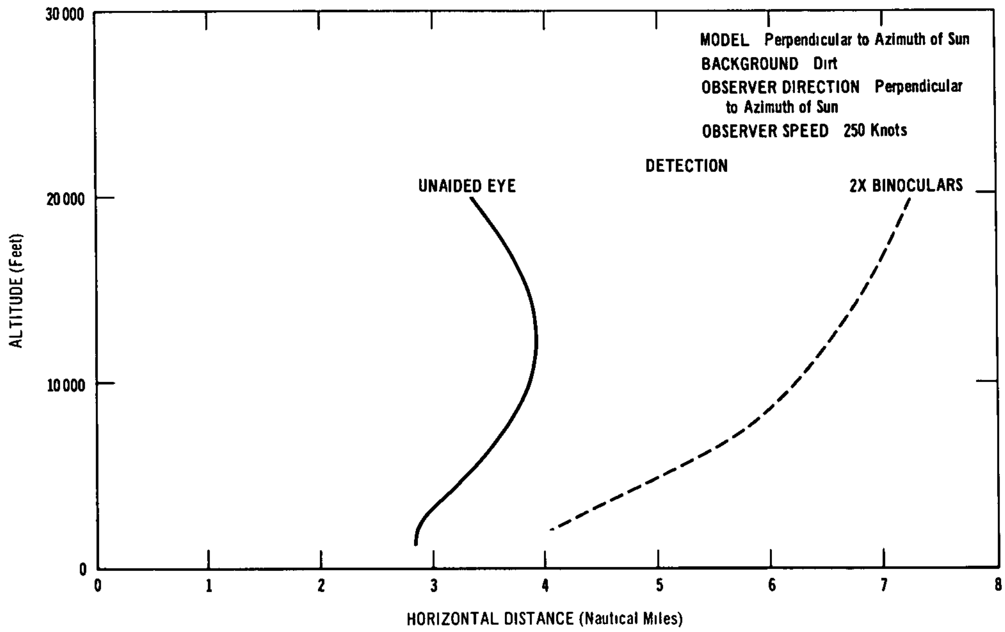


Fig. 43

Recognition

It is assumed that search is conducted without a visual aid as described in Sec. 1. After the object has been detected with the unaided eye, the observer switches to 2X binoculars to study the object. Sample case 2 for 250 knots was chosen to illustrate the increase in recognition range. (Fig. 44) Recognition is greatly aided in this case when "sufficient detail" is the predominant requirement.

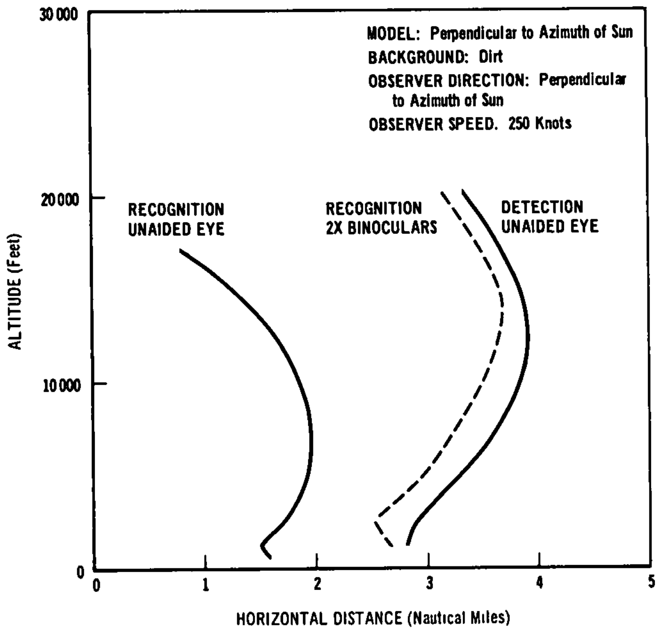


Fig. 44

For case 1, where the 2.7 second requirement predominates, there is no change in recognition range. Recognition occurs shortly after detection, and a visual aid does not help.

The general effect of using binoculars to aid recognition after detection has occurred is to bring the recognition curve closer to the detection curve.

III.4 Pre-knowledge of Object Location

What is the effect on detection and/or recognition if the observer is in possession of advance information on object location?

It is assumed that the observer had advance information that the object would be at a crossroads.

Detection

It is assumed that the crossroads is highly visible and that the observer will fixate on the crossroads until detection of the object occurs. Sample case 2 was chosen to illustrate the gain in detection range for both aircraft speeds. (Fig. 45) The same general gain would occur in sample case 1.

Recognition

For sample case 1 the recognition distances will be somewhat increased for the object at the crossroads since the recognition was primarily dependent upon a time lapse after detection.

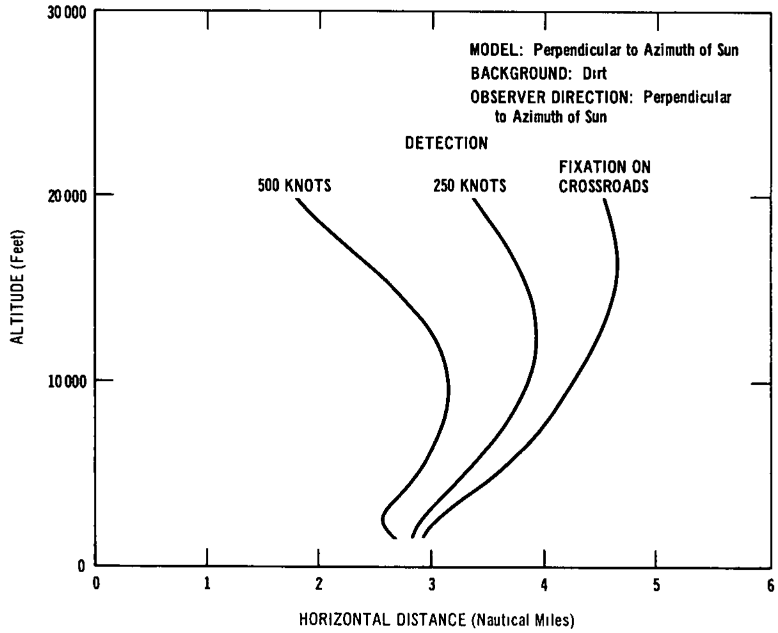


Fig. 45

For sample case 2, no change in recognition range will occur after detection of object at the crossroads. In this case, recognition occurs only when sufficient detail is available to the observer.

IV. DETECTION USING DISCRETE FIXATIONS

In all of Sec. II and most of Sec. III the eye of the observer was held at a fixed angle; thus the motion of the plane provided the area coverage. Also, the tip of the detection lobe was used for determining detection. This defines the best detection ranges that can be achieved when the static eye method of search is used. The purpose of this section is to explore the use of other search methods.

Another method of search which may be utilized is to fixate on the terrain for a short period of time, and then move to a new fixational position. Common fixation times during this type of search are 1/4 to 1/3 sec. in duration (Ref. 6). Three 1/4 sec. fixations per second can be made. (There is a small loss of time between looks.) In this method, a cross section of the detection lobe is used rather than the tip.

A visual detection lobe is a three-dimensional surface which bounds the volume within which a specified object can be detected with a stated probability. In the ensuing calculations a hard-shell lobe was used. That is, a level of probability was chosen representing confident detection, and the volume drawn. It was then assumed that within the volume detection would occur, and that outside the volume the object would not be seen.

In Fig. 46 is presented a cross section of the detection lobe for a circular object of uniform contrast against a background luminance of 75 ft-L, assuming no contrast reduction in the intervening path. The lobe is for 1/3 second fixations (Ref. 7) and is symmetrical about the fixational

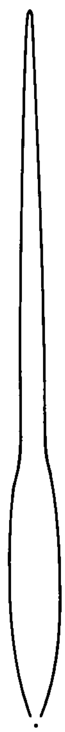
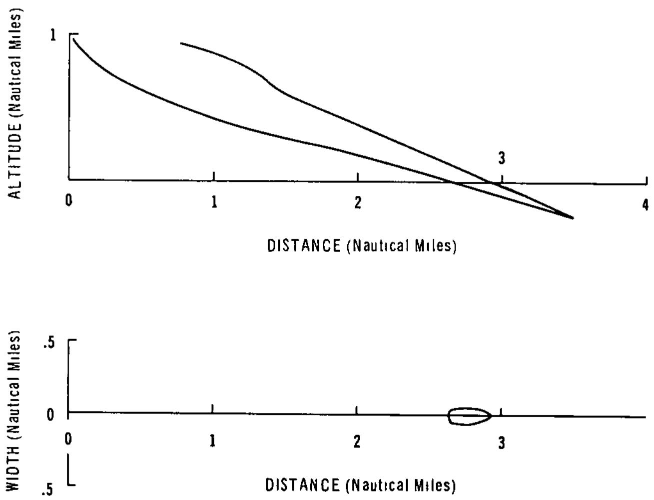


Fig. 46. Detection Lobe for Uniform Circular Object, Background Luminance 75 Ft-L, No Contrast Attenuation; 1/3 Second Fixation.

axis. Detection lobes incorporate the features of the object, background, atmosphere and visual system. Thus for a complex object viewed on a road, screened by the intervening atmosphere, lobes are non-symmetric.

The case selected to illustrate the use of fixational search methods was that of a model heading perpendicular to the sun on grass at the edge of the road with the observer heading cross sun at the two speeds, 250 knots and 500 knots. The comparable case, using the static eye, was given in Sec. II for the two speeds as Figs. 36 and 39. This case was chosen since both the detection and recognition curves were somewhat typical, being neither the shortest nor the longest ranges found for the series of conditions covered in Sec. II.

The observer was assumed for this example to be in a plane flying at 6 000 feet. In Fig. 47 is presented the vertical section of detection lobe and the horizontal intersection of the lobe with ground level. The path of sight (fixational center) is at a depression angle of 19° (zenith angle of 109°).

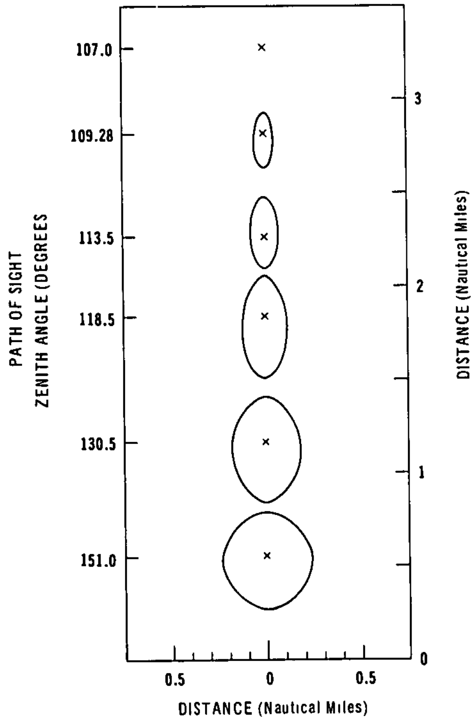


MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Grass
OBSERVER DIRECTION: Perpendicular to Azimuth of Sun
OBSERVER ALTITUDE: 6000 ft.
OBSERVER PATH OF SIGHT: Zenith Angle 109°

Fig. 47. Lobe and intersection for 1/3 second fixation

The lobe was defined by assuming that the eye can move along the axis of the lobe and that the object only moves on the surface of the earth. The vertical section of the lobe illustrates that if the observer were 2 000 feet higher (at 8 000 feet) the lobe would not quite reach the surface of the earth at this angle of sight, and the object could not be seen.

Actually in this search situation, the observer is flying at one horizontal plane at 6 000 feet, and the object is on the horizontal plane of the earth. Therefore, it is the lobe intersections with the object plane (earth) that are pertinent to the evaluation of the search problem. Thus, the picture of the lobe intersections at a series of paths of sight further defines the search problem. This is depicted in Fig. 48. At the smallest zenith angle the lobe intersection has no real area, for the object is visible only foveally at the tip of the detection lobe.

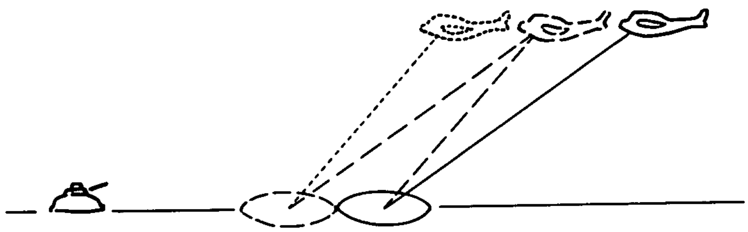


MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Grass
OBSERVER DIRECTION: Perpendicular to Azimuth of Sun
OBSERVER ALTITUDE: 6000 ft.

Fig. 48. Lobe intersection with object plane for various paths of sight, 1/3 second fixations.

IV.1 Searching Down a Road

If the object is on a road or at the edge of a road, one method of search is to fixate on the road for 1/3 sec., then to move the fixation to a point just ahead. An angle of sight can be determined for a given aircraft speed which will provide full coverage of the road with the detection lobe intersections, as illustrated in Fig. 49. This defines the maximal detection distance for complete search coverage, using this method of search.



1/3 SECOND GLIMPSE FIXATED ON TERRAIN

Fig. 49

In Fig. 50 is shown a comparison of the maximal detection range for static eye search, compared to the discrete fixational search for an observer flying at 250 knots. The detection ranges for the observer at 6 000 feet altitude are very similar, for the two methods of search for an observer heading cross sun looking along a road for the object on the grass at the edge of the road.

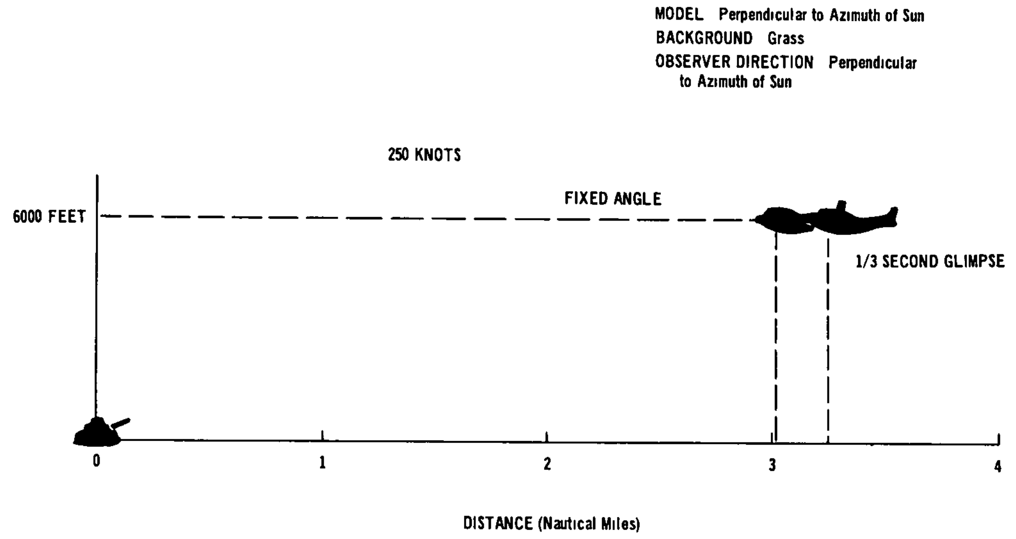


Fig. 50

For the observer flying at a speed of 500 knots, the gain obtained by using discrete glimpses is more dramatic, as illustrated in Fig. 51. The faster speed handicaps the observer who is searching at a fixed angle of sight, but makes very little difference to the observer making 1/3 second glimpses. The eye lobe intersection enlarges rapidly with a slightly steeper angle of sight to twice the length necessary for the slower 250 knot speed.

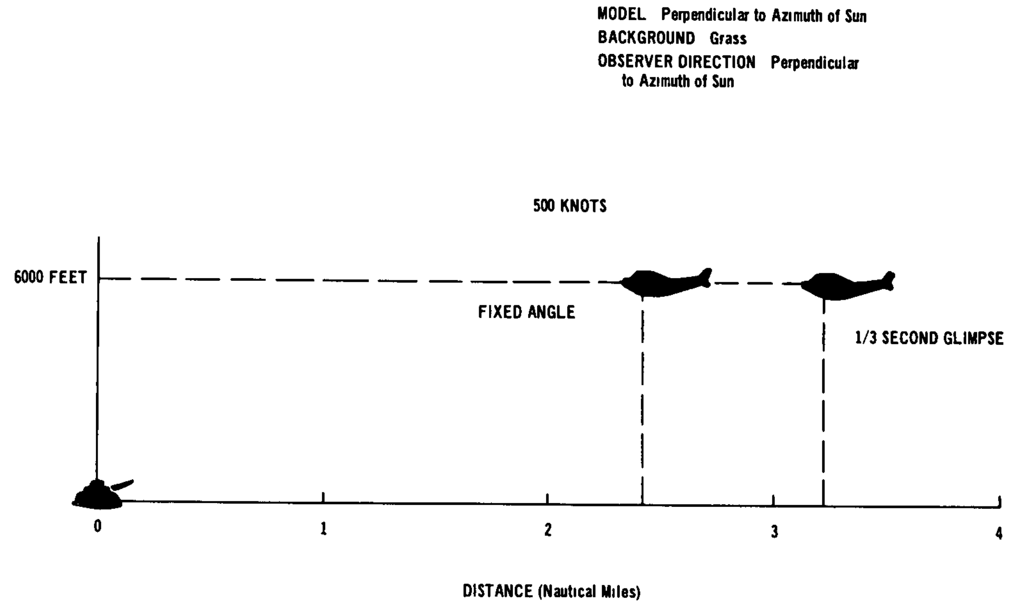


Fig. 51

IV.2 Model in an Uncluttered Field or Moving in a Cluttered Field

If there is no clutter, or distracting secondary objects in a large field, or if the object is moving fast enough for the movement to be discernible from 6 000 feet,[5] search for the object can successfully be accomplished by discrete glimpses of 1/3 second at a fixed zenith angle of sight, scanning azimuthally. This method is illustrated in Fig. 52. It is assumed that the observer can maximize the search by overlapping the lobe intersections, so that a width of corridor can be searched with 100% probability of detection.

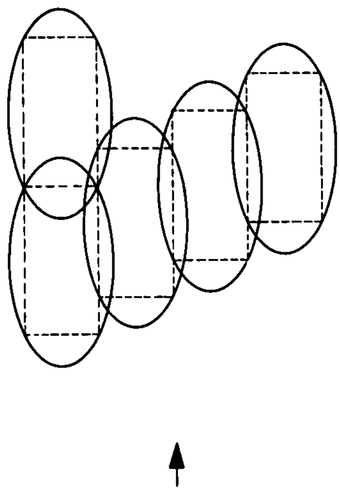


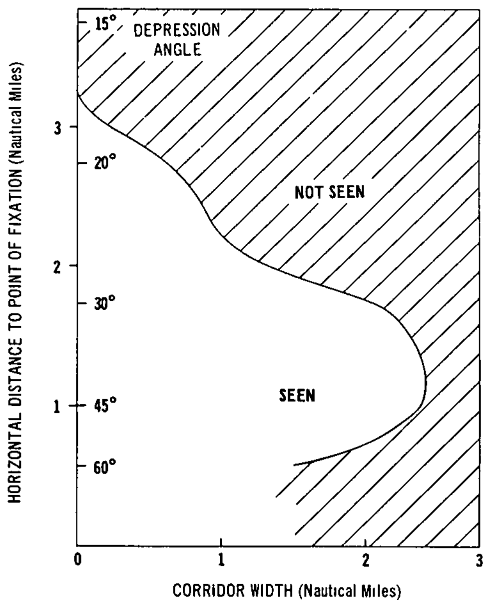
Fig. 52. Ground plane lobe intersections for moving observer making fixations at a fixed zenith angle for a series of azimuths of path of sight.

A map of the terrain beneath which can be covered by search at different angles of sight while flying at 250 knots is presented in Fig. 53. This is the same case as has been previously described: the model is in a grassy field, both the plane and model are headed cross sun, but in opposing directions.

The decreasing corridor width, from 45° to 60° depression angle, is due to having more than sufficient time to scan 180° in azimuth. The width of corridor covered is limited by the radius of the scan, since a scan is assumed to be at a fixed depression angle. Such coverage would only be possible, however, if the cockpit of the observing plane has an unlimited field of view. If, for example, a cockpit cuts off at or by a 30° depression angle, the greatest depression of the line of sight must not exceed 26° if the corresponding lobe intersection is not limited by the cockpit. It must be remembered that the 26° value pertains only to the particular conditions detailed above.

In Fig. 54 is provided a plot of probability of detection versus corridor width for the 26° depression angle of sight, which provides maximal search coverage from a cockpit with a 30° depression angle cutoff. The observer is capable of covering a definable corridor with 100% probability of detection. Attempts to cover a wider corridor only serve to produce gaps in the scan and, thereby, to reduce the probability of detection.

[5]The model moving at 25 mph (21.7 knots) headed toward the observer would have a just discernible angular velocity at this altitude for an observer flying at 250 knots.



MODEL: Perpendicular to Azimuth of Sun
BACKGROUND: Grass
OBSERVER DIRECTION: Perpendicular to Azimuth of Sun
OBWERVER ALTITUDE: 6000 ft.
OBSERVER SPEED: 250 Knots

Fig. 53

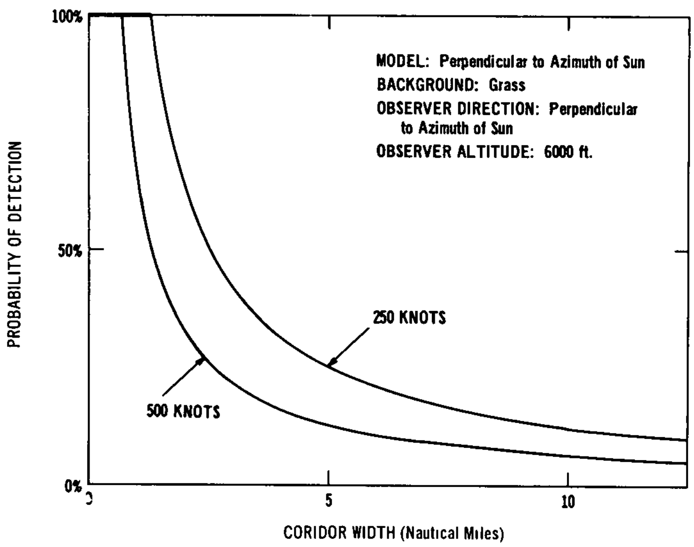


Fig. 54

V. REFERENCES

1. Jacqueline I. Gordon and Peggy V. Church, "Sky Luminances and the Directional Luminous Reflectances of Objects and Backgrounds for a Moderately High Sun," Appl. Optics **5**, 793-801 (1964); also SIO Ref. 64-5 (1964).

2. S. Q. Duntley, **et al.**, Appl. Optics **3**, 549-599 (1964); also SIO Ref. 64-3 (1964).

3. S. Q. Duntley, "The Limiting Capabilities of Unaided Human Vision in Aerial Reconnaissance," Armed Forces-National Research Council, Vision Committee Secretariat, Ann Arbor, Michigan (Jan. 1953).

4. Ailene Morris, "Pattern Target Analysis," Univ. of Calif., Scripps Inst. of Oceanog., Visibility Lab., SIO Ref. 59-62 (1959).

5. Reference 3.

6. A. Ford, C. T. White and M. Lichtenstein, "Analysis of Eye Movements During Free Search," J. Opt. Soc. Am. **49**, 287-292 (1959).

7. John H. Taylor, "Contrast Thresholds as a Function of Retinal Position and Target Size for the Light-Adapted Eye," Univ. of Calif., Scripps Inst. of Oceanog., Visibility Lab., SIO Ref. 61-10 (Mar. 1961).

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

Visibility Laboratory
University of California
San Diego, California 92152

2a. REPORT SECURITY CLASSIFICATION

UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

AN EXAMPLE OF AN EARLY TECHNIQUE FOR VISIBILITY CALCULATIONS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (Last name, first name, initial)

Gordon, Jacqueline I. and Church, Peggy V.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
May 1968	37	7

8a. CONTRACT OR GRANT NO.

NObs-84075

b. PROJECT NO.

c. Assignment 9

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

SIO Ref. 68-13

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

Naval Ship Systems Command
Department of the Navy
Washington, D. C. 20360

13. ABSTRACT

This report describes results from previously unreported visibility calculations made in the spring of 1957, of aerial observer sighting and recognition ranges for a complex object. The object is a toy model scaled to vehicle size, lighted by sun and sky, and screened by the real atmosphere. Most of the ranges are presented graphically as a function of altitude for one search method; viz, visual fixation at the optimal angle of sight, area coverage being provided by the forward movement of the plane. Sample results are also given for other methods of search.

DD FORM 1 JAN 64 1473 0101-807-6800

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Visibility Calculations Aerial Sighting Predictions Search						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8c, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
______________________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
______________________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
______________________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, *or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.