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DESCRIPTION OF THE GDC PROGRAM
FOR THE GRAPHIC DISPLAY
OF THREE-DIMENSIONAL MODELS
PREPARED BY THE
COMBINATORIAL GEOMETRY TECHNIQUE

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1. DESCRIPTION OF THE GDC PROGRAM

The GDC (Graphic Display of Combinatorial Geometry) program is a FORTRAN IV code for the display (on the EAI Data plotter 3500) of orthogonal views of models prepared by the Combinatorial Geometry technique. The program operates on any large IBM 360 (in particular, the Goddard Space Flight Center 360/91) and produces a plot tape for input to the EAI Data Plotter 3500.

The code consists of a main program which generates the curves (from a user-supplied viewing angle) to be plotted, a set of subroutines comprising the Combinatorial Geometry package (as used in the VIP¹ program) and a set of subroutines to output the curves on a tape for use by the EAI² plotter.

The basic program reads in the Combinatorial Geometry description, reads in the viewing angle parameters, generates the curves to be plotted, and finally generates the plot tape.

¹ DESCRIPTION OF THE VIP PROGRAM FOR COMPUTING INCIDENT AND ABSORBED ENERGY AT THE SURFACE OF AN ORBITING SATELLITE, R. Goldstein, Mathematical Applications Group, Inc., 180 South Broadway, White Plains, New York (March, 1969).

1.1 CAPABILITIES OF THE PROGRAM

In general the program is capable of generating an orthogonal view of the Combinatorial Geometry model from any user specified angle. This view is then plotted on the EAI plotter where the size of the plot and the position on the plotting surface is user specified.

Any number of views can be generated in a single computer run.

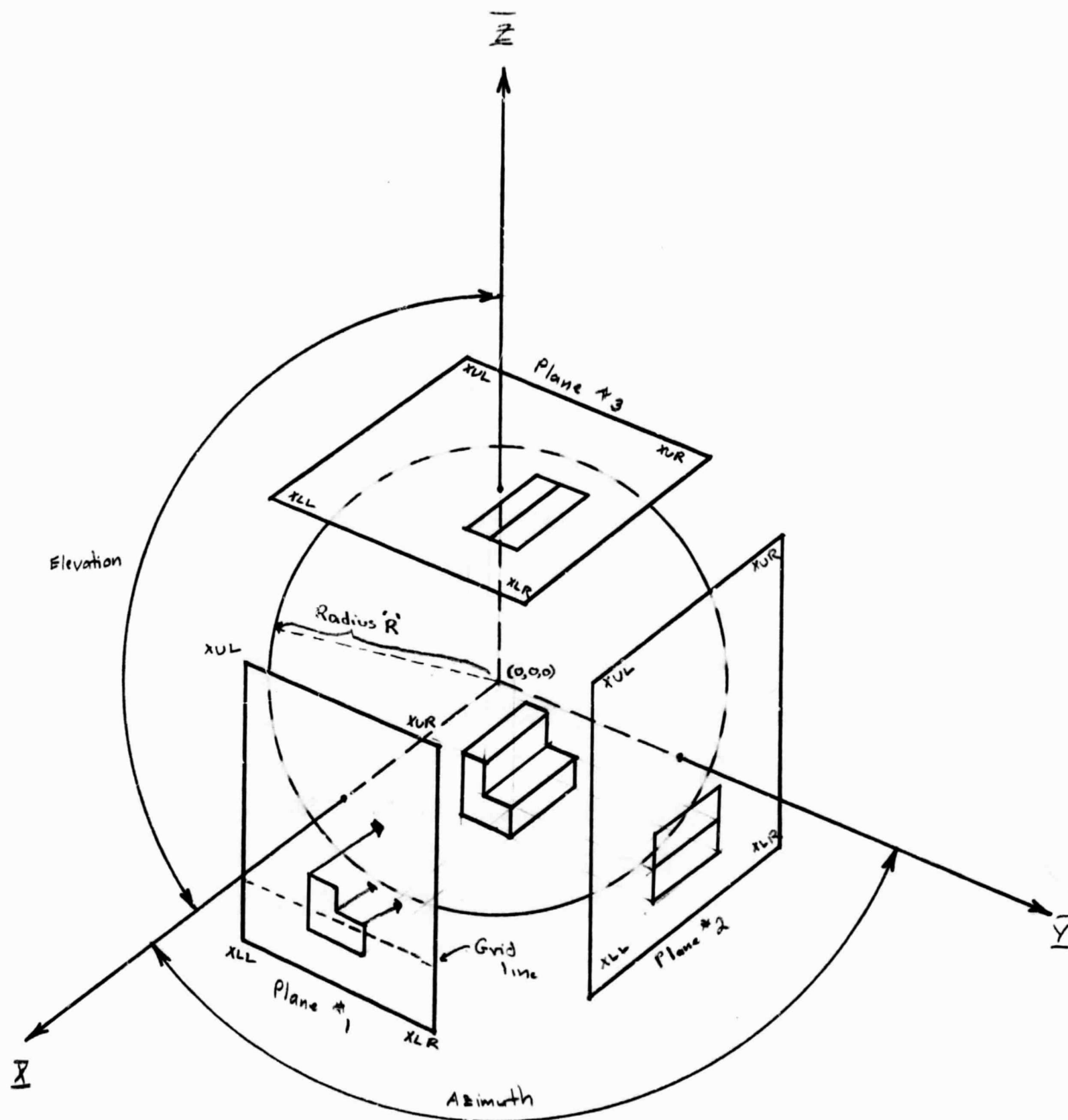
In addition to the plot tape the program will output (on the printer) the Combinatorial Geometry input, the results of the geometry processor and a list of geometry errors encountered during the view generation phase of the program. It should be noted that a certain class of geometry errors are fatal and prevent the program from generating the desired views.

1.2 VIEWING ANGLE SPECIFICATION

Given a Combinatorial Geometry model centered at $(0,0,0)$ in the coordinate system shown in Figure 1, the viewing plane orientation is given as a function of an azimuthal angle 'A' and an elevation angle 'E'. In addition, the size of the viewing plane is given as a function of 'R' the radius of a sphere enclosing the model. Note that the enclosing sphere is not part of the Combinatorial Geometry description and must be contained within the enclosing region of the Combinatorial Geometry.

From the figure the azimuthal angle is measured from x to y and the elevation angle is measured from the x,y plane to the z axis. The size of the viewing plane in the same units as the model is then $2R$.

Thus, the basic inputs for a given view are the azimuthal angle 'A' the elevation angle 'E' and the radius of the enclosing sphere 'R'.



	Azimuth	Elevation
Plane #1	0°	0°
Plane #2	90°	0°
Plane #3	90°	90°

Figure 1 - Viewing Angle Specification

1.3 PLOT SIZE SPECIFICATION

The EAI Data Plotter 3500 has a useable plotting area of 29.5" in X and 22.0" in Y. Thus, the size of a given view must be within these bounds. A user supplied picture size (in inches) and the lower left hand corner (X_{corner} , Y_{corner}) of the picture are supplied as input and the program scales accordingly. Note that the

$$X_{\text{corner}} + \text{Picture Size} \leq 29.5"$$

$$Y_{\text{corner}} + \text{Picture Size} \leq 22.0"$$

Figure 2 illustrates the case.

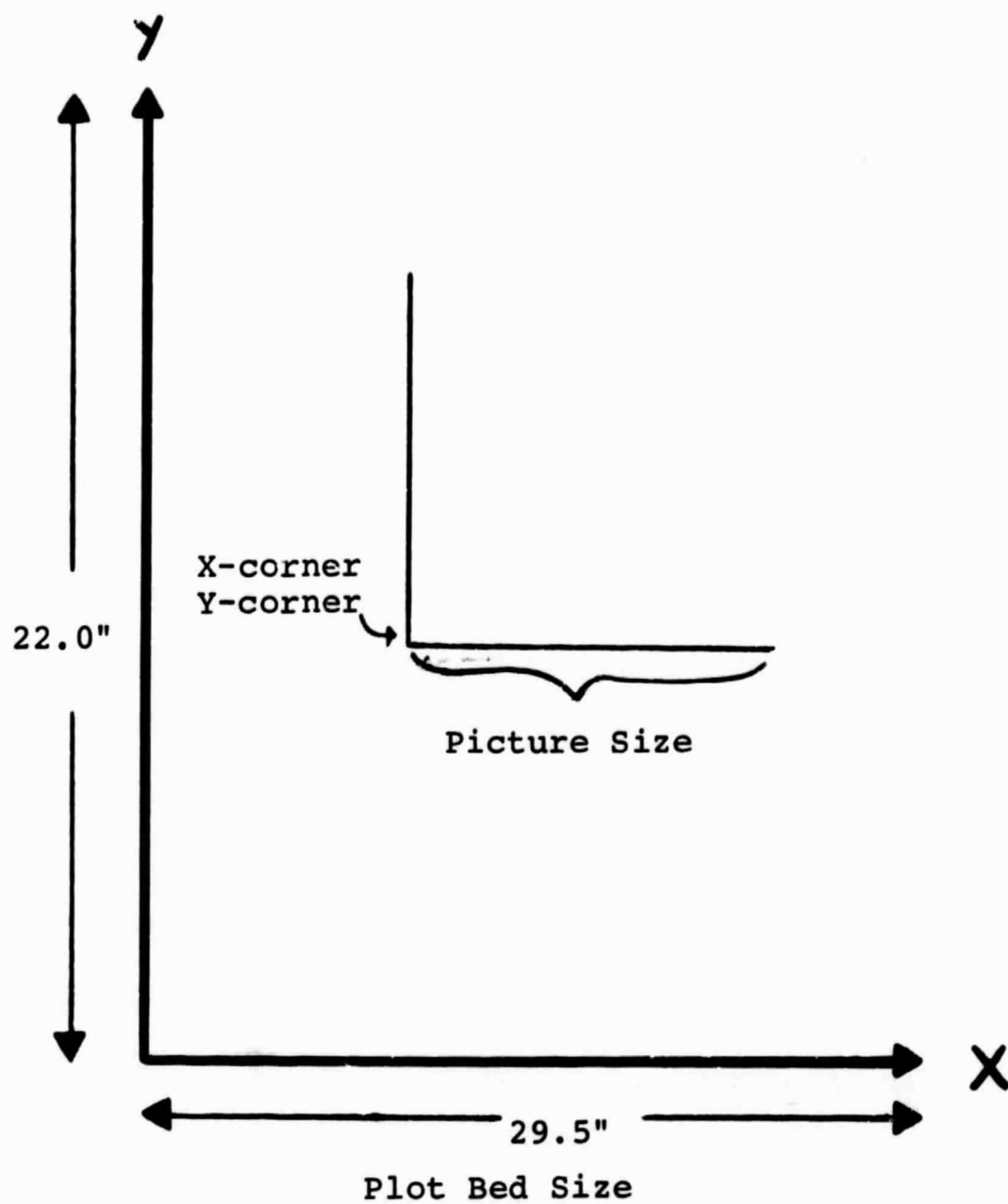
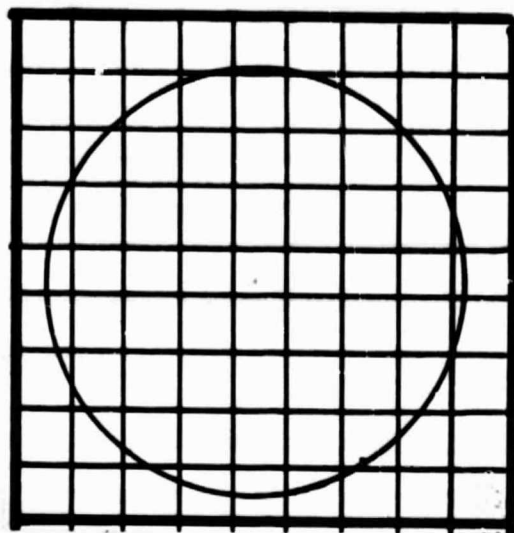


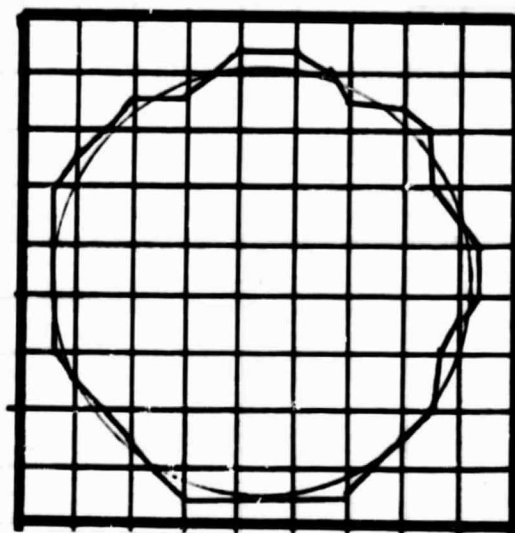
Figure 2 - Plot Size Specification

1.4 PLOT RESOLUTION SPECIFICATION

The plot is produced by tracing the projection of the model on the viewing plane. The viewing plane is divided into a small grid and the projected curve is considered to be a straight line in each grid square. The circle shown in Figure 3A would appear as shown in Figure 3B for the given grid size. Thus, the 'fineness' of the picture is a function of the grid size. The smaller the grid ~~the finer the picture~~. Note, however, that the running time on the computer increases with the number of grid squares. The actual number entered as input for a given view is 'the number of grid lines - 1'. Experience has shown that '500' is a reasonable number.



3A



3B

Note that for the above illustration
the input item 'number of grid lines -1' = 9

Figure 3 - Plot Resolution Specification

2. GDC USERS GUIDE

The following sections of this report describe the GDC users guide. Card deck configurations and input card formats will be given. A description of outputs is also included. Error stops and remedial actions are given. A general discussion of operating procedures is also included.

2.1 CARD INPUT AND DECK CONFIGURATION

The data deck for a computer run consists of the Combinatorial Geometry deck followed by single card for each view. The Combinatorial Geometry deck begins with the title card (page 17 of the VIP manual) and ends with a -1 in columns 4 and 5 (page 22 of the VIP manual).

The view card format is given below:

<u>Columns</u>	<u>Description</u>	
1-10	Azimuth angle (degrees)	} see Section 1.2
11-20	Elevation angle (degrees)	
21-30	Radius of sphere surrounding the model	
31-40	Paper size (inches)	} see Section 1.3
41-50	X _{corner} (inches)	
51-60	Y _{corner} (inches)	
61-65	Region number of region enclosing the model	
66-70	Number of intervals in the grid (see Section 1.4)	

The first 6 items are all 'E' or 'F' format and the last two items are integers (right adjusted).

A completely blank card denotes the end of the view cards. A deck illustration is given in Figure 4.

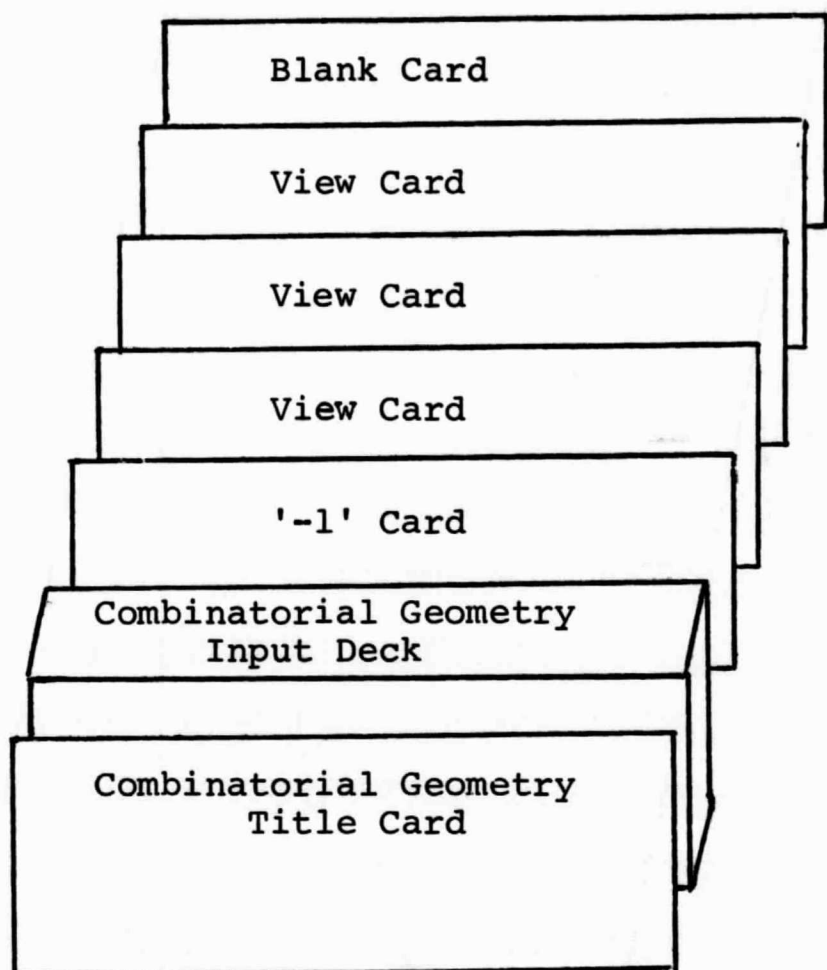


Figure 4 - Input Deck Configuration

2.2 ERROR MESSAGES

Errors can occur in three major sections of the program:

- (a) The Combinatorial Geometry Package,
- (b) The EAI plotter subroutines,
- (c) The Main program for curve generation

The errors in items (a) and (b) are covered in the VIP and EAI manuals. The errors and remedial actions for item (c) are given below:

Printout

'PAPER SIZE ERROR'

'** TOO MANY NODES'

'ERROR IN NEW CELL'

Remedial Action

Check that the plot paper parameters supplied as input are within the allowed dimensions (see Section 1.3)

There is insufficient storage for the plotting data. Decrease the number of intervals in the grid.

This error is the result of a previous error in the Combinatorial Geometry Section. Correct the Combinatorial Geometry input and resubmit.

A brief discussion of the Combinatorial Geometry errors is given below.

There are numerous places in the Combinatorial Geometry where a printout will occur upon detection of an input error. The job will terminate but the source of the error will be indicated. There is one possible error which does not terminate a job. It occurs while tracing a ray in subroutine G1. In general, the cause of this error is that a ray gets 'lost' at the boundary between two regions. This is due to insufficient computing precision of the machine. If this occurs, some error printout will appear and the code will abandon this ray and go on to the next one. As long as this is a relatively rare event, the user need not be concerned with it. Experience has shown that it might be expected once every few thousand rays. If, however, it occurs much more often than this, the cause is probably an undetected input geometry error. The printout can usually provide clues to the exact source of the error but lacking a detailed knowledge of the coding, the best thing to do is to carefully go over the input. The error is likely either in a body dimension or a region description.

2.3 OUTPUT EDIT

The output edit consists of:

- a) Printout of the Combinatorial Geometry input (see the VIP Manual),
- b) Printout of the View Card,
- c) Parameters calculated from the View Card as defined below:

'UPPER LEFT'	Upper left hand x-y-z coordinates of viewing plane
'UPPER RIGHT'	Upper right hand x-y-z- coordinates of viewing plane
'LOWER LEFT'	Lower left hand x-y-z coordinates of viewing plane
'LOWER RIGHT'	Lower right hand x-y-z coordinates of viewing plane
'RAY DIRECTION'	Direction cosines from viewing plane to model
'DIRECTION LR'	Direction cosines from upper left to upper right
'DIRECTION TB'	Direction cosines from upper left to lower left

- d) The end of the plot for a given View Card is indicated by the following printout:

'END OF PLOT-NUMBER OF RAYS' = XXXXX

where XXXXX is the number of calls to G1.

Items (b) (c) (d) are printed for each View Card.

2.4 GENERAL OPERATING PROCEDURE

The program has no special requirements other than the plot tape. Each plot is terminated by an 'END-FILE' mark and the last plot is terminated by two END-FILE marks. Note that any number of plots can be made on a single sheet by changing the X_{corner} , Y_{corner} and paper size parameters. It is suggested that the multiple plot capability be used only after the geometry has been checked out by generating single views.

3.0- 3.0 DESCRIPTION OF THE GDC MAIN ROUTINE

The MAIN routine performs all the calculations required in creating the set of points that describe the desired orthogonal view. The points are connected and output on a tape by the EAI plotter subroutine package. The general procedure for the calculation of the points is called 'curve tracing' and is described below.

Given the viewing plane as described by its four corners:
(see Figure 1)

$\overline{XUL}$ = Upper left hand corner

$\overline{XUR}$ = Upper right hand corner

$\overline{XLL}$ = Lower left hand corner

$\overline{XLR}$ = Lower right hand corner

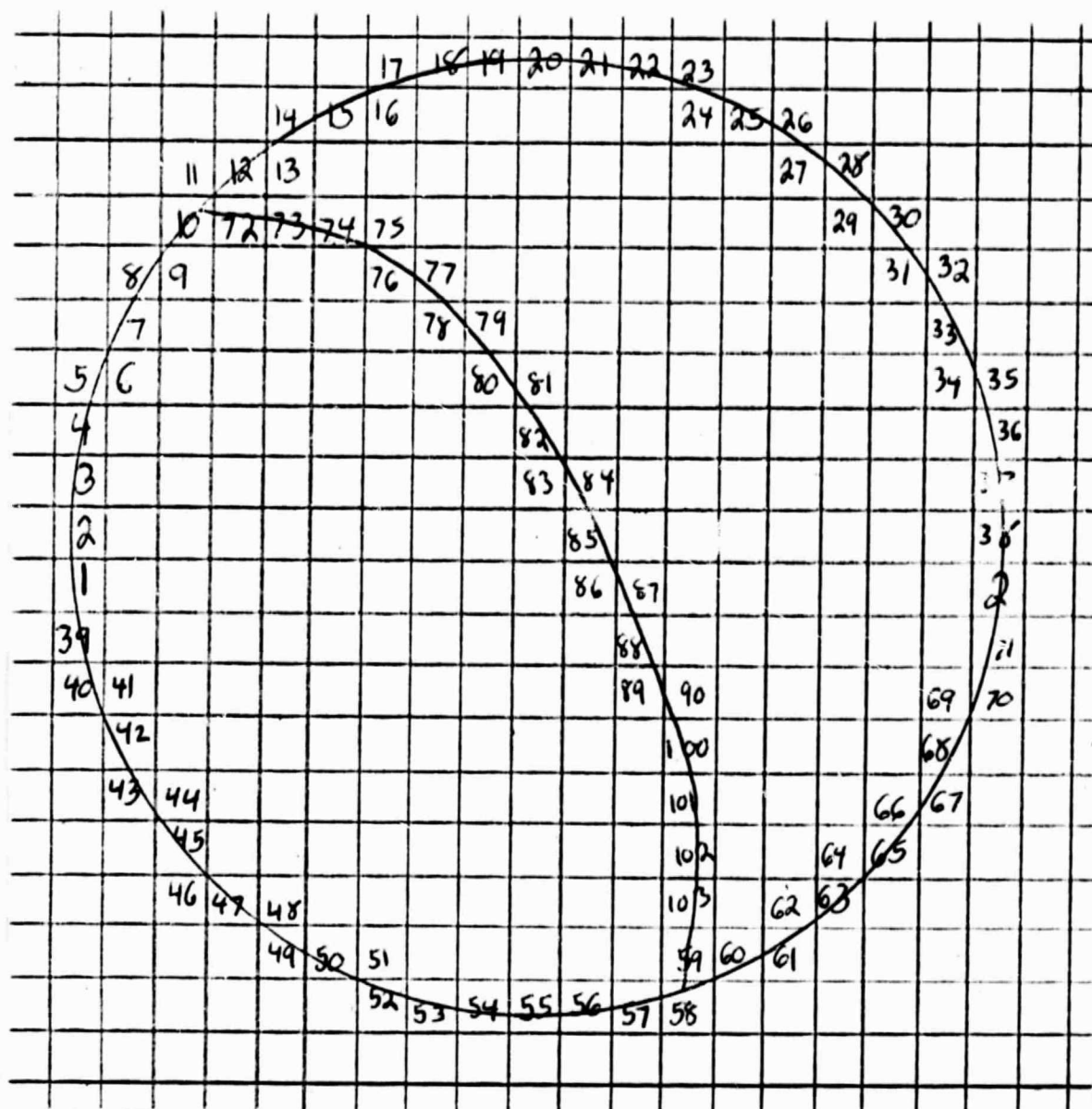
and the direction cosines $\overline{WB}$ from the plane to the Combinatorial Geometry model, consider the grid discussed in Section 1.4. A sequence of rays is fired at equally spaced intervals from left to right along a grid line as shown in Figure 1. For each ray, its position on the grid and the region, body and surface encountered is saved. If the region or body or surface of two adjacent rays differ, then a point on the curve lies between the two ray positions. In this case the interval between the rays is halved and another ray is fired. The procedure is repeated until two rays are 1 grid square apart. Thus, after processing a grid line a set of 'nodes' has been stored, each of which contains a point on the projected image. The above procedure is repeated for every $MESHA/10$ grid lines where MESHA is the input number of intervals in the grid.

This completes the first phase of the MAIN program. For each node found the following nine items are stored.

NUL	{	Region, Body, Surface identifiers for
NUR		Upper-left, Upper-right, Lower-right,
NLR		and Lower-left corners of the node.
NLL		
INDU	{	For each side of the node we indicate
INDL		the status by:
INDD		0 curve exists on this side
INDR		1 no curve
		2 0 at this point
NCL		the location in the grid for this node

Given the nodes the program proceeds to follow the projected curve from each node until the node list has been exhausted. This curve-following procedure is outlined below:

A node is picked up and its status is examined. If a curve exists between any two corners of the node, a pair of rays are fired forming a second node with a point on the boundary between the two nodes. Note here that a node is the size of a grid square. For each new node created the node list is examined to see if the new node has been previously created. The process of creating nodes and calculating plot points for the plotter subroutines continues until all nodes are processed. Figure 5 shows the sequence of new nodes for a simple case.



Nodes 1 and 2 are created by the initial scan.

All other nodes are generated by the curve tracing procedure. Note that the path from nodes 10 to 72 was 'discovered' during the tracing.

Figure 5 - Sequence of New Node Generation

APPENDIX 1

SUBROUTINES REQUIRED BY THE GDC MAIN PROGRAM

Combinatorial Geometry Package

ARB

ARBLAD

CROSS

DOT

DCOSP

ELL

GENI

G1

RCC

REC

RPP

RPP2

S

SPH

TRC

UN3

UNIT

XDIST

EAI Subroutine Package

INSRT (BAL)

OUT (BAL)

LINE