ETL-0223

Advanced feature symbolization for three-dimensional views

Brian J. Cullis

APRIL 1980

U.S. ARMY CORPS OF ENGINEERS
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FORT BELVOIR, VIRGINIA 22060

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This report documents initial research into the development of line-drawn symbols for point features in tactical terrain computer graphics. In this report, 21 significant point features for aircraft in tactical operations were selected for study. Symbols were designed for these 21 point features, with primary emphasis placed upon enhancing rapid user recognition, minimizing computer drawing time and computer storage requirements. Three candidate computer storage strategies, X-Y Absolute, Starburst and Run-Length-Starburst, were evaluated. The most efficient storage strategy for these symbols was the X-Y

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20. Continued

Absolute technique. The symbols were digitized, and software was developed to plot them in conjunction with existing three-dimensional terrain view software.

FOREWORD

The work described in this report was performed in the Automated Cartography Branch, Mapping Development Division, United States Army Engineer Topographic Laboratories (USAETL) by a summer research student from the United States Air Force Academy (USAF), Cadet First Class Brian J. Cullis. The purpose of the research, which was conducted from 11 June to 6 July 1979, was to enable Cadet Cullis to become familiar with the research and development now being conducted in the field of automated cartography and other areas of interest to the Defense Mapping Agency (DMA). The work was supported by DMA under the sub-task "Software for Automated Cartography." Major Mark Mekaru, USAF, Headquarters, DMA was Cadet Cullis' sponsor and Mr. James R. Jancaitis, Computer Scientist, USAETL, was his technical advisor for this effort. Mr. Jancaitis developed a project plan for Cadet Cullis for this research (Appendix A). Because of the short duration of Cadet Cullis' internship, the scope of his effort was somewhat limited. The progress made by Cadet Cullis was quite significant and was important to many projects, prompting publication of this report.

WILLIAM HOWARD CARR, Chief
Automated Cartography Branch

PREFACE

This study was conducted under DMA Project 64701B/4303, "Software for Automated Cartography." The study was done from 11 June to 6 July 1979 under the supervision of Mr. William Howard Carr, Chief, Automated Cartography Branch; Mr. E. P. Griffin, Chief, Mapping Development Division; and Mr. H. O. McComas, Director, Topographic Developments Laboratory.

Thanks are due to Major Mekaru, DMA project sponsor, for the opportunity afforded by this work and for arranging the logistics of my stay at Fort Belvoir. Sincere appreciation to Mr. Jancaitis for his direction and technical guidance. Special thanks to Mssrs. Ed Hoover and Cy Taylor of the Automated Cartography Branch for their assistance in teaching programing and use of the applications software on the PDP 11/45 minicomputer.

COL Daniel L. Lycan, CE was Commander and Director and Mr. Robert P. Macchia was Technical Director of the Engineer Topographic Laboratories during the study and report preparation.

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ADVANCED FEATURE SYMBOLIZATION FOR THREE-DIMENSIONAL VIEWS

INTRODUCTION

In a recent report by the Rand Corporation and in an ETL Technical Report, the authors noted that today the state-of-the-art for employing dynamic and three-dimensional symbols on line-drawn computer-generated topographic perspective views is extremely rudimentary.[1,2] Rand conducted informal experiments to determine the type of symbols that would maximize user performance of interactive command-and-control map display systems. Rand determined that although the resulting line-drawings were at an early stage of development, they still were more useful to planners and problem solvers than the technologically advanced simulative and realistic characters that are available in the simulation technology.

As a step beyond the Rand studies, this report will show that abstract line drawings can be constructed that are extremely useful three-dimensional symbols. These symbols have been designed to minimize symbol recognition time. Expected applications are CRT displays and other military graphics in hostile environments. For these applications, storage requirements, plotting speed and recognition speed are the most important issues. The purpose of this report is to show a more advanced symbol package that will enhance user performance and comprehension and will identify areas for further development.

First the report contains a listing of those symbols needed for this research with a brief analysis of the method of creating these symbols.

Second, there is a discussion of the method of transforming the symbols into the most efficient form for computer usage. A choice had to be made during the research as to the exact encoding format to be used. Today there are three well-used methods to store symbols using computer hardware: (1) starbust coding, (2) run length encoded starburst and (3) x-y coordinates or absolute storage. A comparison was conducted with the outcomes discussed in the second section.

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[1] R. H. Anderson, *Design Studies and Experimentation for a Computer-Based Interactive Command and Control Map Display System*, Unpublished Progress Report, Rand Corporation.

[2] James R. Jancaitis and William R. Moore, *Near Real Time Application of Digital Terrain Data in a Minicomputer Environment*, U. S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0142, April 1978, AD-A054 008.

Third, the results of the computer implementation of these symbols are presented. Also discussed in this section are proposed enhancements to this initial effort.

Fourth, in the conclusions the major results of this research are summarized and discussed in light of future requirements. Several appendixes have been included in the report to document the research and methodology used.

SYMBOL DESIGN

The first step in the design of advanced symbology was to survey and document the current technology. Figures 1 and 2 contain command and control CRT computer graphics from references 1 and 2.

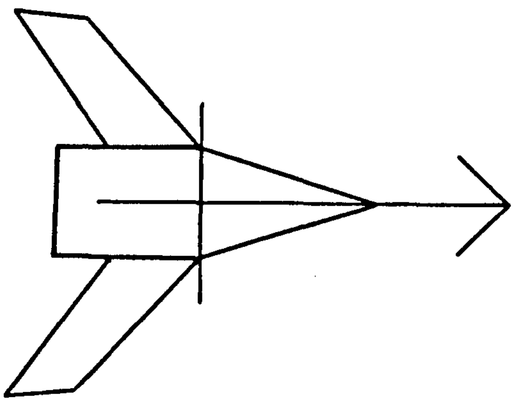


Figure 1. Stylized Jet Plane (Reference 1).

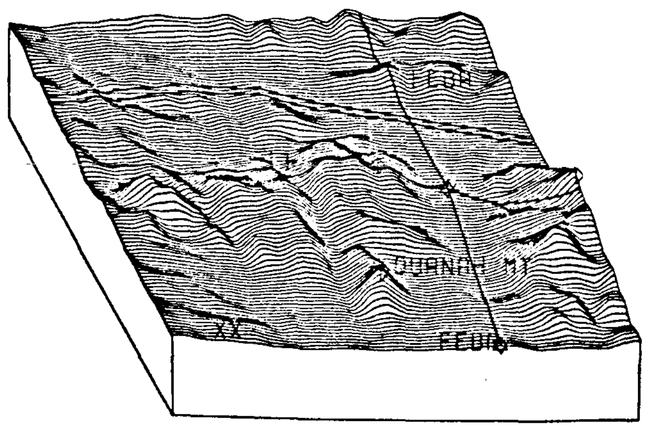


Figure 2. Three-D View with Symbology (Reference 2).

Figure 3 contains the "standard" CALCOMP symbol library. Although they do not represent the best available line-drawn three-dimensional computer symbology, these examples do accurately portray the extent of symbolization available for evaluation at ETL at the start of this work.

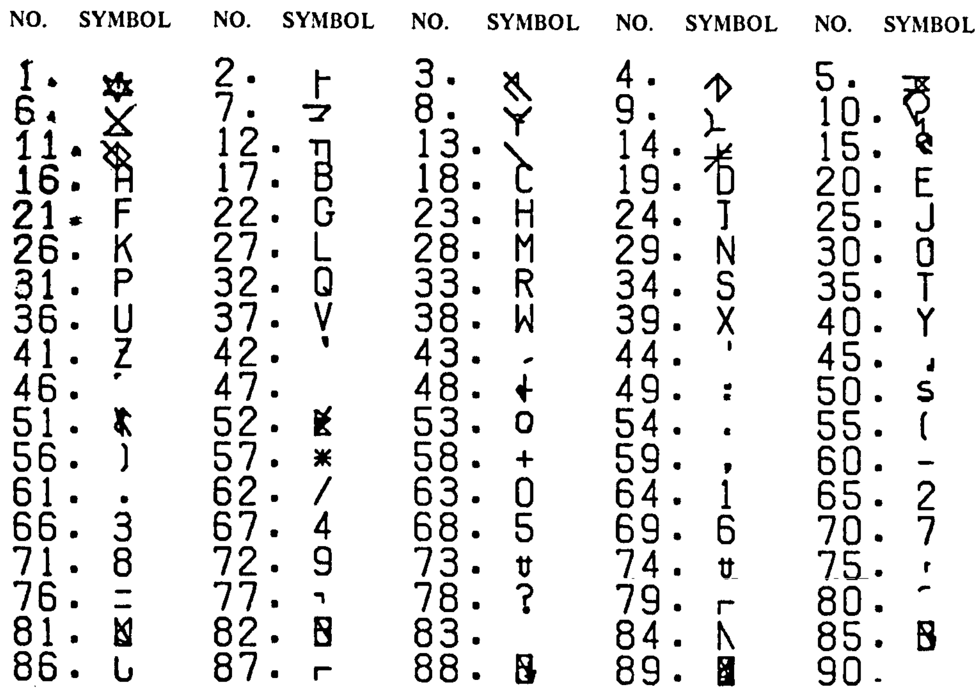
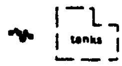
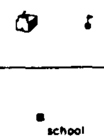
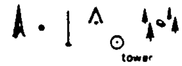
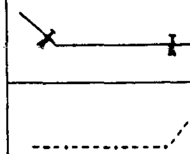


Figure 3. Standard CALCOMP Symbols.

The second step was to examine the current DOD symbology so that standard conventions could be used wherever possible. Figure 4 contains examples of the current military map symbols.

FEATURE NAME (Title)	MAP SYMBOL	FEATURE NAME (Title)	MAP SYMBOL	FEATURE NAME (Title)	MAP SYMBOL
Government Administration Building		Tanks (general)		Airport Control Tower	
School		Tank Cylindrical (with flat top)		Airport Hangar (curved roof)	
Hospital		Tank Cylindrical (with peaked/ conical top on tower)		Communication Tower (general)	
Houses of Religious Worship		Tank Spherical (with column support)		Observation Tower	
Monument		Grain Elevator		Power Transmission Towers (general)	

Source: *Defense Mapping Agency Product Specifications for Digital Landmass System Data Base*, DMA Aerospace Center, St. Louis, MO. First Edition, July 1977, PS/ICD/100, Appendix IV.

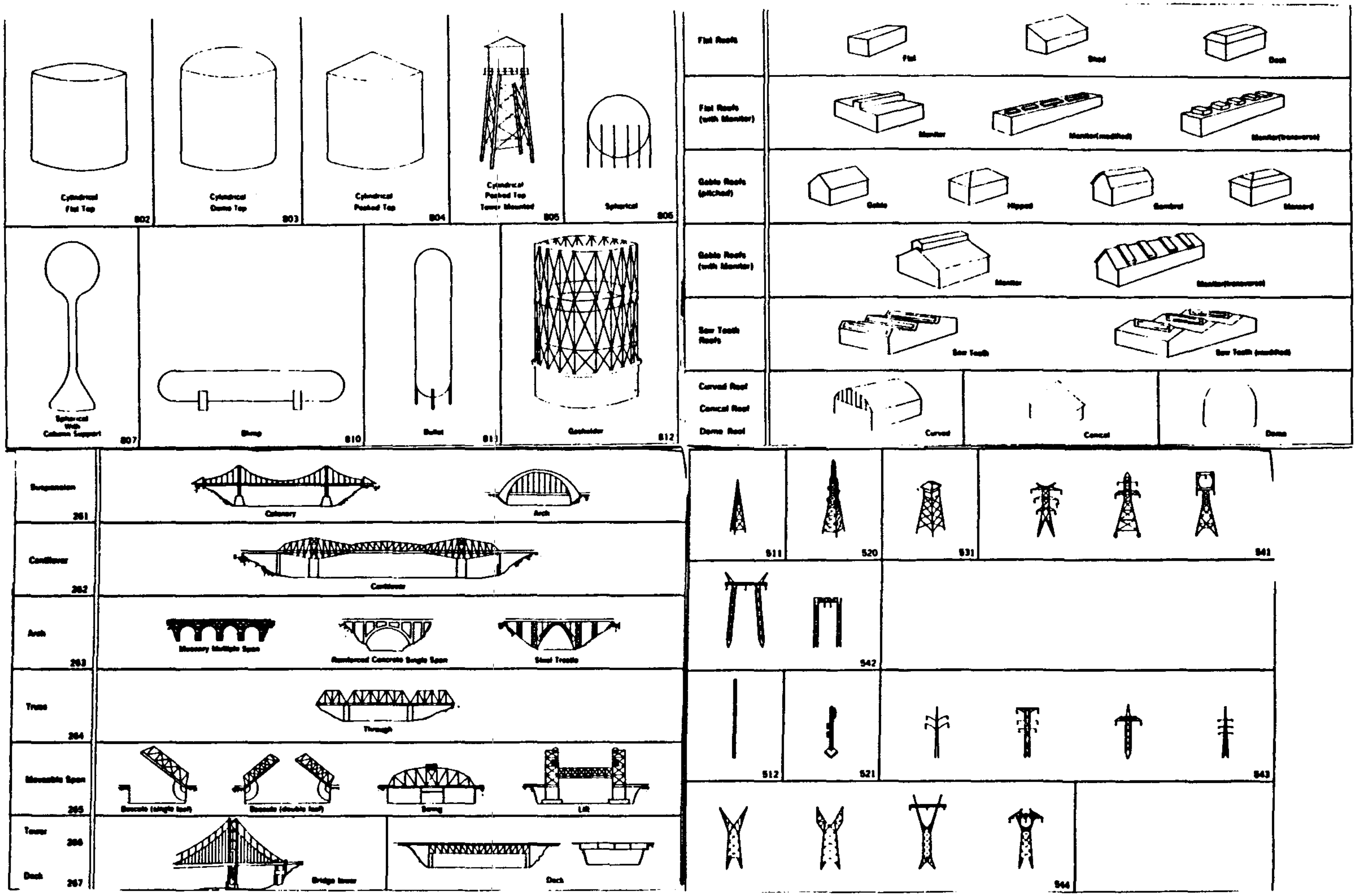
Figure 4. Current Map Symbols (Reference 4).

The third step was to define the special features to be examined. The features in table 1 were selected for their importance to a low-level penetrator in a hostile environment. An artist's rendition of some of these features are shown in figure 5. The purpose of this research is to approach this quality within the restrictions of simplicity, speed, and enhanced recognition.

TABLE 1. Features Selected for Sympolization

Civilian Features	Military Features
Building	Surface-to-Air Missile Installation
Church	Gas Storage Depot
School	Ammunition Bunker
Factory	Oil Storage Depot
Hospital	Prisoner/of/War Compound
Airport Control Tower	
Bridge (Truss)	
Bridge (Beam/Deck)	
Cemetery	
Microwave Tower	
Observation Tower	
Light Tower/Beacon	
High Power Lines	
Telephone/Electric Service Lines	
Dam	
Water Tower	

In anticipation of the digital encoding of the symbols, the desire for simplicity and speed, and the line-drawing CRT constraint, the basis of the symbol design was a 9 x 9 grid, see figure 6.



Source: *Defense Mapping Agency Product Specifications for Digital Landmass System Data Base,* DMA Aerospace Center, St. Louis, MO, First Edition, July 1977. PS/ICD/100, Appendix IV.

Figure 5. Artist Renditions of Features.

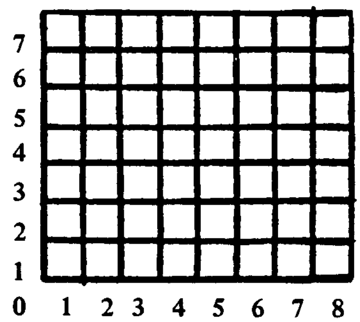


Figure 6. Basic Grid for Symbol Design.

This basic grid was chosen to aid in designing the symbols. The end points for each line segment of the proposed symbol must coincide with one of the 81 grid intersections. One example of the symbols designed is shown below in figure 7, with the current standard symbol shown in figure 8. Appendix B contains a complete listing of the symbols and appendix C contains a complete comparison of the symbols.

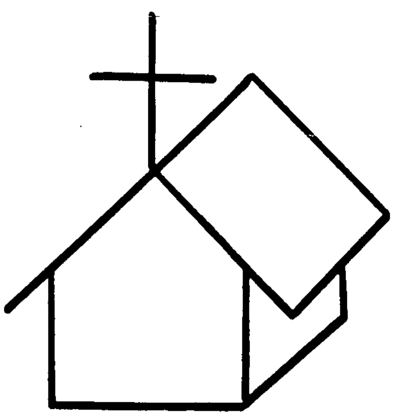


Figure 7. CRT Graphics Church Symbol.

Figure 8. DMA Standard Church Symbol.

Having designed a set of test CRT symbology, one must provide for digital representation for compact storage in the computer. One step toward the compact representation was accomplished by restricting all line end-points to the intersections of a 9 by 9 grid. This restriction aids in compact representation because only small magnitude integers are required to specify the location of the end-points of any line making up the symbol. Another step is selection of the specific format for digital storage of these line end-point coordinates. Three basic widely utilized ways to construct symbols were investigated, (1) the starburst, (2) the run-length coded, and (3) the X-Y grid coordinate method.

SYMBOL ENCODING

Recently the starburst method has been used more because of its proven smaller computer storage space requirement when compared to the required storage space of the grid method for many applications. When using the starburst method, either a unit increment code or a run-length code must be selected. The run-length code has two arguments, one being the direction and the other the magnitude. The grid method involves moving the plotter pen to X-Y grid point with either pen up or down and then moving to the next X-Y grid point.

Both types of starburst formats were compared in a test against the grid system using a standard eight-bit byte using four of the symbols created.

The following byte format was used in each respective case:

	X-Y Grid Format	Starburst Unit Format	Starburst Run-Length Format
Bite	1 2 3 4 5 6 7 8	1 2 3 4 5 6 7 8	1 2 3 4 5 6 7 8
	X-Val Y-Val	1st Cmd 2nd Cmd	Direction Magnitude

The pen-up or pen-down command can be stored in a bit array and would be the same length for all three formats.

After constructing four separate three-dimensional symbols using both the X-Y and starburst codes, it was concluded that the X-Y method was superior for the following reasons:

1. It used less computer storage space because of the number of lines in graphing the symbols and thus was slightly more economical.

2. It enabled the user to have more flexibility, as starburst software restricted the user to a 45° rotational increment.

3. It did not limit the design potential and capabilities (see figures 9 and 10).

4. It did not limit the three-dimensional perspective (see figure 10).

5. It enhanced the goal of limited symbol recognition time.

Appendix D contains a detailed technical comparison.

Based upon the superior performance of the X-Y method, the coordinates for all the line segments for the new symbols were computed and are contained in appendix E.

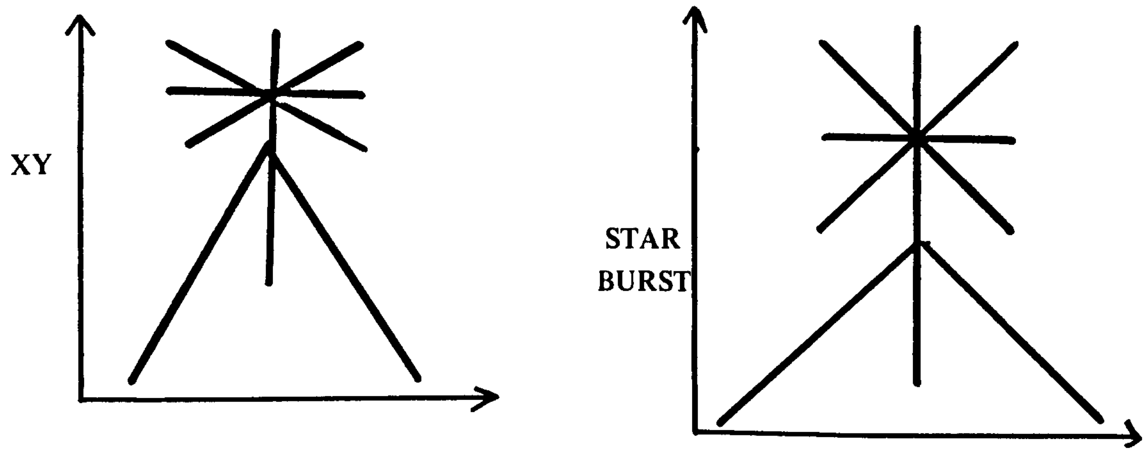


Figure 9. Microwave Tower.

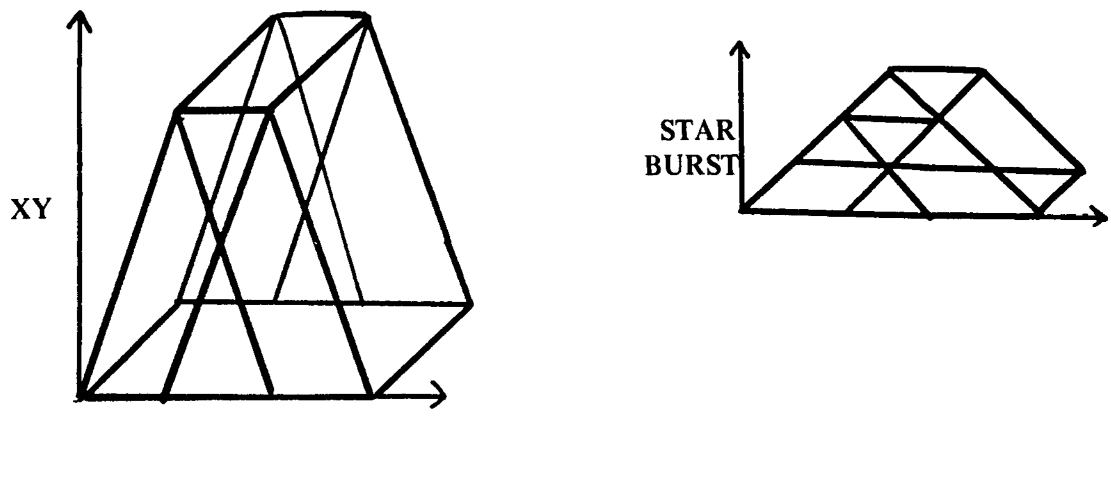


Figure 10. Truss Bridge.

RESULTS

The evaluation of the new symbology could only be accomplished by its simultaneous display on the CRT with digital map data. Therefore, the symbol coordinates were used to create a disk file on a DEC PDP 11/45 minicomputer. A FORTRAN subroutine was written to enable processing of the data disk file for plotting the features on the CRT plotter (Tektronix 4014). A listing of the data file and subroutine are contained in appendix F. This plotting capability was then integrated with the ETL oblique view software.[3] Figures 11 and 12 are three-dimensional plots with and without the new symbology.

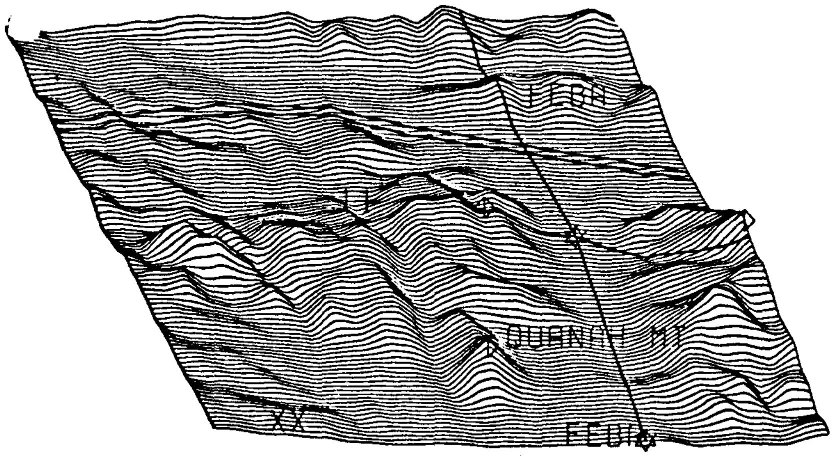


Figure 11. Three-Dimensional Plot with Initial Symbology.

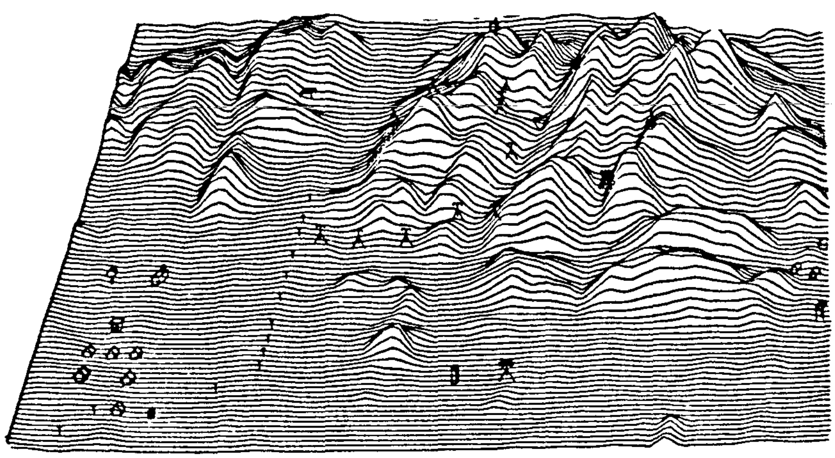


Figure 12. Three-Dimensional Plot with New Symbology.

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[3] James R. Jancaitis and William R. Moore, *Near Real Time Application of Digital Terrain Data in a Minicomputer Environment*, U. S. Army Engineer Topographic Laboratories, Ft. Belvoir, VA, ETL-0142, April 1978, AD-A054 008.

This research is a brief first step toward defining the optimal set of three-dimensional symbology. The purposed use of additional feature detail and shading appears to offer some promise for increasing comprehension without unduly affecting speed and storage.

The following is an example of the proposed enhancement project that could be implemented with the basic symbols shown in the Manual of Symbols (appendix B).

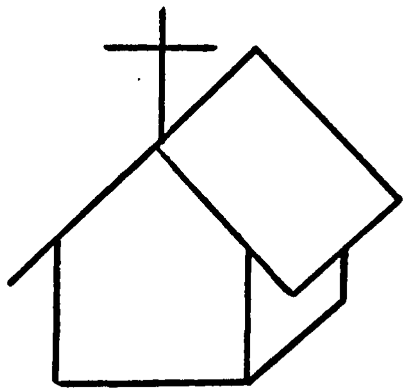


Figure 13. Basic Symbol Created In-House Representing a Church.

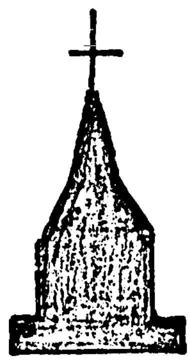


Figure 14. Basic Symbol Used by DMAHTC, AlsoRepresenting a Church.

Although figure 14 is only two-dimensional, the outline method is very effective in ac :urately suggesting the actual feature.

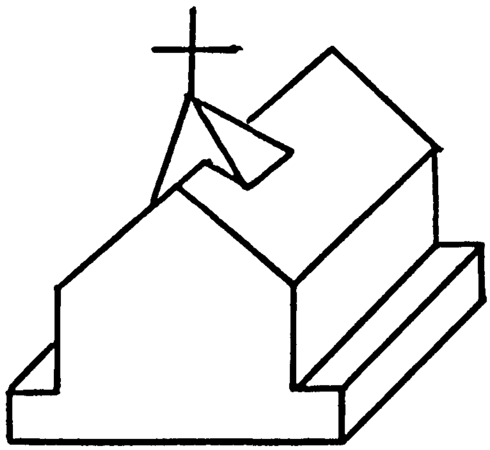


Figure 15. Three-Dimensional Symbol Made In-House From the Pictoral Symbol.

Notice how this figure compares to the basic symbol from the Manual. Such an enhancement process could prove extremely valuable in the area of feature identification.

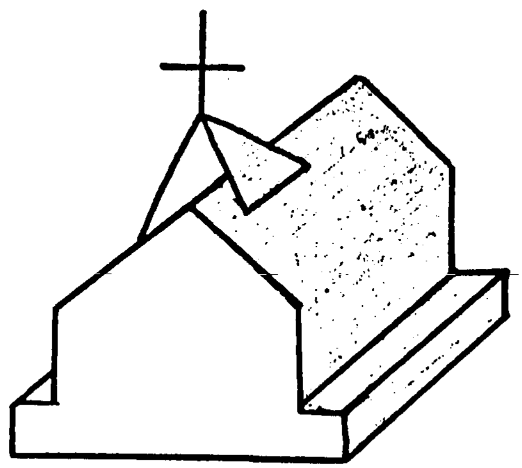


Figure 16. Example of Shading.

Shading lends a greater three-dimensional effect to the symbol.

Basic symbol analysis and revision takes time, but it should be seriously considered in the future as a part of the Advanced Feature Symbolization Project. The results would contribute greatly to the field of automated cartography.

CONCLUSIONS

This research has led to the conclusions that: a. symbology can be designed for optimal utilization in hostile environments. b. Although highly simulative, realistic, technologically intensive displays are potentially available for use in the command-and-control map display systems, they are not desirable. c. Three-dimensional, computer-generated line-drawn symbols can require considerably less computer resources and offer the potential of faster user recognition. d. The X-Y grid coordinate format proved to be the most efficient computer storage technique for the line-drawn symbology. e. Although the basic symbols represented in this report comprise only the beginning of advanced feature symbology for hostile environment computer graphics, the results are very promising.

APPENDIX A. PROJECT OUTLINE

PROJECT OUTLINE

for

CADET BRIAN CULLIS

by

JAMES R. JANCAITIS

PROJECT TITLE: Development of Advanced Feature Symbolization for Three-Dimensional Views

PROJECT DURATION: Six Weeks

PROJECT END PRODUCT: Technical Report

HOSTING LABORATORY: U. S. Army Engineer Topographic Laboratories (ETL), Fort Belvoir, Virginia 22060

TECHNICAL POINT OF CONTACT: Mr. James R. Jancaitis

PROJECT TECHNICAL AREA: Computer Applications of DMA Digital Data

PROJECT OBJECTIVE:

The objectives of this assignment are to acquaint the student with an R&D laboratory and its procedures; to expose the student to applications of DMA digital data in strategic, tactical, training and planning problems; and to provide hands-on experience in use, modification, and documentation of state-of-the-art computer graphics software.

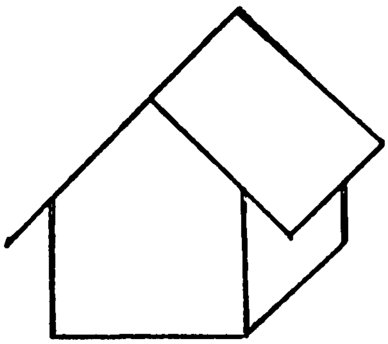
PROJECT DESCRIPTION:

WEEK 1	—	The student will receive an orientation of DMA's mission and activities. If possible, the student will visit one or two of DMA's production centers. The student will receive a two-day introduction to ETL, use of the minicomputer facility, and operation of the applications software.
WEEK 2	—	The student will analyze the currently employed symbology and the source code utilized to portray them in the three-dimensional views.
WEEK 3 and 4	—	The student will study previous work on cockpit display symbolization and develop new, more sophisticated symbology.
WEEK 5	—	The student will implement these symbols in source code using ETL technical personnel assistance.
WEEK 6	—	The student will incorporate the resulting graphics in a report which documents the student's activities during the six-week period.

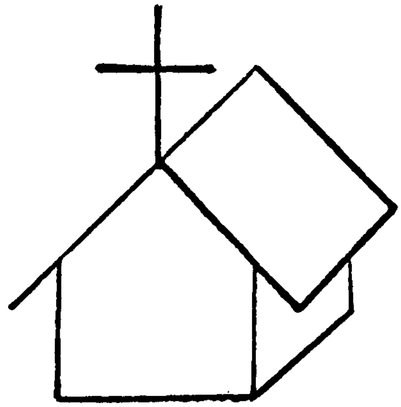
NOTE: Cadet Cullis will meet with Major Mekaru once a week.

Appendix B.

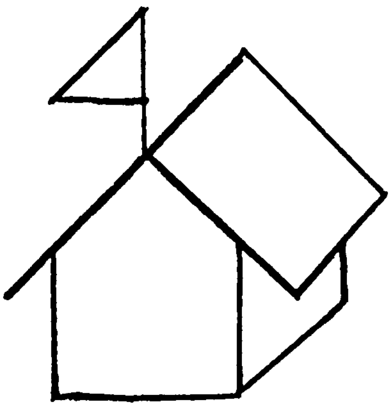
Manual of New Symbols



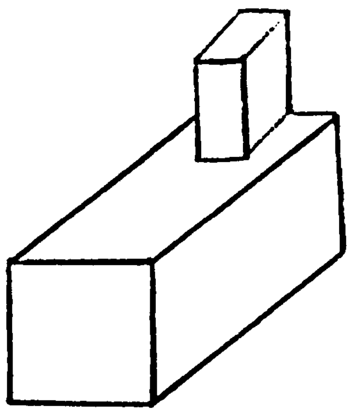
1. Building



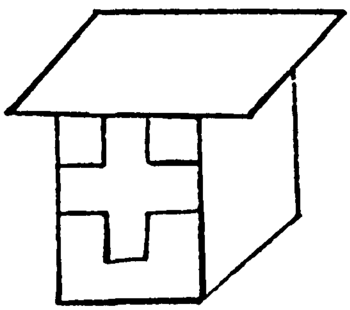
2. Church



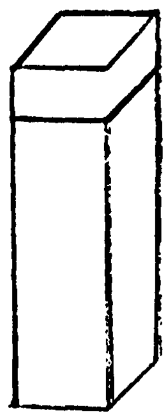
3. School



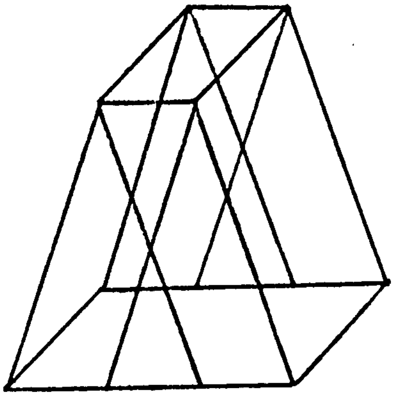
4. Factory



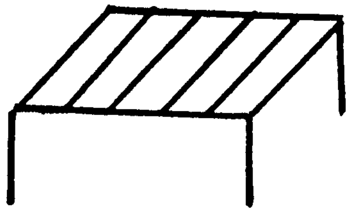
5. Hospital



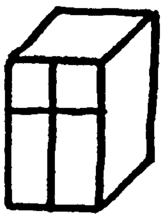
6. Control Tower



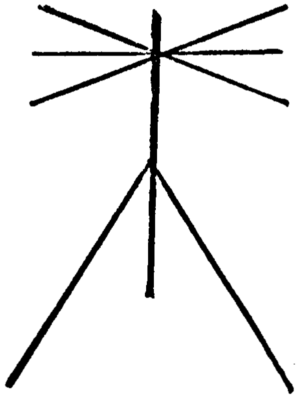
7. Bridge (Truss)



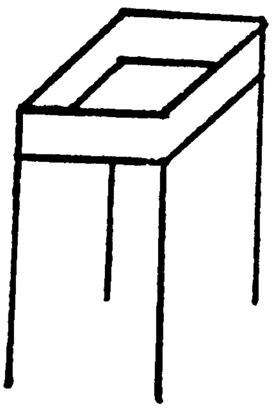
8. Bridge (Beam/Deck)



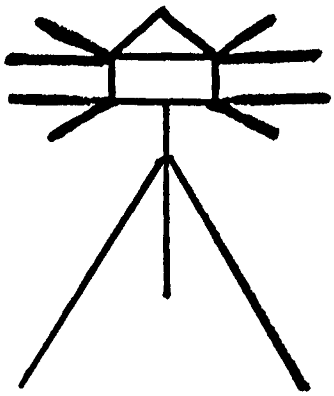
9. Cemetery



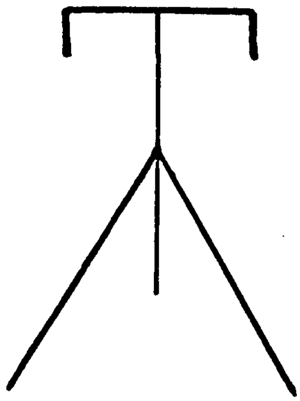
10. Microwave Tower



11. Observation Tower

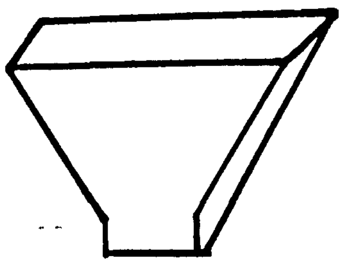


12. Light Tower/Lighthouse

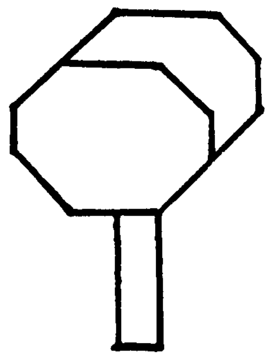


13. High Power Service Lines

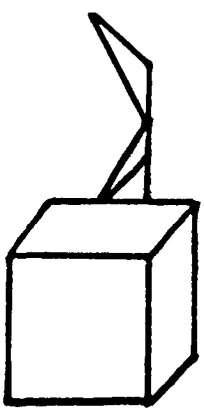
Telephone/EL SRVC Lines



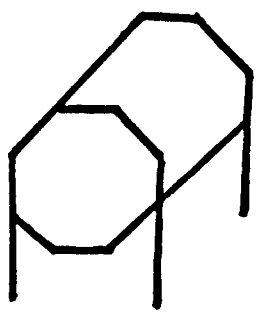
15. Dam



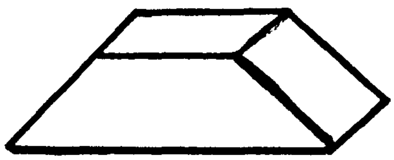
16. Water Tower



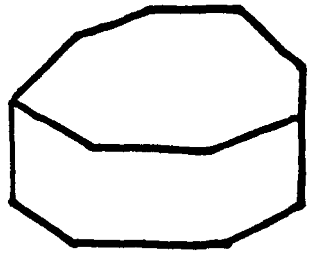
17. Surface-To-Air Missile Installation



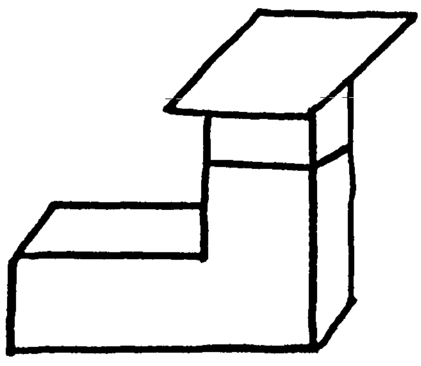
18. Gas Storage Depot



19. Ammunition Bunker



20. Oil Storage Depot

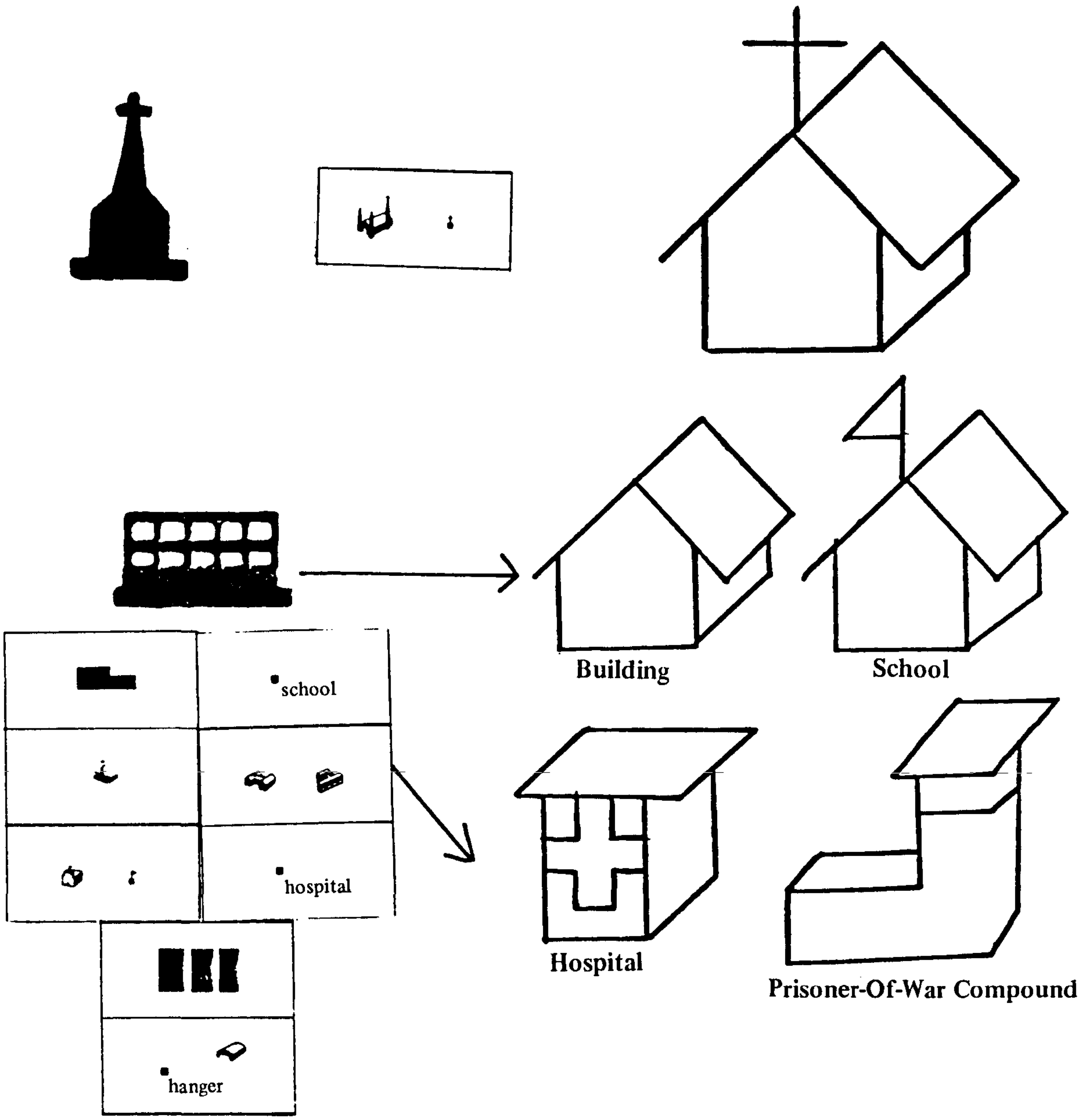


21. Prisoner-of-War Compound

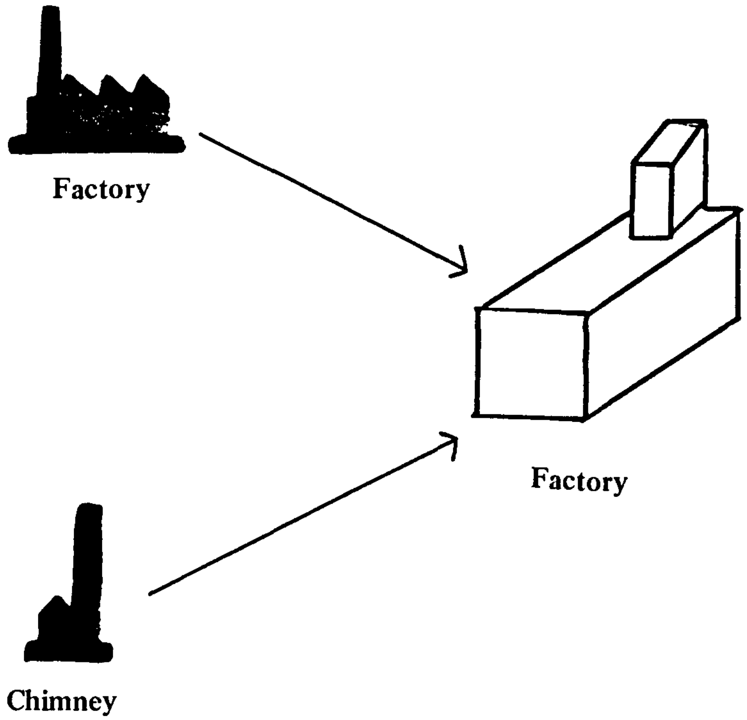
Appendix C

Comparison of Symbols and DOD Pictorial Symbols

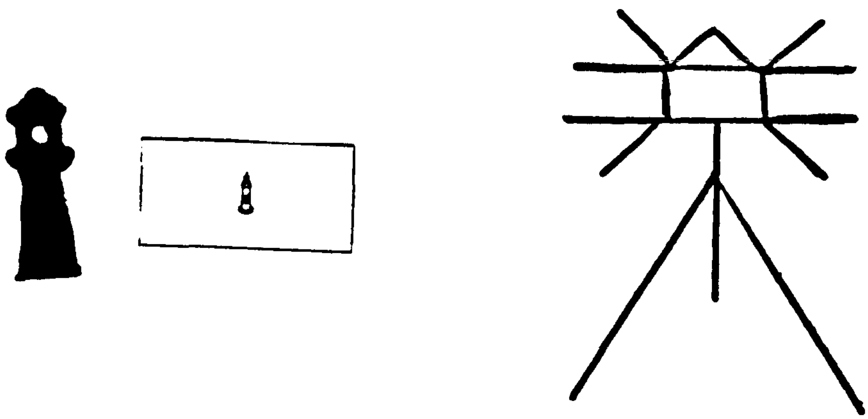
An individual comparison of established DMAHTC pictorial symbols with the basic three-dimensional symbol.



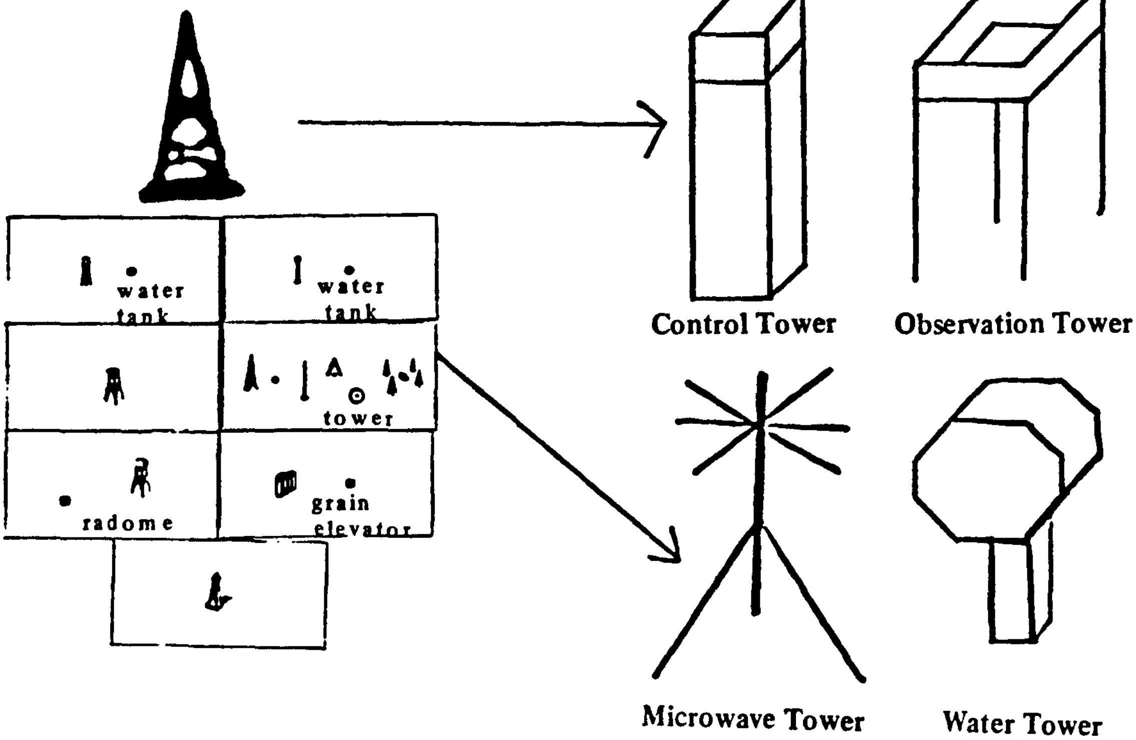
2. Building(s)



3. Factory



4. Lighthouse



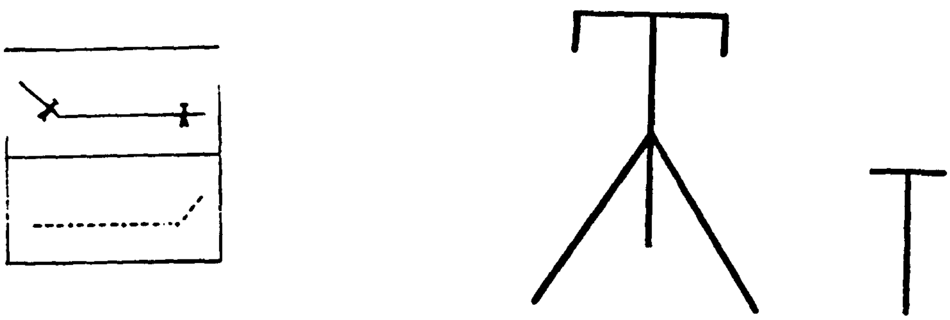
5. Tower(s)

(There is no corresponding three-dimensional basic symbol for specific monuments. The monument is considered a vertical obstruction worth noting but such specificity was not deemed necessary)

6. Monument

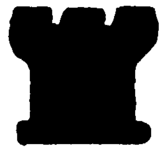
7. Oil Storage Depot

8. Gas Storage Depot



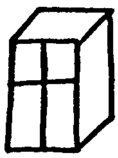
9. High Power And TEL/EL Service Lines

Slag Pile

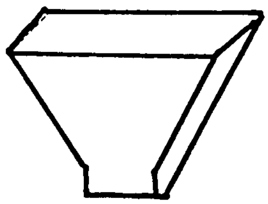


Castle

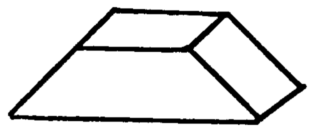
10. DMAHTC Pictorial Symbols With No Basic Symbol Comparison



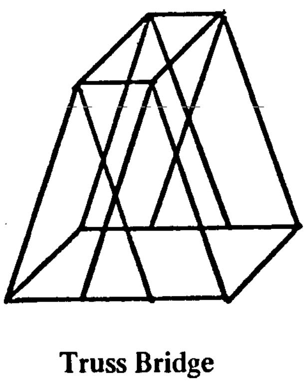
Cemetery



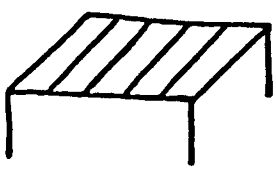
Dam



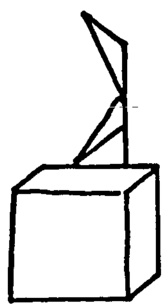
Ammunition Depot



Truss Bridge



Beam/Deck Bridge

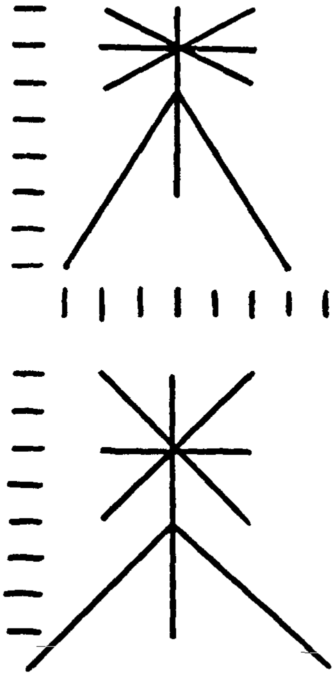


Surface-To-Air Missile Installation

11. Basic Three-Dimensional Symbols With No DMAHTC Pictorial Symbol Comparison

Appendix D.

Comparison of Storage Alternatives: X-Y Coordinate and Starburst Codes

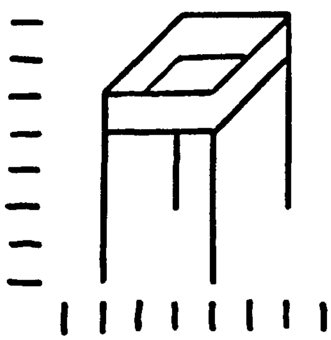


	XY			STARBURST		
	I	X	Y	I	2nd Comm	1st Comm
1.	1	1	1	2	1	1
2.	2	4	6	2	1	1
3.	2	7	1	2	3	3
4.	1	4	3	2	3	3
5.	2	4	8	2	7	7
6.	1	2	8	2	7	7
7.	2	6	6	2	4	4
8.	1	2	6	2	0	4
9.	2	6	8	2	0	0
10.	1	2	8	2	0	0
11.	2	6	8	2	0	0
12.				2	4	4
13.				2	7	7
14.				2	3	3
15.				2	1	1
16.				2	5	5
17.				2	5	5
18.				2	1	1
19.				2	3	3
20.				2	7	7
21.				2	6	6
22.				2	2	2
23.				2	2	2

Required Byte Size
X-Y 11 bytes

STARBURST 23 Bytes *Design Limitation

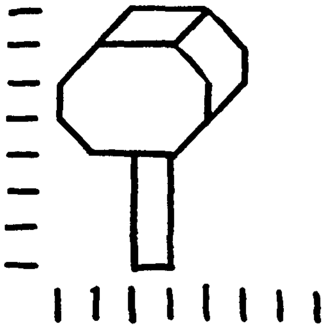
Appendix D. Continued



	XY			STARBURST		
	I	X	Y	I	2nd Comm	1st Comm
1.	1	7	3	2	0	0
2.	2	7	8	2	0	0
3.	2	4	8	2	1	0
4.	2	2	6	2	2	1
5.	2	2	1	2	2	2
6.	1	2	5	2	6	6
7.	2	5	5	2	6	6
8.	2	7	7	2	0	6
9.	1	6	7	2	0	0
10.	2	4	7	2	5	0
11.	2	3	6	2	6	5
12.	1	4	5	2	4	4
13.	2	4	3	2	0	0
14.	1	5	1	2	6	6
15.	2	5	5	2	2	0
16.				2	2	1
17.				2	1	2
18.				2	5	5
19.				2	6	6

Required Byte Size
X-Y 15 Bytes

STARBURST 19 Bytes

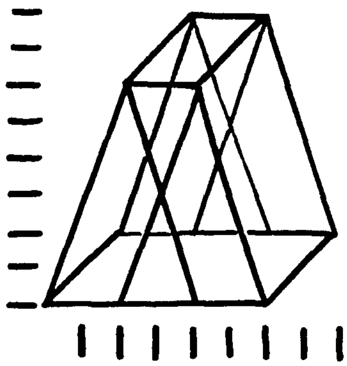


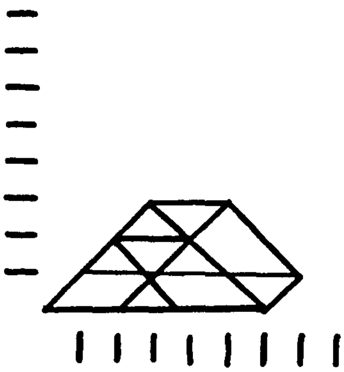
	XY			STARBURST		
	I	X	Y	I	2nd Comm	1st Comm
1.	1	3	4	2	0	0
2.	2	4	4	2	6	0
3.	2	4	1	2	0	7
4.	2	3	1	2	1	1
5.	2	3	4	2	3	2
6.	2	2	4	2	5	4
7.	2	1	5	2	7	0
8.	2	1	6	2	2	6
9.	2	3	8	2	5	1
10.	2	5	8	2(1)	4	3
11.	2	6	7	2	6	5
12.	2	6	6	2	4	2
13.	2	4	4	2	4	4
14.	1	2	7			
15.	2	4	7			
16.	2	5	6			
17.	2	5	5			
18.	1	4	7			
19.	2	5	8			

76	543	210	76	543	210
IPEN	XVAL	YVAL	IPEN	2nd Comm	1st Comm

Required Byte Size
X-Y 19 Bytes

STARBURST 13 Bytes

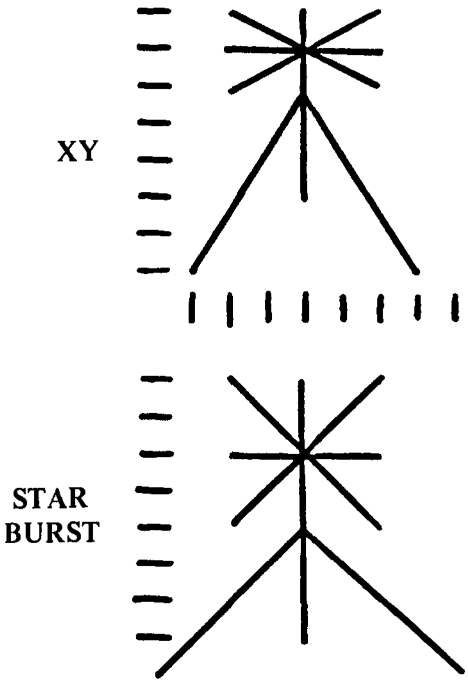




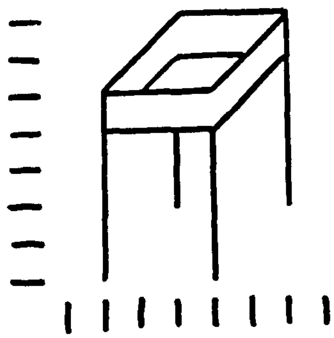
	XY			STARBURST		
	I	X	Y	I	2nd Comm	1st Comm
1.	1	2	0	2	1	1
2.	2	0	0	2	2	1
3.	2	2	6	2	3	2
4.	2	4	0	2	5	3
5.	2	2	0	2	6	6
6.	2	4	6	2	6	6
7.	2	6	0	2	6	6
8.	1	4	2	2	2	2
9.	2	2	2	2	1	1
10.	2	4	8	2	6	1
11.	2	6	2	2	3	6
12.	2	4	2	2	6	6
13.	2	6	8	2	3	3
14.	2	8	2	2	2	2
15.	2	6	2	2	7	7
16.	1	2	6	2	5	7
17.	2	4	8			
18.	2	6	8			
19.	2	4	6			
20.	2	2	6			

Required Byte Size
X-Y 20 Bytes

STARBURST 16 Bytes *Design Limitation
*Factor Call Needed

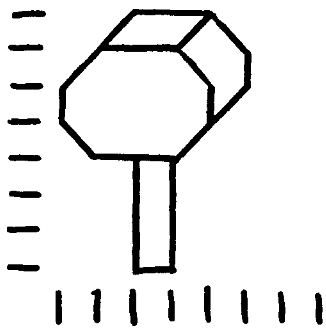


XY		IPEN
I	DIR	MAG
2	1	4
2	3	4
1	7	4
2	4	3
2	0	5
2	7	2
2	3	4
1	7	2
2	5	2
2	1	4
1	5	2
2	6	2
2	2	4



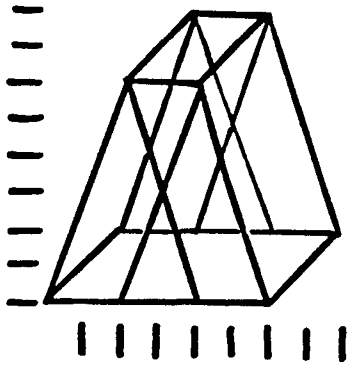
X Y		IPEN
I	DIR	MAG
2	0	5
2	1	2
2	2	3
2	4	5
1	0	4
2	5	2
2	4	4
1	0	4
2	6	1
2	4	2
1	0	2
2	6	2
1	0	1
2	2	3
2	1	2
1	5	1
2	6	2
2	5	1

Appendix D. Continued

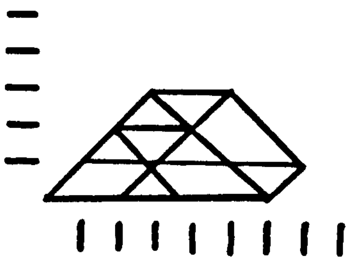


X Y		IPEN
I	DIR	MAG
2	0	3
2	2	1
2	4	3
2	6	1
2	3	3
2	6	1
2	7	1
2	0	1
2	1	2
2	2	2
2	3	1
2	4	1
2	5	2
1	1	1
2	0	1
2	7	1
2	6	2
1	2	2
2	1	1

XY



STAR BURST



	X Y	IPEN
I	DIR	MAG
2	1	3
2	2	2
2	3	2
2	5	1
2	6	6
2	1	1
2	2	6
2	7	2
2	5	3
2	2	2
2	7	2
2	1	1
2	2	2
2	7	1
2	3	3

Appendix E.

Digitizing Basic Manual Symbols

Table 1. Building

13 Bytes

	IPEN	X--VAL	Y--VAL
1.	3	5	3
2.	2	5	0
3.	2	1	0
4.	2	1	3
5.	2	0	2
6.	2	5	7
7.	2	8	4
8.	2	6	2
9.	2	3	5
10.	3	7	3
11.	2	7	2
12.	2	5	0
13.	3	0	0

Table 2. Church

16 Bytes

	IPEN	X--VAL	Y--VAL
1.	3	5	3
2.	2	5	0
3.	2	1	0
4.	2	1	3
5.	2	0	2
6.	2	5	7
7.	2	8	4
8.	2	6	2
9.	2	3	5
10.	2	3	8
11.	3	2	7
12.	2	4	7
13.	3	7	3
14.	2	7	2
15.	2	5	0
16.	3	0	0

Appendix E. Continued

Table 3. School

16 Bytes

	IPEN	X--VAL	Y--VAL
1.	3	5	3
2.	2	5	0
3.	2	1	0
4.	2	1	3
5.	2	0	2
6.	2	5	7
7.	2	8	4
8.	2	6	2
9.	2	3	5
10.	2	3	8
11.	2	1	6
12.	2	3	6
13.	3	7	3
14.	2	7	2
15.	2	5	0
16.	3	0	0

Table 4. Factory

25 Bytes

	IPEN	X--VAL	Y--VAL
1.	3	0	3
2.	2	0	0
3.	2	3	0
4.	2	3	3
5.	2	0	3
6.	2	4	6
7.	2	4	7
8.	2	5	8
9.	2	6	8
10.	2	6	6
11.	2	5	5
12.	2	4	5
13.	2	4	6
14.	2	4	7
15.	2	5	7
16.	2	6	8
17.	3	5	5
18.	2	5	7
19.	3	6	6
20.	2	7	6
21.	2	3	3
22.	3	3	0
23.	2	7	3
24.	2	7	6
25.	3	0	0

Appendix E. Continued

Table 5. Hospital

25 Bytes

	IPEN	X-VAL	Y-VAL
1.	3	0	4
2.	2	2	6
3.	2	7	6
4.	2	5	4
5.	2	0	4
6.	3	6	5
7.	2	6	2
8.	2	4	0
9.	2	1	0
10.	2	1	4
11.	3	4	4
12.	2	4	0
13.	3	1	3
14.	2	2	3
15.	2	2	4
16.	3	3	4
17.	2	3	3
18.	2	4	3
19.	3	4	2
20.	2	3	2
21.	2	3	1
22.	2	2	1
23.	2	2	2
24.	2	1	2
25.	3	0	0

Table 6. Control Tower

15 Bytes

	IPEN	X-VAL	Y-VAL
1.	3	2	0
2.	2	0	0
3.	2	7	0
4.	2	1	8
5.	2	3	8
6.	2	2	7
7.	2	0	7
8.	3	0	6
9.	2	2	6
10.	2	2	0
11.	2	3	1
12.	2	3	8
13.	3	3	7
14.	2	2	6
15.	3	0	0

Appendix E. Continued

Table 7. Bridge (Truss)

		IPEN	X--VAL	Y--VAL
	1.	3	2	0
	2.	2	0	0
	3.	2	2	6
	4.	2	4	0
	5.	2	2	0
21 Bytes	6.	2	4	6
	7.	2	6	0
	8.	3	4	2
	9.	2	2	2
	10.	2	4	8
	11.	2	6	2
	12.	2	4	2
	13.	2	6	8
	14.	2	8	2
	15.	2	6	2
	16.	3	2	6
	17.	2	4	8
	18.	2	6	8
	19.	2	4	6
	20.	2	2	6
	21.	3	0	0

Table 8. Bridge (Beam/Deck)

		IPEN	X--VAL	Y--VAL
	1.	2	0	0
	2.	2	0	2
	3.	2	2	4
	4.	2	7	4
	5.	2	7	2
19 Bytes	6.	3	5	0
	7.	2	5	2
	8.	2	7	4
	9.	3	5	2
	10.	2	0	2
	11.	3	1	2
	12.	2	3	4
	13.	3	2	2
	14.	2	4	4
	15.	3	3	2
	16.	2	5	4
	17.	3	4	2
	18.	2	6	4
	19.	3	0	0

Appendix E. Continued

Table 9. Cemetery

		IPEN	X--VAL	Y--VAL
	1.	2	0	0
	2.	2	0	3
	3.	2	1	4
	4.	2	3	4
	5.	2	3	1
	6.	2	2	0
	7.	2	0	0
17 Bytes	8.	3	1	0
	9.	2	1	3
	10.	3	0	2
	11.	2	2	2
	12.	3	0	3
	13.	2	2	3
	14.	2	2	0
	15.	3	2	3
	16.	2	3	4
	17.	3	0	0

Table 10. Microwave Tower

		IPEN	X--VAL	Y--VAL
	1.	3	1	1
	2.	2	4	6
	3.	2	7	1
	4.	3	4	3
	5.	2	4	8
	6.	3	2	8
	7.	2	6	6
12 Bytes	8.	3	2	6
	9.	2	6	8
	10.	3	2	8
	11.	2	6	8
	12.	3	0	0

Table 11. Observation Tower

16 Bytes

	IPEN	X--VAL	Y--VAL
1.	3	7	3
2.	2	7	8
3.	2	4	8
4.	2	2	6
5.	2	2	1
6.	3	2	5
7.	2	5	5
8.	2	7	7
9.	3	6	7
10.	2	4	7
11.	2	3	6
12.	3	4	5
13.	2	4	3
14.	3	5	1
15.	2	5	5
16.	3	0	0

Table 12. Light Tower/Beacon

21 Bytes

	IPEN	X--VAL	Y--VAL
1.	2	0	0
2.	2	3	5
3.	2	6	0
4.	3	3	2
5.	2	3	6
6.	3	0	6
7.	2	6	6
8.	3	0	7
9.	2	6	7
10.	3	1	8
11.	2	2	7
12.	2	3	8
13.	2	4	7
14.	2	5	8
15.	3	4	7
16.	2	4	6
17.	2	5	5
18.	3	1	5
19.	2	2	6
20.	2	2	7
21.	3	0	0

Appendix E. Continued

Table 13. High Power Lines

		IPEN	X--VAL	Y--VAL
	1.	2	0	0
	2.	2	3	5
	3.	2	6	0
10 Bytes	4.	3	3	2
	5.	2	3	8
	6.	3	1	7
	7.	2	1	8
	8.	2	5	8
	9.	2	5	7
	10.	3	0	0

Table 14. Telephone/Electric Service Lines

		IPEN	X--VAL	Y--VAL
	1.	3	1	0
	2.	2	1	4
	3.	3	0	4
5 Bytes	4.	2	2	4
	5.	3	0	0

Table 15. Dam

		IPEN	X--VAL	Y--VAL
	1.	3	4	0
	2.	2	2	0
	3.	2	2	1
	4.	2	0	4
	5.	2	1	5
13 Bytes	6.	2	7	5
	7.	2	4	0
	8.	2	4	1
	9.	2	6	4
	10.	2	7	5
	11.	3	6	4
	12.	2	0	4
	13.	3	0	0

Appendix E. Continued

Table 16. Water Tower

		IPEN	X--VAL	Y-VAL
	1.	3	3	4
	2.	2	4	4
	3.	2	4	1
	4.	2	3	1
	5.	2	3	4
	6.	2	2	4
20 Bytes	7.	2	1	5
	8.	2	1	6
	9.	2	3	8
	10.	2	5	8
	11.	2	6	7
	12.	2	6	6
	13.	2	4	4
	14.	3	2	7
	15.	2	4	7
	16.	2	5	6
	17.	2	5	5
	18.	3	4	7
	19.	2	5	8
	20.	3	0	0

Table 17. Sam Installation

		IPEN	X--VAL	Y--VAL
	1.	3	0	3
	2.	2	3	3
	3.	2	3	0
	4.	2	0	0
	5.	2	0	3
	6.	2	1	4
18 Bytes	7.	2	4	4
	8.	2	4	1
	9.	2	3	0
	10.	3	3	3
	11.	2	4	4
	12.	3	3	4
	13.	2	3	7
	14.	2	2	8
	15.	2	3	6
	16.	2	2	4
	17.	2	3	5
	18.	3	0	0

Table 18. Gas Storage Depot

15 Bytes

	IPEN	X--VAL	Y--VAL
1.	2	0	0
2.	2	0	3
3.	2	3	6
4.	2	4	6
5.	2	5	5
6.	2	5	2
7.	3	5	4
8.	2	2	1
9.	2	1	1
10.	2	0	2
11.	3	3	0
12.	2	3	3
13.	2	2	4
14.	2	1	4
15.	3	0	0

Table 19. Ammunition Bunker

12 Bytes

	IPEN	X--VAL	Y--VAL
1.	2	0	0
2.	2	3	3
3.	2	6	3
4.	2	8	1
5.	2	7	0
6.	2	5	2
7.	2	2	2
8.	2	0	0
9.	2	7	0
10.	3	5	2
11.	2	6	3
12.	3	0	0

Appendix E. Continued

Table 20. Oil Storage Depot

		IPEN	X--VAL	Y--VAL
	1.	3	0	3
	2.	2	0	1
	3.	2	2	0
	4.	2	4	0
14 Bytes	5.	2	6	1
	6.	2	6	4
	7.	2	5	5
	8.	2	3	5
	9.	2	1	4
	10.	2	0	3
	11.	2	2	2
	12.	2	4	2
	13.	2	6	3
	14.	3	0	0

Table 21. POW Compound

		IPEN	X--VAL	Y--VAL
	1.	3	7	6
	2.	2	7	1
	3.	2	6	0
	4.	2	0	0
19 Bytes	5.	2	0	2
	6.	2	1	3
	7.	2	4	3
	8.	3	0	2
	9.	2	4	2
	10.	2	4	5
	11.	2	3	5
	12.	2	5	7
	13.	2	8	7
	14.	2	6	5
	15.	2	4	5
	16.	3	4	4
	17.	2	6	4
	18.	2	7	6
	19.	3	0	0

Appendix F.

Computer Listings

```
      SUBROUTINE BRISYM
      PARAMETER IZERO=0
      LOGICAL*1 ANS
      INTEGER*2 XVAL, YVAL
      COMMON / FETUR / XLL, YLL, DUM1(4), OSCL, DUM2(3), XMAP, YMAP,
     *  DUM3(4)
      COMMON / OBLIQ / DY, TNTHA, SNTHA, CSTHA, KFUNCT
      DATA PI / 3.14159 /
      DATA LSYM / 0 /
      DATA HLFROT / 180. /
      DATA EIGHT / 8.0 /
      DATA I99 / 99 /
C
      KFUNCT = IZERO
C
      DEGRAD = PI / HLFROT
C
100   WRITE(5,101)
101   FORMAT(1X,'ENTER NUMSYM, THETA, SIZE, XMAP AND YMAP')
      READ(5, *) NUMSYM, THETA, SIZE, XMAP, YMAP
      IF(NUMSYM .LT. IZERO) GO TO 950
      THETA = THETA * DEGRAD
C  TRANSFORM POINT ON MAP SHEET TO PLOTTER SURFACE.
      CALL UFIND(XP, YP, IFLAG, IOUT)
      IF(IOUT .NE. IZERO) GO TO 100
700   REWIND 9
800   FORMAT(1X,I2)
900   READ(9, 800) ITEST
      IF(ITEST .EQ. I99) GO TO 700
      IF(ITEST .GT. NUMSYM) GO TO 700
      IF(ITEST .LT. NUMSYM) GO TO 900
200   FORMAT(I1,I2,I1,1X,I1)
201   READ(9, 200) IPEN, ITEST, XVAL, YVAL
      IF(ITEST .GT. NUMSYM) GO TO 600
      XVL = FLOAT(XVAL) / EIGHT * SIZE
      YVL = FLOAT(YVAL) / EIGHT * SIZE
      XROT = XP + XVL*COS(THETA) + YVL*SIN(THETA)
      YROT = YP + YVL*COS(THETA) - XVL*SIN(THETA)
      CALL PLOT(XROT, YROT, IPEN)
      GO TO 201
600   CALL FINITT(IZERO, IZERO)
      LSYM = NUMSYM
      GO TO 100
950   RETURN
      END
```

Appendix F. Continued

1
3 5 3
2 5 0
2 1 0
2 1 3
2 0 2
2 5 7
2 8 4
2 6 2
2 3 5
3 7 3
2 7 2
2 5 0
3 0 0

2
3 5 3
2 5 0
2 1 0
2 1 3
2 0 2
2 5 7
2 8 4
2 6 2
2 3 5
2 3 8
3 2 7
2 4 7
3 7 3
2 7 2
2 5 0
3 0 0

3
3 5 3
2 5 0
2 1 0
2 1 3
3 6 2
2 3 5
2 3 8
2 1 6
2 3 6
3 7 3
2 7 2
2 5 0
3 0 2
2 5 7
2 8 4
2 6 2
2 3 5
3 0 0

4
3 0 3
2 0 0
2 3 0
2 3 3
2 0 3
2 4 6
2 4 7
2 5 8
2 6 8
2 6 6
2 5 5
2 4 5
2 4 6
2 4 7
2 5 7
2 6 8
3 5 5
2 5 7
3 6 6
2 7 6
2 3 3
3 3 0
2 7 3
2 7 6
3 0 0

5
3 0 4
2 2 6
2 7 6
2 5 4
2 0 4
3 6 5
2 6 2
2 4 0
2 1 0
2 1 4
3 4 4
2 4 0
3 1 3
2 2 3
2 2 4
3 3 4
2 3 3
2 4 3
3 4 2
2 3 2
2 3 1
2 2 1
2 2 2
2 1 2
3 0 0
3 2 0

6
3 2 0
2 0 0
2 0 7
2 1 8
2 3 8
2 2 7
2 0 7
3 0 6
2 2 6
2 2 0
2 3 1
2 3 8
3 3 7
2 2 6
3 0 0

7
3 2 0
2 0 0
2 2 6
2 4 0
2 2 0
2 4 6
2 6 0
2 4 0
2 4 8
2 6 2
2 4 2
2 6 8
2 8 2
2 6 2
8 2 6
2 4 8
2 6 8
2 4 6
2 2 6
3 6 0
2 8 2
3 2 2
2 0 0
3 0 0

8
3 0 0
2 0 2
2 2 4
2 7 4
2 7 2
3 5 0
2 5 2
2 7 4
3 5 2
2 0 2
3 1 2
2 3 4
3 2 2
2 4 4
3 3 2
2 5 4
3 4 2
2 6 4
3 0 0

9
3 0 0
2 0 3
2 1 4
2 3 4
2 3 1
2 2 0
2 0 0
3 1 0
2 1 3
3 0 2
2 2 2
3 0 3
2 2 3
2 2 0
3 2 3
2 3 4
3 0 0

10
3 0 0
2 3 5
2 6 0
3 3 2
2 3 8
3 1 8
2 5 6
3 1 7
2 5 7
3 1 6
2 5 8
3 0 0

11
3 5 2
2 5 8
2 2 8
2 0 6
2 0 0
3 0 5
2 3 5
2 5 7
3 4 7
2 2 7
2 1 6
3 2 5
2 2 2
3 3 0
2 3 5
3 0 6
2 3 6
2 5 8
3 0 0

12
3 0 0
2 3 5
2 6 0
3 3 2
2 3 6
3 0 6
2 6 6
3 0 7
2 6 7
3 1 8
2 2 7
2 3 8
2 4 7
2 5 8
3 4 7
2 4 6
2 5 5
3 1 5
2 2 6
2 2 7
3 0 0

13
3 0 0
2 3 5
2 6 0
3 3 2
2 3 8
3 1 7
2 1 8
2 5 8
2 5 7
3 0 0

14
3 1 0
2 1 4
3 0 4
2 2 4
3 0 0

15
3 4 0
2 2 0
2 2 1
2 0 4
2 1 5
2 7 5
2 4 0
2 4 1
2 6 4
2 7 5
3 6 4
2 0 4
3 0 0

16
3 3 3
2 4 3
2 4 0
2 3 0
2 3 3
2 2 3
2 1 4
2 1 5
2 3 7
2 5 7
2 6 6
2 6 5
2 4 3
3 2 6
2 4 6
2 5 5
3 4 6
2 5 7
3 0 0

17
3 0 3
2 3 3
2 3 0
2 0 0
2 0 3
2 1 4
2 4 4
2 4 1
2 3 0
3 3 3
2 4 4
3 3 4
2 3 7
2 2 8
2 3 6
2 2 4
2 3 5
3 0 0

18
3 0 0
2 0 3
2 3 6
2 4 6
2 5 5
2 5 2
3 5 4
2 2 1
2 1 1
2 0 2
3 3 0
2 3 3
2 2 4
2 1 4
3 0 0

19
3 0 0
2 3 3
2 6 3
2 8 1
2 7 0
2 5 2
2 2 2
2 0 0
2 7 0
2 5 2
2 6 3
3 0 0

20
3 0 3
2 0 1
2 2 0
2 4 0
2 6 1
2 6 4
2 5 5
2 3 5
2 1 4
2 0 3
2 2 2
2 4 2
2 6 3
3 0 0

21
3 7 6
2 7 1
2 6 0
2 0 0
2 0 2
2 1 3
2 4 3
3 0 2
2 4 2
2 4 5
2 3 5
2 5 7
2 8 7
2 6 5
2 4 5
3 4 4
2 6 4
2 7 5
3 0 0

99