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MASTERSIMULATED MONITOR DISPLAY FOR CCTV

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ABSTRACT

Two computer programs have been developed which generate a two-dimensional graphic perspective of the video output produced by a Closed Circuit Television (CCTV) camera. Both programs were primarily written to produce a graphic display simulating the field-of-view (FOV) of a perimeter assessment system as seen on a CCTV monitor. The original program was developed for use on a Tektronix 4054 desktop computer; however, the usefulness of this graphic display program led to the development of a similar program for a Hewlett-Packard 9845B desktop computer. After entry of various input parameters, such as, camera lens and orientation, the programs automatically calculate and graphically plot the locations of various items, e.g., fences, an assessment zone, running men, and intrusion detection sensors. Numerous special effects can be generated to simulate such things as roads, interior walls, or sides of buildings. Other objects can be digitized and entered into permanent memory similar to the running men. With this type of simulated monitor perspective, proposed camera locations with respect to fences and a particular assessment zone can be rapidly evaluated without the costly time delays and expenditures associated with field evaluation.

INTRODUCTION

Ongoing programs to upgrade the safeguarding of Special Nuclear Material (SNM) are being conducted at various facilities worldwide. Thus far, upgrading requirements have included the relocating and consolidation of SNM processing and storage, improved perimeter lighting, the installation of intrusion detection and assessments systems, entry control systems, and many other measures. Assessment is usually provided through CCTV coverage of each sector, complemented by visual surveillance from towers or roving patrols. The feasibility of the CCTV system both operationally and economically is a major consideration in the security upgrade measures.

A major problem associated with the design of CCTV assessment systems is the determination of the video camera parameters to produce an optimum FOV of the area to be assessed. In the past, detailed geometrical calculations could be performed to calculate the FOV parameters, but in many cases a movable camera platform, such as a bucket truck, was used to empirically determine the optimum parameters. The perimeter to be assessed is often being redesigned along with the CCTV system to be installed; therefore, the CCTV designer needed a means to rapidly optimize the FOV parameter and visualize a camera's FOV of a typical perimeter zone not yet in existence. If the budget permitted, test beds could be constructed and actual field tests could be performed to determine the optimum locations of the cameras.

Another method used to determine the locations of the cameras was to use templates of the angular FOV overlaid on the facility site drawings. Unfortunately, this type of designing did not provide the FOV perspective that would be encountered in the actual assessment system.

In 1978 several hand sketches were calculated and drawn of different perimeters simulating the perspective FOV a particular camera and lens would produce on a video monitor. The usefulness of the sketches led to the development of a computer program which, when given certain parameters of the CCTV camera and location, would automatically produce a computer graphic simulated display of a video monitor. With this computer simulation, a designer could now study various camera locations with respect to fences, sensors, and a particular assessment zone without spending costly time and money to actually build a working model of the perimeter to be upgraded. Since the first working program was written, many modifications and improvements have been added to create the version presented in this paper. The present computer program is written in Tektronix Basic for use on a 4054 desktop computer.

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Since the original program proved to be a very useful design tool, a second program was written and developed with similar capability but using a Hewlett Packard 9845B desktop computer. The two programs were developed independent of one another and vary in capabilities. The primary reason for the differences is due to the structure of the two desktop computers. The Tektronix 4054 computer uses a direct storage CRT which allows the program to calculate and plot without using computer memory to store the data plotted. The Hewlett-Packard 9848B computer uses a raster scan refresh CRT which requires the program to remember the data being plotted. A brief discussion concerning the capabilities of both programs is presented in this paper.

PROGRAM FOR THE TEXTRONIX 4054

This program is written in Textronix extended Basic for use on a Textronix 4054 desktop computer with 64K bytes total memory and a Textronix 4631 Hard Copy unit. All input parameters are entered under program control. The program is self-prompting, i.e., it automatically requests the user to input the required data for plotting each object in the monitor display simulation. All parameter locations are measured with respect to the origin which is also the camera location as shown in Figure 1. Objects, such as fences, can be located anywhere in the four quadrants shown in Figure 1 and the camera can be panned + or - 180° to view these objects. The positive y-axis is defined as zero pan degrees.

This graphic simulation program uses the following input parameters:

- Camera - focal length, height, pan angle, tilt angle
- Assessment Zone - length, width, location, near edge, angle
- Fence - number, location, height, pole width and spacing, start, length, angle
- Pole - number, location, height, width, spacing, start, length, angle
- Sensor - number, location, start, length, offset, angle
- Concertina Rolls - number, location, diameter, spacing, angle
- Running Men - number, location, spacing, start, length, angle
- Elevation Charges - number, location, slope

Once all parameters are entered, any particular value can be changed without effecting the other parameters. The camera's location can also be changed and all other input parameters'

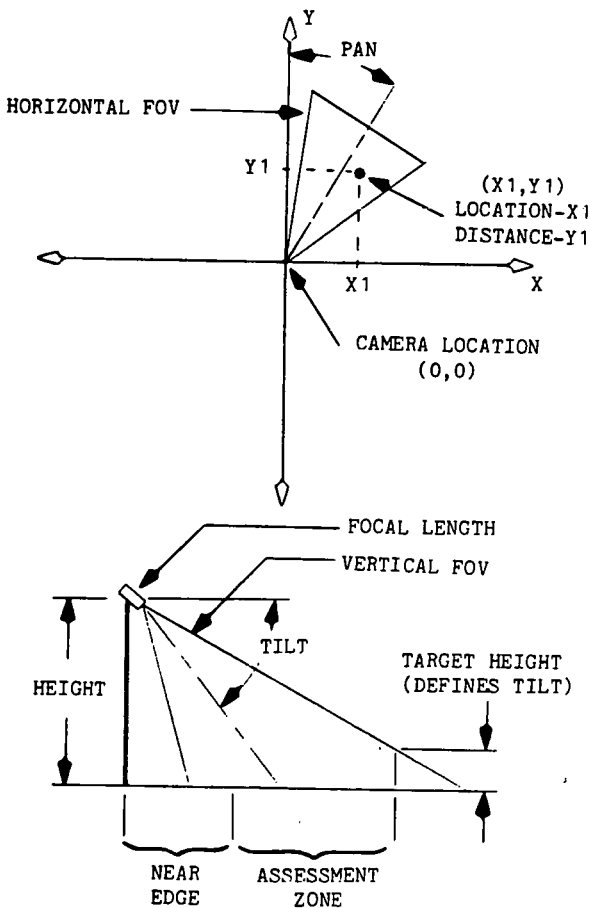


Figure 1
FOV and Input Parameters

relative distances will be updated automatically.

After entry of the input parameters and all changes are complete, the program automatically lists the input parameters and also calculates and lists the following FOV data:

- Horizontal FOV angle
- Vertical FOV angle
- Camera Tilt angle
- Camera Pan angle
- Distance to far edge of sector
- Width at far edge
- Distance to closest edge of sector
- Width at closest edge
- Minimum FOV distance
- Width at minimum distance
- Maximum FOV distance
- Width at maximum distance
- Resolution at far edge of sector
- Sector percentage of monitor

Using the calculated data and the input parameters, the program locates the defined objects with respect to the camera location, orientation, and lens. A point-by-point two dimensional graphic perspective of the FOV is generated on the Tektronix 4054 CRT. Each point being plotted can also be stored on magnetic tape for future use. While plotting the objects in the FOV of the camera, the program is also locating those objects outside the FOV. Therefore, there is a scaling factor in the program which allows the user to view objects outside the FOV of the camera. This feature is helpful in determining the final orientation of a particular camera and lens.

To have a continuously operating perimeter CCTV system, the existing perimeter lighting usually requires upgrading or complete redesign. Adequate scene illumination is critical for proper assessment with a CCTV system. Uniformity and minimum illumination levels are critical in the design of a CCTV lighting system. With the horizontal illumination (in footcandles) for a particular assessment zone, the program can generate a graphic simulation perspective which illustrates the ground illuminated contour patterns as seen on a video monitor. This lighting routine is presently written for lighting systems producing horizontal illumination levels between 0 to 3 footcandles. Higher illumination levels are not resolved by the program.

Even though the original purpose for this particular program was to simulate perimeter assessment, the input parameters can be defined to simulate interior walls, door or sides of buildings so that any number of different interior or exterior assessment scenes can be modeled by this monitor display program. Also, any number of objects can be digitized and entered into permanent memory similar to the digitized running men and sensors. The current objects stored in memory are the ones frequently used for perimeter assessment.

If the Tektronix 4054 desktop computer is equipped with a Dynamic Graphics option, objects can be moved across the CRT without being stored. With this option, the program is able to move the running men across the assessment zone simulating a moving intruder. Also, with Dynamic Graphics, the program allows the designer to pan and tilt the camera to various orientations of the lens.

Design Examples

The following examples are to demonstrate the major capabilities of the graphic display program as a designer's tool. The first example uses an existing perimeter test bed. This particular test bed, as shown in Figure 2, included light poles, three camera supports (wooden pole, well-casing, and tower), an inner security fence, and several sensors. To model this test bed, the designer entered the input parameters as shown in Table 1. A 75mm lens, located 300 feet from the assessment and 30 feet high, was used for this example. Once the parameters were entered, the program automatically calculated the output data also shown in Table 1. Using this data, the program plotted the graphic simulation perspective shown in Figure 3. An actual photograph of the perimeter test bed is shown in Figure 4. The fence routine in the program was used to model the camera tower and the pole routine modeled in the IR sensors. Comparison of the photograph and computer plot in this example illustrates how accurately this program depicts a real scene.

Two lighting systems were constructed for evaluation in this test bed. The first system used the new and old lights in line with the inner security fence and the second system used the old lights and the new lights offset 70 feet from the inner fence. A computer generated graphic simulation and a photograph of the first lighting system are shown in Figures 5 and 6 respectively. The second lighting system is modeled in Figure 7 and a photograph is shown in Figure 8.

The next example models the perimeter segment as shown in Figure 9. The designer would like to model this sector with zig-zagging fences and elevation changes. Using several camera locations and lenses, the computer plots in Figures 10, 11, and 12 were generated. The two plots in Figure 13 were generated from the same input parameters, but the first with elevation changes and the second without.

The final example simulates the FOV of a camera in a Mardex booth as shown in Figure 14. Fences are used to model the walls and doors. The counter top was created by changing the elevations at that point. The computer generated graphic display of the booth is shown in Figure 15.

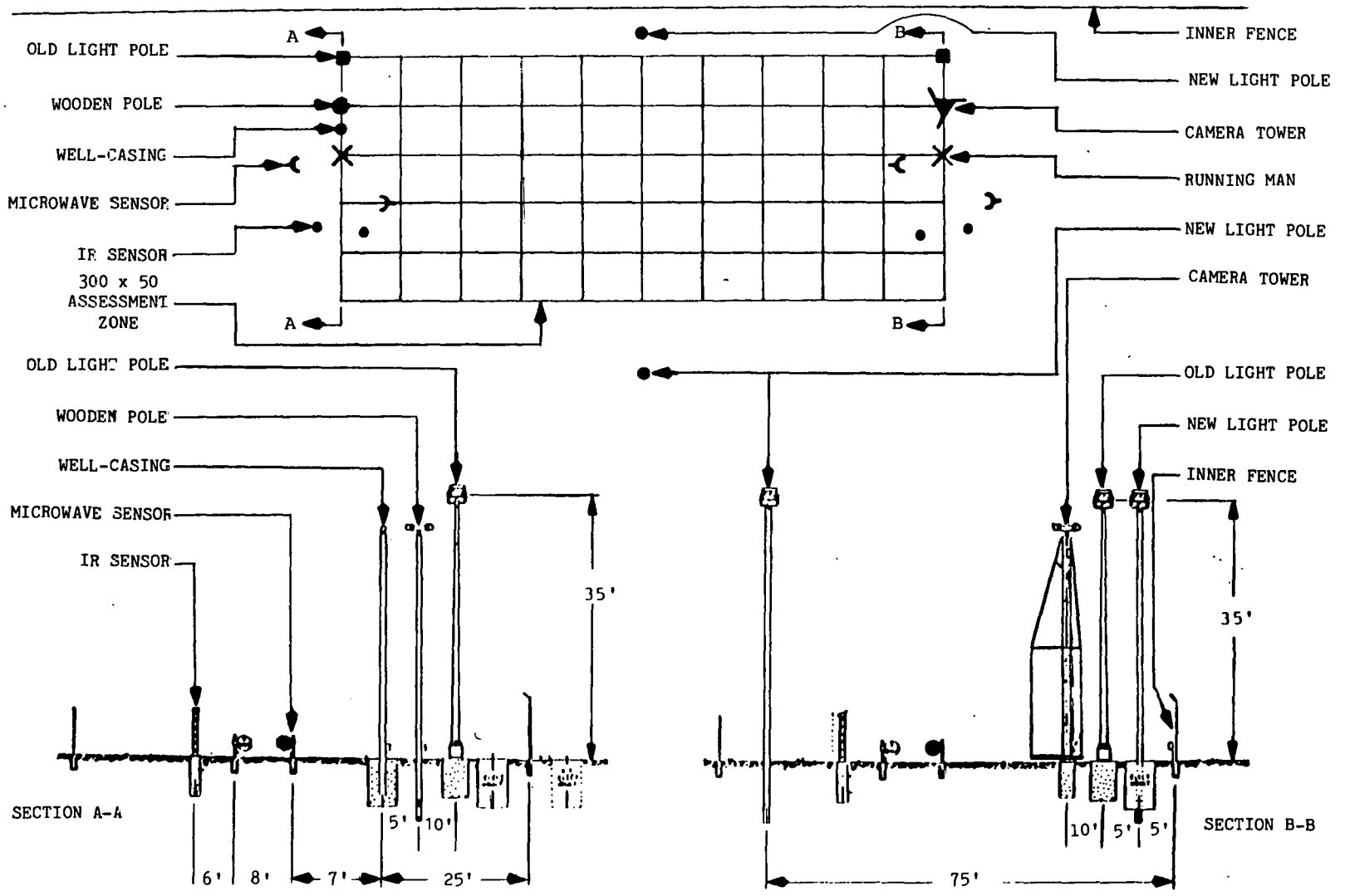


Figure 2
Perimeter Sector to be Modeled

```

**DATA FILE FOR PLOT#542**
1 CAMERA FOCAL LENGTH = 75.00
2 CAMERA HEIGHT = 31.00
3 CAMERA PAN ANGLE IN DEGREES = -2.00
4 SECTOR LENGTH = 300.00
5 SECTOR WIDTH = 50.00
6 SECTOR LOCATION = -41.00
7 SECTOR NEAR EDGE = 300.00
8 SECTOR ANGLE = 0.00
9 PLOT SECTOR GRID (YES=1:NO=0) = 1
10 TARGET HEIGHT AT FAR EDGE = 10.00
11 SYSTEM RESOLUTION = 600.00
12 NUMBER OF FENCE LINES = 6
13 FENCE# 1 LOCATION = 10.00
14 FENCE# 1 HEIGHT = 0.00
15 FENCE# 1 POLE WIDTH = 0.00
16 FENCE# 1 SPACING = 10.00
17 FENCE# 1 START = 0.00
18 FENCE# 1 LENGTH = 900.00
19 FENCE# 1 ANGLE = 0.00
20 FENCE# 2 LOCATION = -181.00
21 FENCE# 2 HEIGHT = 5.00
22 FENCE# 2 POLE WIDTH = 0.00
23 FENCE# 2 SPACING = 20.00
24 FENCE# 2 START = 0.00
25 FENCE# 2 LENGTH = 900.00
26 FENCE# 2 ANGLE = 0.00
27 FENCE# 3 LOCATION = -0.50
28 FENCE# 3 HEIGHT = 0.50
29 FENCE# 3 POLE WIDTH = 0.00
30 FENCE# 3 SPACING = 0.10
31 FENCE# 3 START = 295.37
32 FENCE# 3 LENGTH = 4.10
33 FENCE# 3 ANGLE = 0.00
34 FENCE# 4 LOCATION = -0.50
35 FENCE# 4 HEIGHT = 0.50
36 FENCE# 4 POLE WIDTH = 0.00
37 FENCE# 4 SPACING = 0.10
38 FENCE# 4 START = 299.53
39 FENCE# 4 LENGTH = 4.10
40 FENCE# 4 ANGLE = -60.00
41 FENCE# 5 LOCATION = -1.41
42 FENCE# 5 HEIGHT = 0.50
43 FENCE# 5 POLE WIDTH = 0.00
44 FENCE# 5 SPACING = 0.10
45 FENCE# 5 START = 300.00
46 FENCE# 5 LENGTH = 4.10
47 FENCE# 5 ANGLE = 60.00
48 FENCE# 6 LOCATION = -1.41
49 FENCE# 6 HEIGHT = 30.00
50 FENCE# 6 POLE WIDTH = 0.15
51 FENCE# 6 SPACING = 0.02
52 FENCE# 6 START = 300.00
53 FENCE# 6 LENGTH = 0.02
54 FENCE# 6 ANGLE = 00.00
55 NUMBER OF POLE LINES = 10
56 POLE# 1 LOCATION = 14.00
57 POLE# 1 HEIGHT = 35.00
58 POLE# 1 WIDTH = 1.27
59 POLE# 1 SPACING = 300.00
60 POLE# 1 START = 150.00
61 POLE# 1 ANGLE = 300.00
62 POLE# 1 LENGTH = 0.00
63 POLE# 2 LOCATION = 0.00
64 POLE# 2 HEIGHT = 2.25
65 POLE# 2 WIDTH = 1.50
66 POLE# 2 SPACING = 300.00
67 POLE# 2 START = 300.00
68 POLE# 2 LENGTH = 900.00
69 POLE# 2 ANGLE = 0.00
70 POLE# 3 LOCATION = 0.00
71 POLE# 3 HEIGHT = 35.00
72 POLE# 3 WIDTH = 0.05
73 POLE# 3 SPACING = 300.00
74 POLE# 3 START = 300.00
75 POLE# 3 LENGTH = 600.00
76 POLE# 3 ANGLE = 0.00
77 POLE# 4 LOCATION = -61.00
78 POLE# 4 HEIGHT = 35.00
79 POLE# 4 WIDTH = 1.27
80 POLE# 4 SPACING = 300.00
81 POLE# 4 START = 150.00
82 POLE# 4 LENGTH = 300.00
83 POLE# 4 ANGLE = 0.00
84 POLE# 5 LOCATION = -1.00
85 POLE# 5 HEIGHT = 30.00
86 POLE# 5 WIDTH = 1.54
87 POLE# 5 SPACING = 300.00
88 POLE# 5 START = 600.00
89 POLE# 5 LENGTH = 0.00
90 POLE# 5 ANGLE = 0.00
91 POLE# 6 LOCATION = -6.00
92 POLE# 6 HEIGHT = 37.00
93 POLE# 6 WIDTH = 0.02
94 POLE# 6 SPACING = 300.00
95 POLE# 6 START = 600.00
96 POLE# 6 LENGTH = 0.00
97 POLE# 6 ANGLE = 0.00
98 POLE# 7 LOCATION = -26.50
99 POLE# 7 HEIGHT = 6.50
100 POLE# 7 WIDTH = 0.50
101 POLE# 7 SPACING = 600.00
102 POLE# 7 START = 290.00
103 POLE# 7 LENGTH = 0.00
104 POLE# 7 ANGLE = 0.00
105 POLE# 8 LOCATION = -26.50
106 POLE# 8 HEIGHT = 6.50
107 POLE# 8 WIDTH = 0.50
108 POLE# 8 SPACING = 600.00
109 POLE# 8 START = 610.00
110 POLE# 8 LENGTH = 0.00
111 POLE# 8 ANGLE = 0.00
112 POLE# 9 LOCATION = -27.50
113 POLE# 9 HEIGHT = 6.50
114 POLE# 9 WIDTH = 0.50
115 POLE# 9 SPACING = 600.00
116 POLE# 0 START = 310.00
117 POLE# 0 LENGTH = 0.00
118 POLE# 0 ANGLE = 0.00
119 POLE# 10 LOCATION = -27.50
120 POLE# 10 HEIGHT = 6.50
121 POLE# 10 WIDTH = 0.50
122 POLE# 10 SPACING = 600.00
123 POLE# 10 START = 500.00
124 POLE# 10 LENGTH = 0.00
125 POLE# 10 ANGLE = 0.00
126 NUMBER OF RACONS = 3
127 RACON# 1 LOCATION = -21.00
128 RACON# 1 START = -20.00
129 RACON# 1 LENGTH = 0.00
130 RACON# 1 SPACING = 0.00
131 RACON# 1 OFFSET = 356.00
132 RACON# 1 ANGLE = 1.20
133 RACON# 2 LOCATION = -21.00
134 RACON# 2 START = 272.00
135 RACON# 2 LENGTH = 0.00
136 RACON# 2 SPACING = 0.00
137 RACON# 2 OFFSET = 356.00
138 RACON# 2 ANGLE = 1.20
139 RACON# 3 LOCATION = -21.00
140 RACON# 3 START = 572.00
141 RACON# 3 LENGTH = 0.00
142 RACON# 3 SPACING = 0.00
143 RACON# 3 OFFSET = 356.00
144 RACON# 3 ANGLE = 1.20
145 NUMBER OF ROLLS OF CONCERTINA = 0
146 NUMBER OF RUNNING MEN = 1
147 ROW# 1 LOCATION = -11.00
148 ROW# 1 SPACING = 300.00
149 ROW# 1 START = 0.00
150 ROW# 1 LENGTH = 900.00
151 ROW# 1 ANGLE = 0.00
152 NUMBER OF ELEVATION CHANGES = 0
**CALCULATED FIELD OF VIEW DATA**
HORIZONTAL FIELD OF VIEW IN DEGREES = 9.68
VERTICAL FIELD OF VIEW IN DEGREES = 7.27
CAMERA TILT ANGLE IN DEGREES = 5.64
CAMERA PAN ANGLE IN DEGREES = -2.00
DISTANCE TO FAR EDGE OF THE SECTOR = 600.00
FAR EDGE CENTER LINE DISTANCE = 600.71
WIDTH AT FARTHEST EDGE = 101.60
DISTANCE TO CLOSEST EDGE OF SECTOR = 300.00
CLOSEST EDGE CENTER LINE DISTANCE = 300.36
WIDTH AT CLOSEST EDGE = 51.00
MINIMUM FIELD OF VIEW DISTANCE = 180.74
MINIMUM CENTER LINE DISTANCE = 180.07
WIDTH AT MINIMUM DISTANCE = 32.51
MAXIMUM FIELD OF VIEW DISTANCE = 885.71
MAXIMUM CENTER LINE DISTANCE = 886.77
WIDTH AT MAXIMUM DISTANCE = 149.88
ACTUAL DISTANCE TO FAR EDGE = 601.51
RESOLUTION AT FAR EDGE OF SECTOR = 5.91
MAXIMUM SECTOR PERCENTAGE = 40.37
**DATA FILE FOR PLOT#542**

```

Table I
Input Parameters and Calculated Output

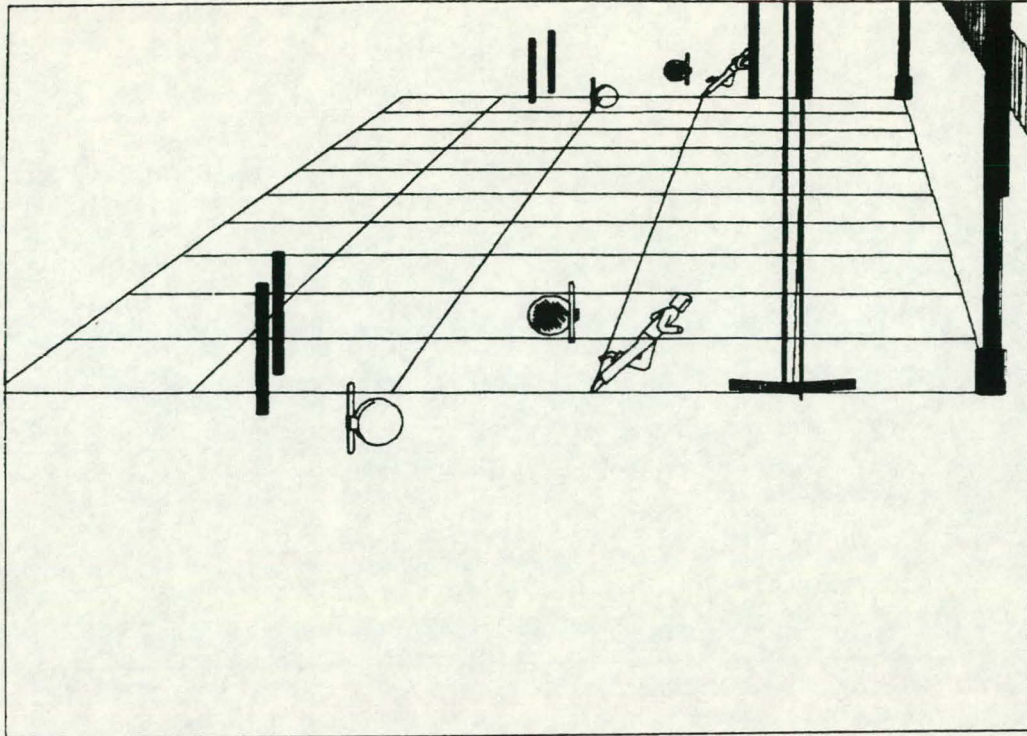


Figure 3
Graphic Simulation of Perimeter

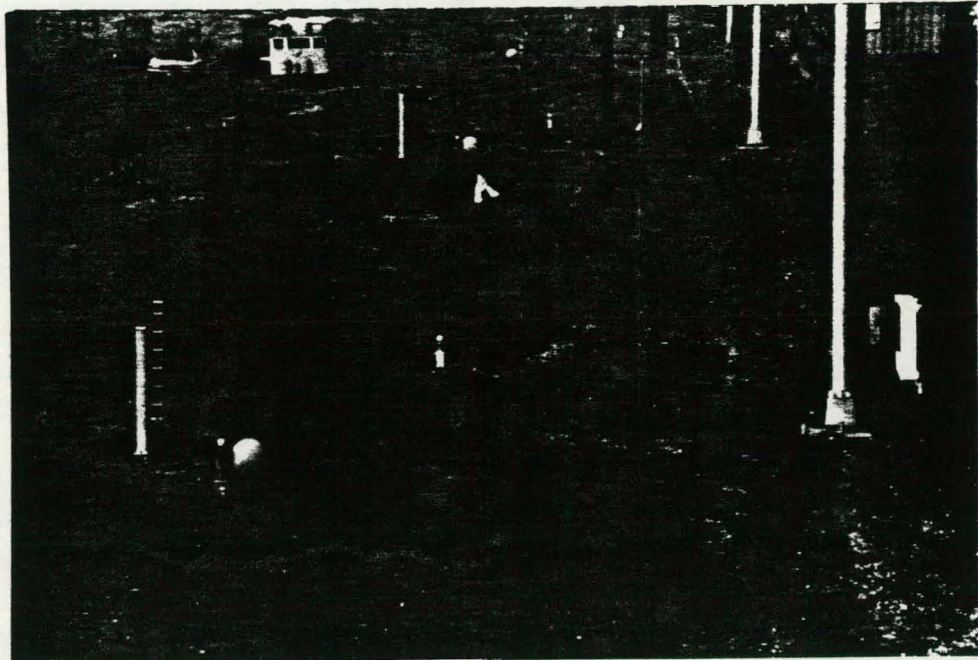


Figure 4
Photograph of Area Simulated

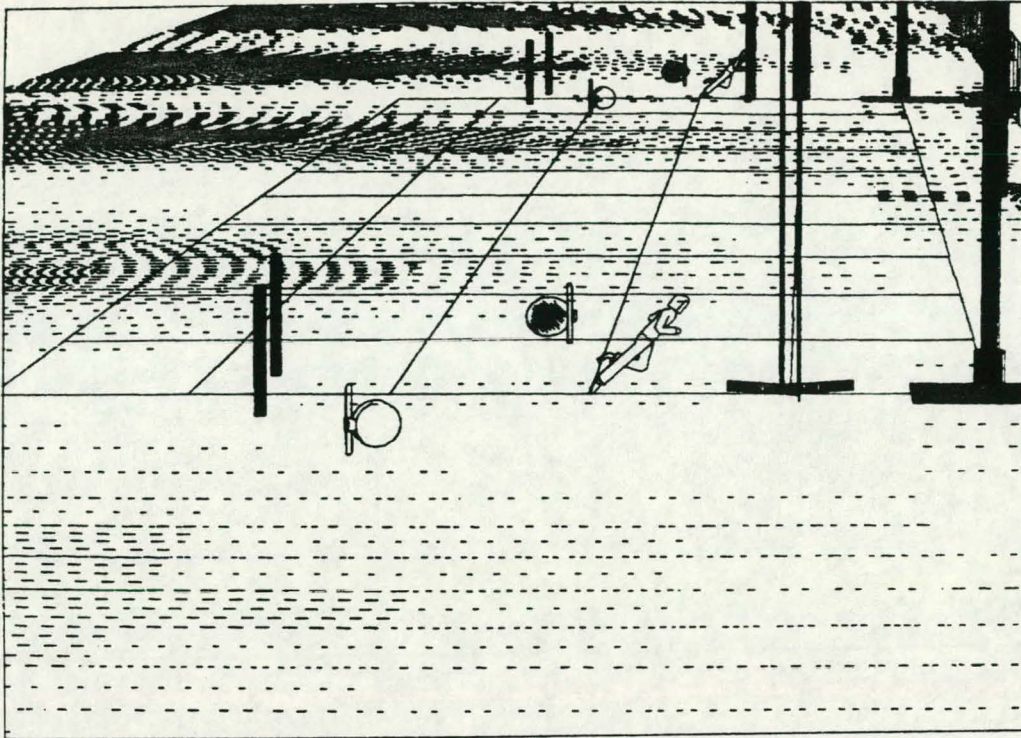


Figure 5
Graphic Simulation with Lighting Contours

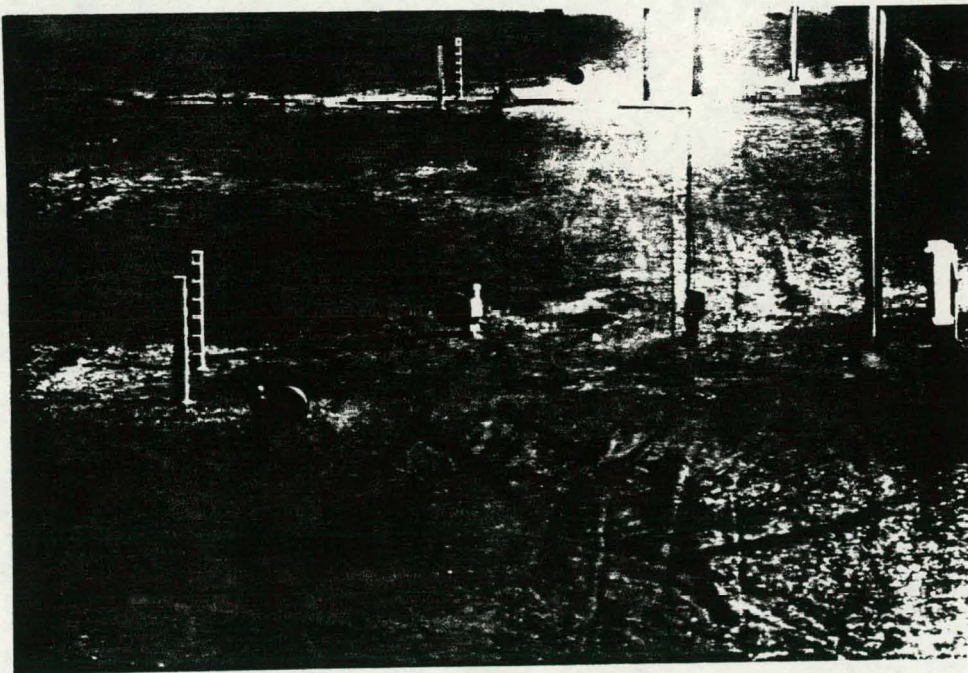


Figure 6
Photograph of Lighted Area

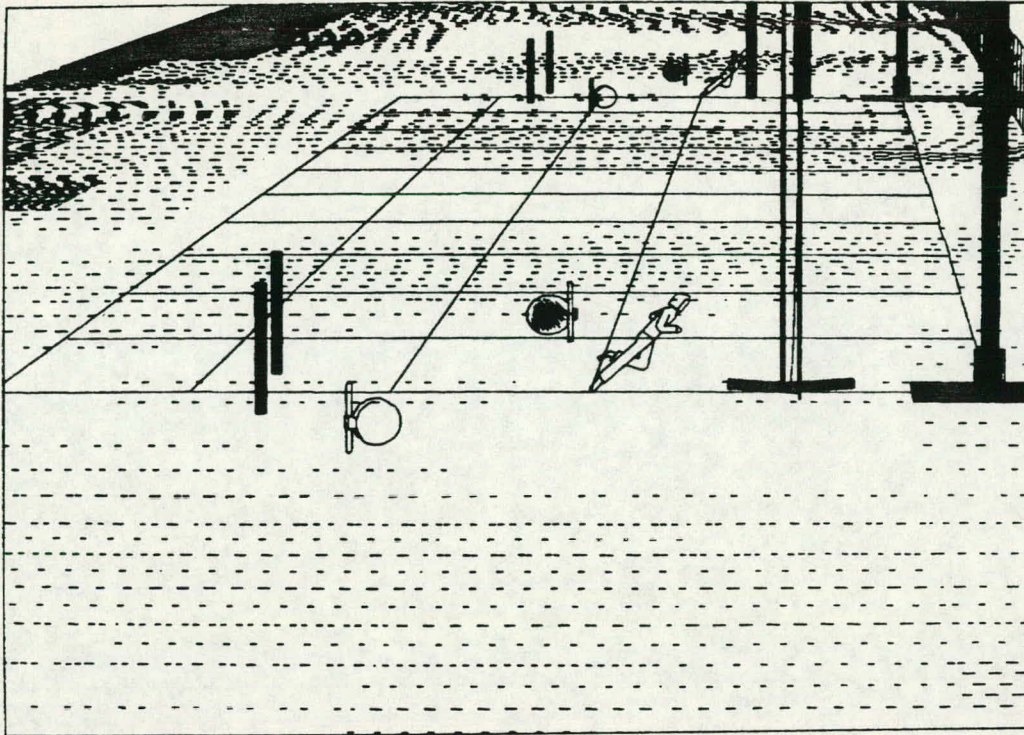


Figure 7
Graphic Simulation with Lighting Contours

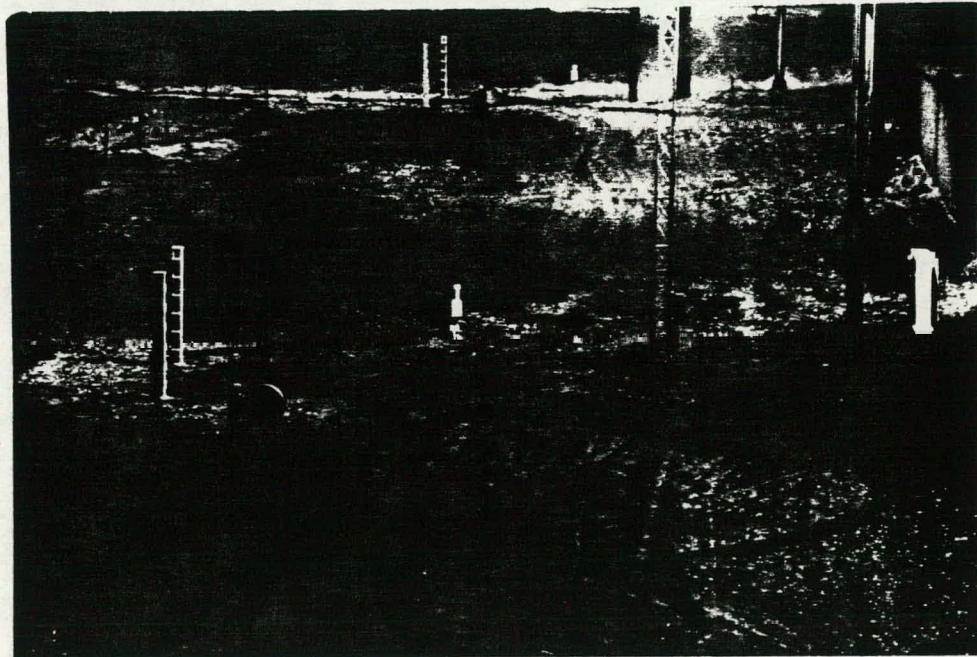


Figure 8
Photograph of Lighted Area

Figure 9
Perimeter Segment

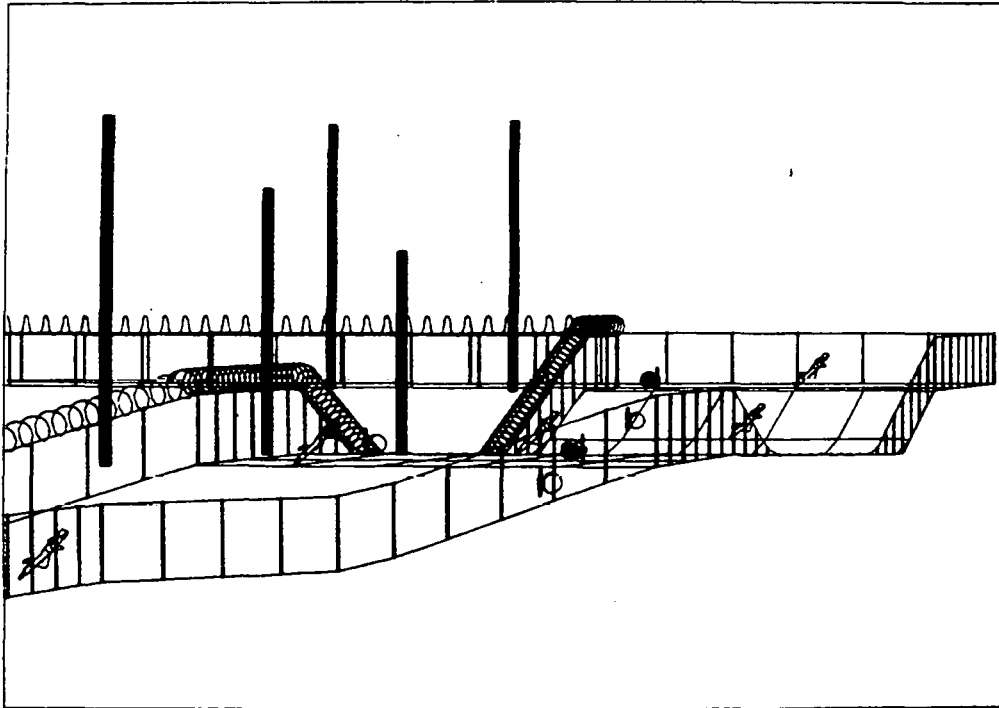
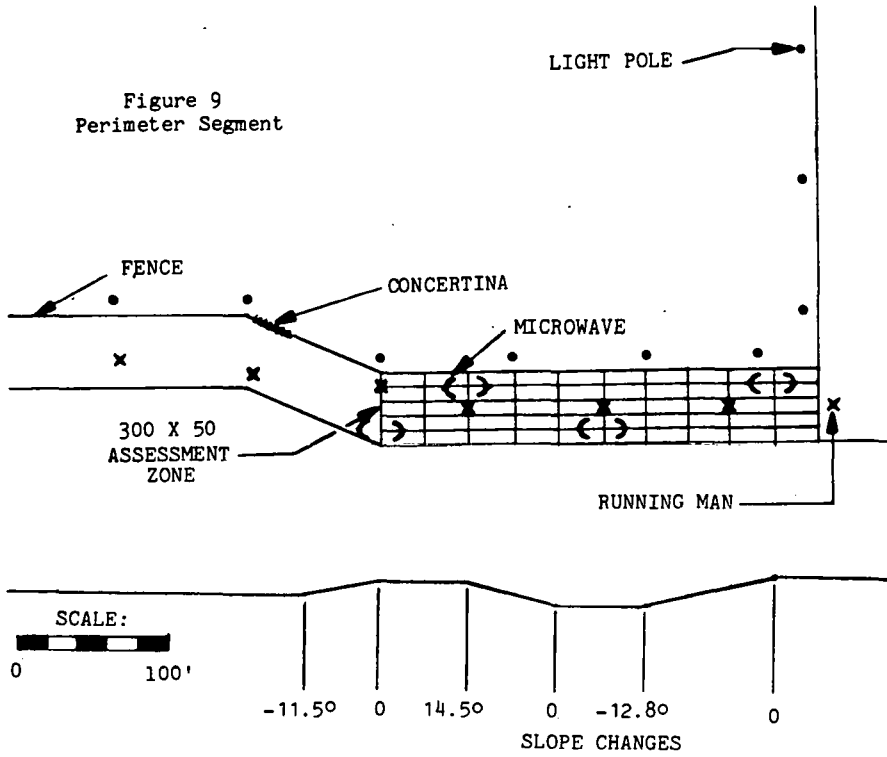


Figure 10
Graphic Simulation of Perimeter Segment
Height: 50' Lens: 135mm

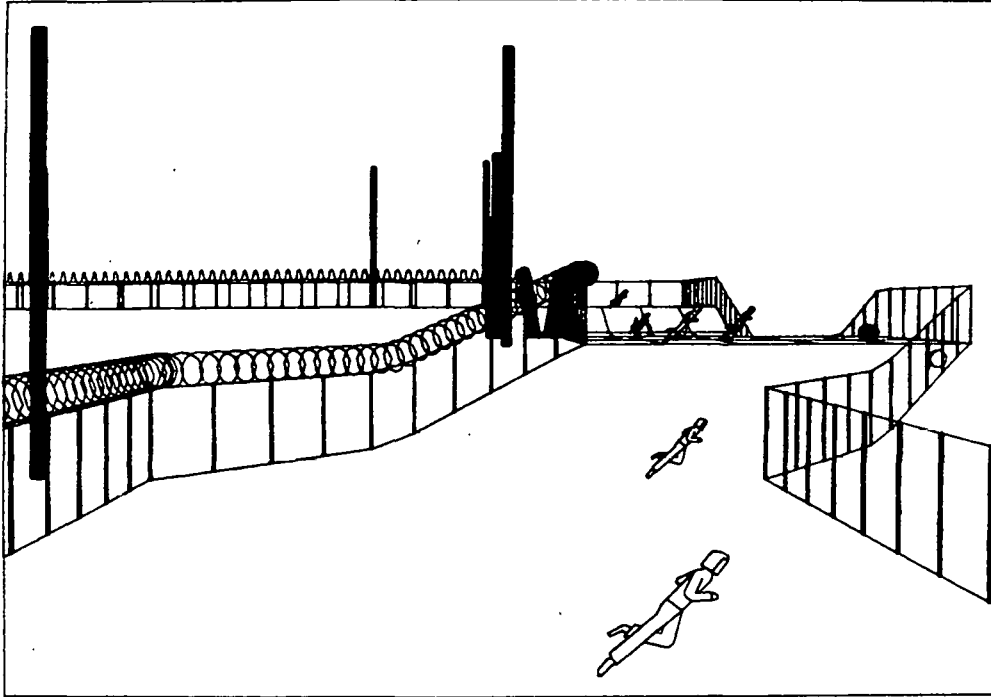


Figure 11
Graphic Simulation - Height: 15' Lens: 25mm

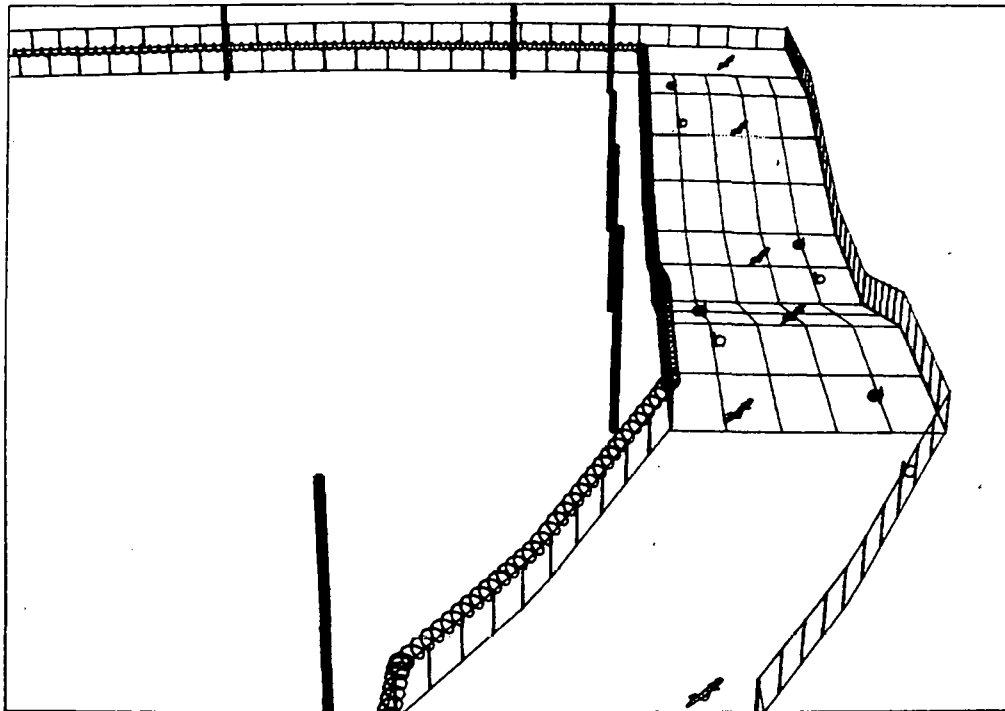


Figure 12
Graphic Simulation - Height: 150' Lens: 25mm

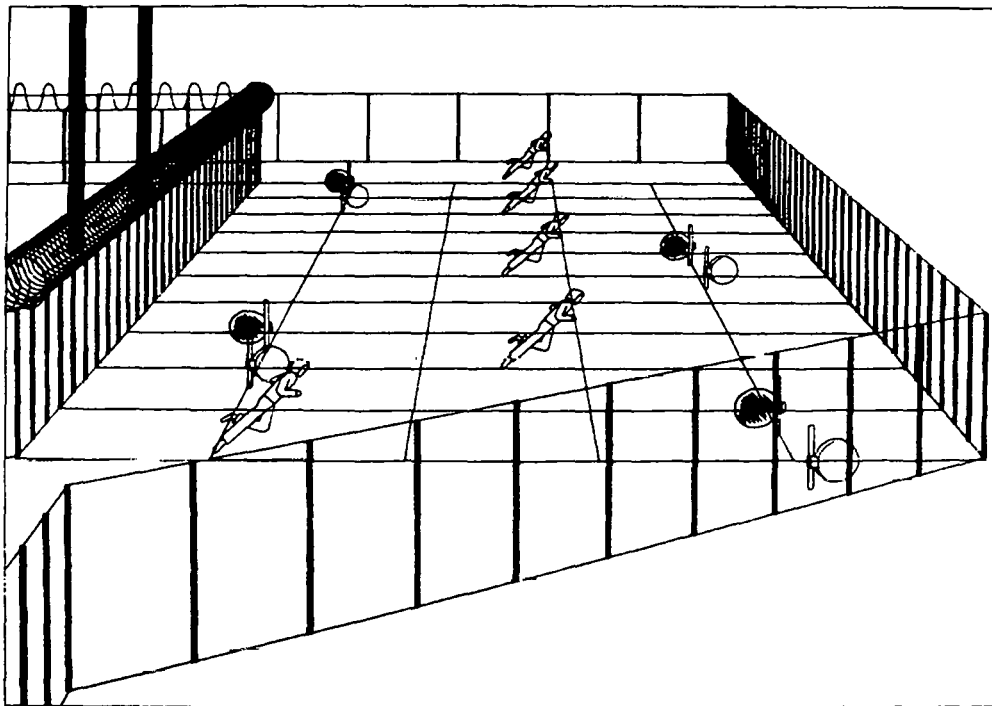
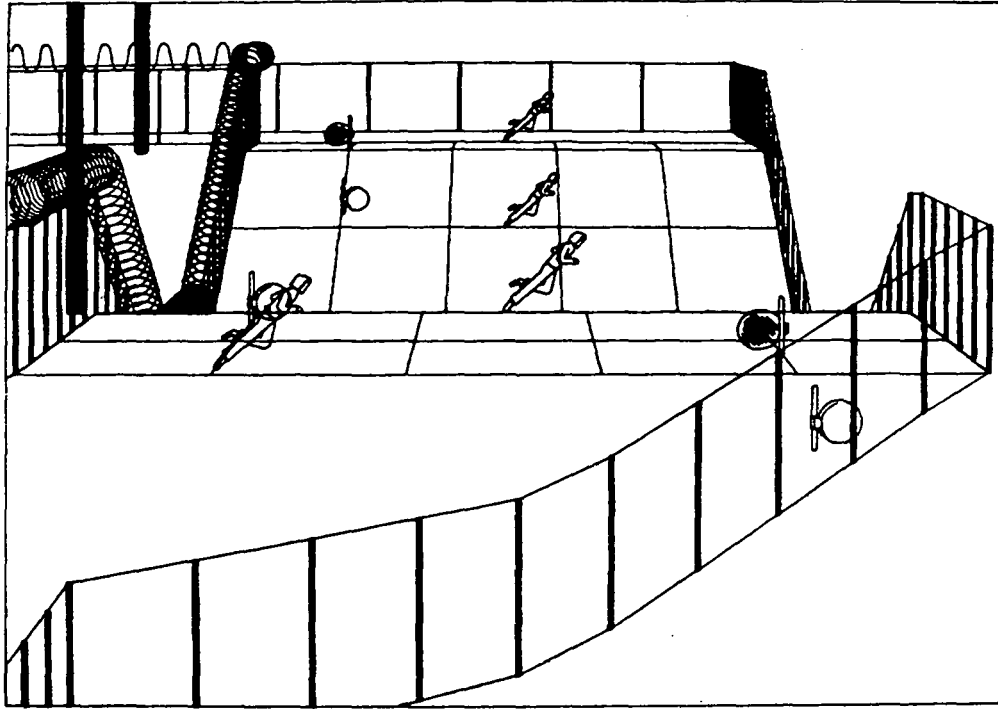


Figure 13
Graphic Simulations With and Without Elevation Changes
Height: 30' Lens: 75 mm

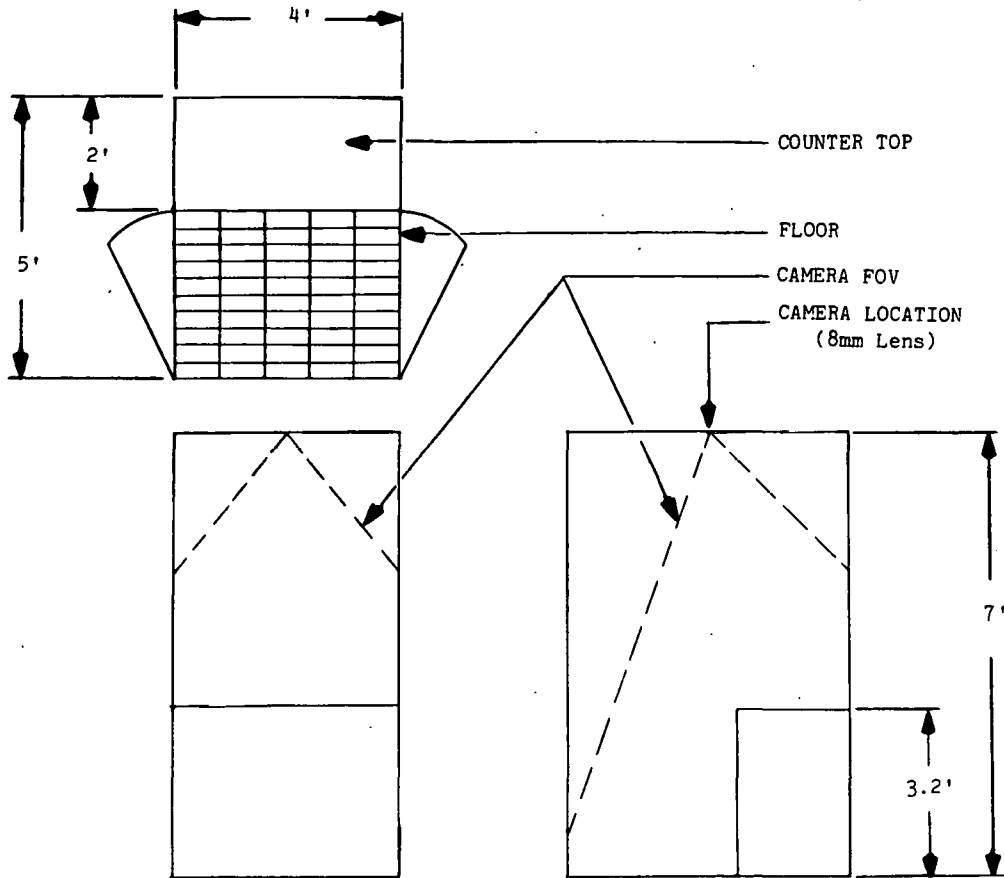


Figure 14
Mardix Booth

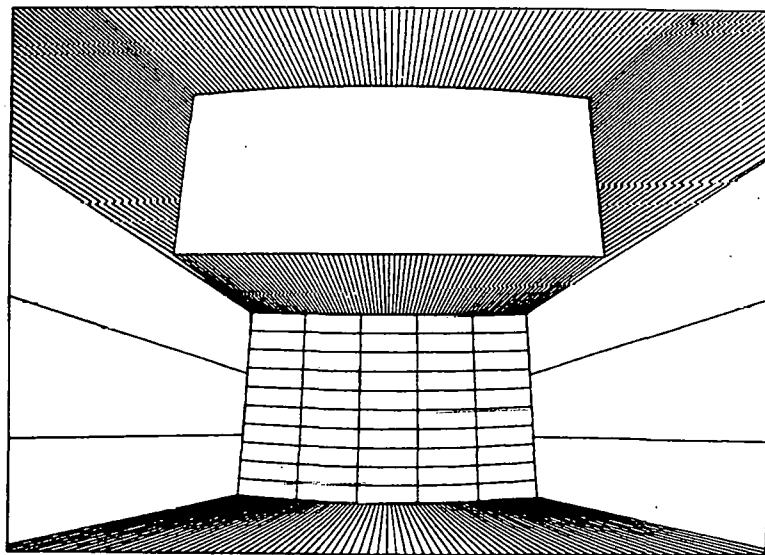


Figure 15
Graphic Simulation of Mardix Booth

PROGRAM FOR THE HEWLETT-PACKARD 9845B

This program is written in HP enhanced Basic for use on a HP-9845B desktop computer with a Graphics ROM, an advanced programming ROM, and a minimum of (approximately) 187 K-bytes of memory.

The program is self-prompting, i.e., it automatically request the user to input the required data for plotting each object in the monitor display simulation. Two important camera variables are the camera tube format and the lens focal length. The two formats which may be used in this program are a 2/3 inch format and a 1-inch format. A 1-inch format will provide a larger FOV for a given lens.

Several elements of the system geometry are described here and are illustrated in Figure 16, these elements are:

1. The camera mounting height, H_c , above the ground.
2. The camera's downward tilt, θ , toward the scene. It is measured from the horizontal.
3. The tilted vertical FOV, HF . It is the distance from the nearest to the farthest visible point in the scene.
4. There is usually a blind zone, between the base of the camera support and the nearest visible point in the scene. The distance from support across this zone is the blind distance, D_d .
5. The center of the FOV will intersect the ground a distance, A_{im} , from the base of the camera support.
6. For the calculations, a six-foot high objective target simulates an intruder. If it is used, then any percentage of its height may be specified. The height, D_r , may either be specified or calculated.

Possible configurations for the area of interest are shown in Figure 17, target examples are shown in Figure 18, and the 6-foot intruder is shown in Figure 19.

The orientation of the site-coordinate system is arbitrary; but once chosen, the following conventions will be observed throughout the program.

North is assigned to the positive Y-axis and east to the positive X-axis. These directional labels are used to provide a familiar vocabulary for the user. Although north, south, east and west are arranged in the same order in this program as on a map, the labels assigned in this program may not correspond to an actual direction. The orientation

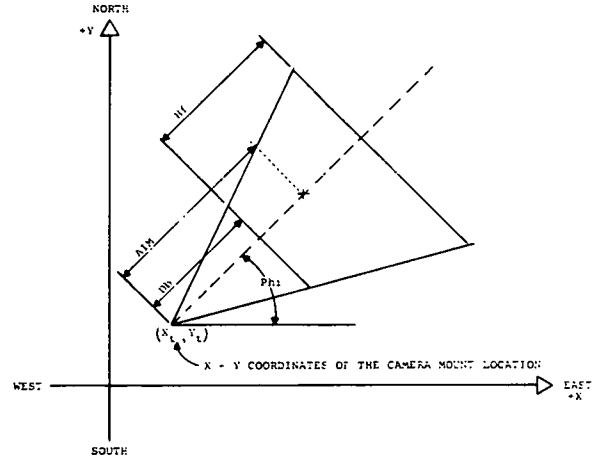


Figure 16
System Geometry

of the coordinate system can be situated at any convenient place. The positive X-axis is also defined as zero degrees.

A perspective view is presented in Figure 20, and labels are added to describe the various scene elements. The "gate" and the "microwave units" are rectangular "targets" placed at the appropriate locations. The microwave units are each made by combining the targets.

Design Examples

The examples presented in this section are to provide a model of the design process using this program. These examples are provided as an overview of system design and, as such, they do not provide an exhaustive description of field layout design. These examples are provided to illustrate the design procedure using this program and to demonstrate the type of output data generated which would otherwise be very difficult to obtain without field evaluation.

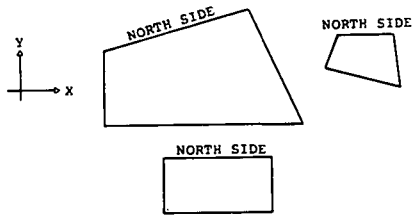


Figure 17
Area of Interest

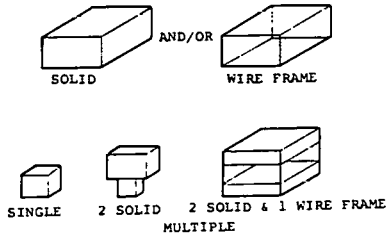


Figure 18
Target Examples

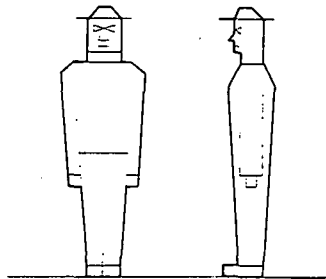


Figure 19
6-Foot Intruder

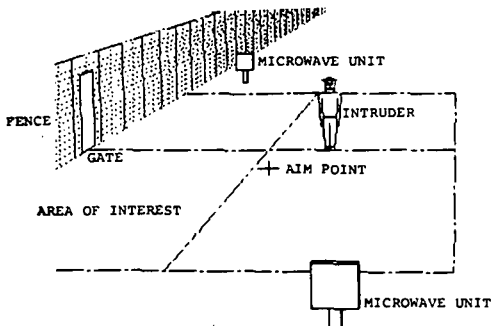


Figure 20
Perspective View

The first example involves a site which is a restricted area with two objects to be monitored. These objects are referred to as "pumps," although they could be any objects of interest. The restricted area is a square, 200 feet on a side. Single camera coverage is desired with the camera within or on the area's perimeter. The area of interest will be defined by the restricted area, where one corner of the area is assigned as the origin. The other three corners will be at (0,200), (200,0), and (200, 200). The pumps are simulated by single targets located at (90,100) and (160,140) as shown in Figure 21. A 50 mm lens and a 1-inch format are selected initially.

After the design objectives, pertinent site data, and initial assumptions were provided, three iterations of the design are performed. In the first iteration, the camera is positioned 20 feet high at (200,0); i.e., the southeast corner from the area of interest, and only one pump could be seen as shown in Figure 22. In the second iteration, the camera is moved to the southwest corner where both pumps can be seen as demonstrated in Figure 23. In the third iteration, the layout is further refined to accommodate a 75 mm lens which provides better resolution in the restricted area. The input and output parameters for the last iteration are shown in Table 2. The final display perspective scene is shown in Figure 24.

The next example demonstrates some of the special effects that can be generated with this type of program. An interior scene of an office with a desk, a chair, and a man is modeled. The required input parameters and calculated output are shown in Table 3, and the computer generated perspective of the scene is shown in Figure 25. As this example illustrates, many objects can be modeled depending on the imagination of the designer.

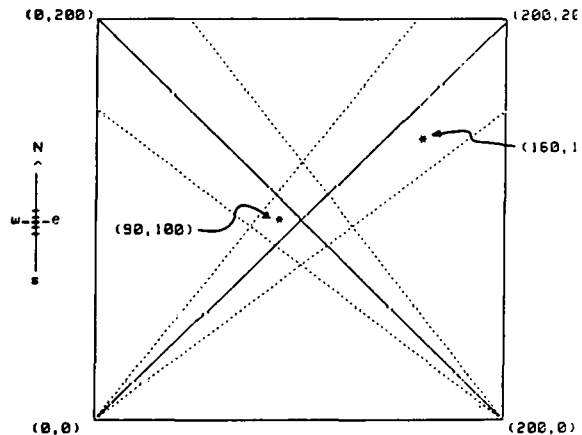


Figure 21
Targets and Restricted Area

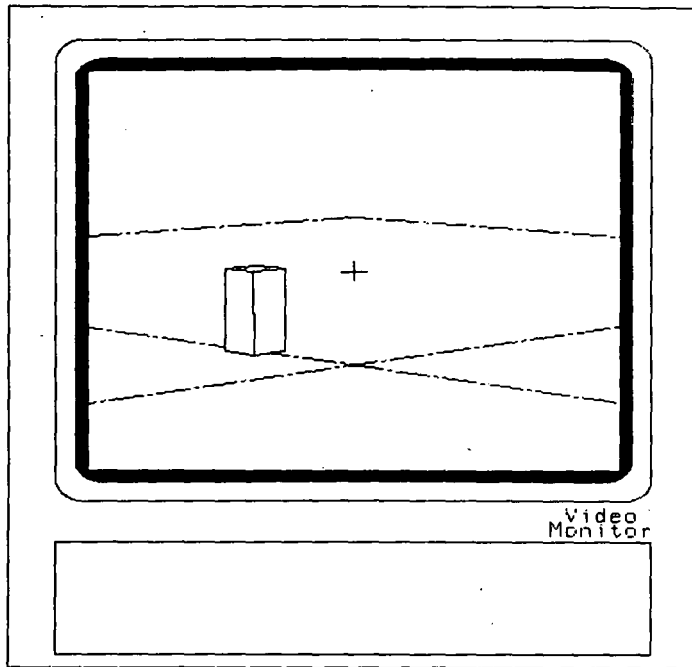


Figure 22
Graphic Simulation from First Iteration

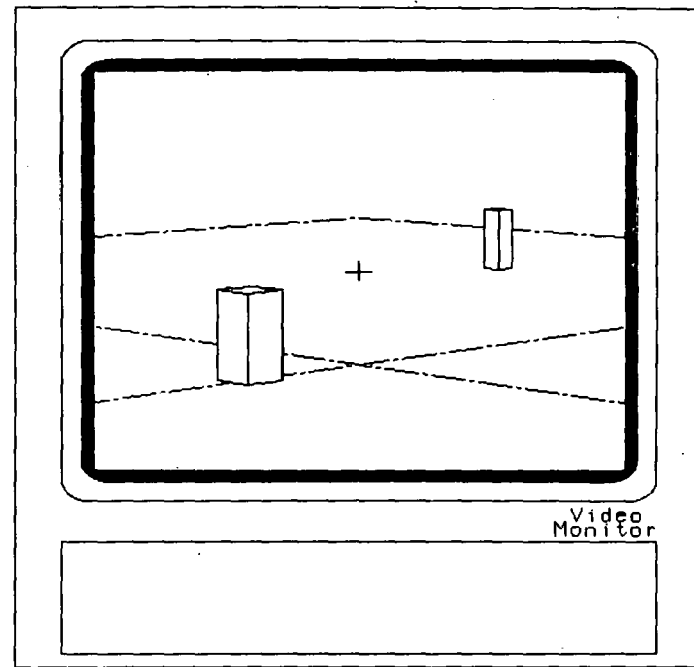
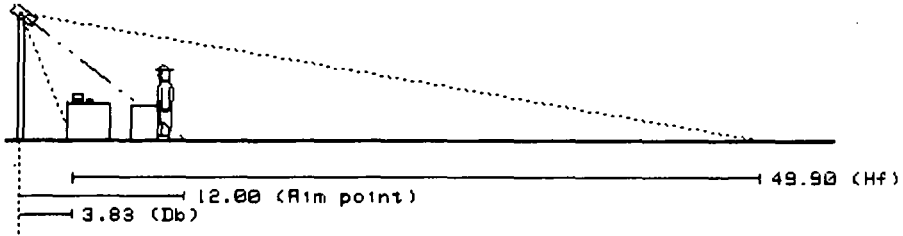


Figure 23
Graphic Simulation from Second Iteration



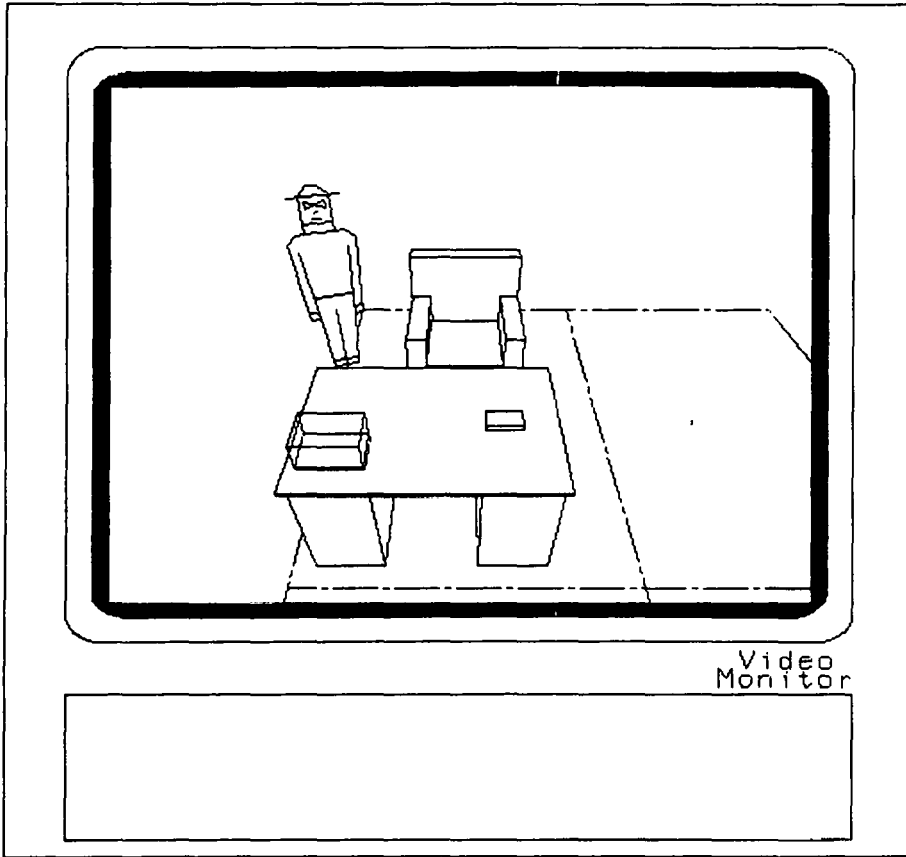


Figure 25
Interior Scene with a Desk, a Chair, and a Man

SUMMARY

The computer programs presented in this paper can be very powerful tools in the development of a CCTV field layout design. Many manual calculations can be avoided and much of the in-the-field designing can be eliminated using these programs.

The simulated monitor displays depict the blind areas caused by fences, poles, concertina, and even elevation changes. When deciding camera locations, lenses, and heights, this type of graphic simulation is very useful. Equally important is the resolution obtained with a particular camera location and lens. The men

in the monitor display can be used to demonstrate the decrease in resolution as their distance from the camera increases.

The ability to rapidly manipulate important parameters and to visually examine the simulated monitor display, provides the engineer with the opportunity to design a field layout more efficiently. Consequently, the cost effectiveness of the design will improve through more efficient engineering work and reduced construction and installation expenses. The purpose of this document is to provide an introduction to these two programs. Future development for both programs will continue to improve their performance and capabilities.