IMPROVED NASTRAN PLOTTING

by

Gordon C. Chan
Unisys Corporation
Huntsville, Alabama

INTRODUCTION

The graphic department of NASTRAN has received few changes since Level 17.5 (1980). Only hidden line and shrink plots were added in 1983 and 1985 respectively. An attempt to straighten up the FIND and NOFIND options in 1985 was not very successful. Color was also added about the same time. However, the basic plotting mechanism and the structure of the plot file remain unchanged, and they are biased towards CDC and UNIVAC machines. The plot commands were built on the technology of six bits per byte that make the 8-bit/byte machine very awkward to use. The new 1991 COSMIC/NASTRAN version, downward compatible with the older versions, tries to remove some of the old constraints, and make it easier to extract information from the plot file. It also includes some useful improvements and new enhancements. The new features available in the 1991 version include:

1. New PLT1 tape with simplified ASCII plot commands and short records.
2. Combined hidden and shrunk plot.
3. An x-y-z coordinate system on all structural plots.
4. Element offset plot.
5. Improved character size control.
6. Improved FIND and NOFIND logic.
7. A new NASTPLOT post-processor to perform screen plotting or generate PostScript files.
8. A BASIC/NASTPLOT program for PC.

PLT1/PLT2 FILE

Since Level 17.5 through the 1990 version, all the plotting goes to a PLT2 file which is described as the "general plotter tape". The structure of the plot commands in the PLT2 file is fully described in the user's and programmer's manuals. The commands, originally designed to be used for all machines with 32-, 36- or 60-bit computer words, were constructed based on 6 bits per byte structure. However, for IBM, VAX, and others, which are using 8-bits/byte word architecture, the 6 bits per byte technology has long been abandoned, leaving the manuals inaccurate and misleading. To use the PLT2 file for graphic plotting, a user needs to write an external program to interpret those NASTRAN generated plot commands, and to drive his particular plotter, if such a program is not already available. Normally this involves heavy bit and byte manipulation and data reconstruction. A disadvantage to the user is that the original bit and byte data on the PLT2 file cannot be printed to assist in debugging of his program.

In the 1991 NASTRAN version, the PLT2 file is left alone as it is. A PLT1 file is re-activated. (Before Level 17.5, PLT1 was used for 7-track plot tape). The PLT1 file contains the same plot commands in ASCII format and in 130 column short records. Therefore, the plot command data can be printed, and can be transported from one machine to another through normal channels. When this file is read by an external program, no data reconstruction from bits and bytes is required. The following table compares the two plot files:

	PLT2 file	PLT1 file
File type - sequential, formatted	No carriage ctrl	Carriage ctrl
Record type	ASCII/Binary*	ASCII
Record length	3000 bytes	130 columns
FORTRAN format	(10(180A4))*	(5(213,415))
Plot commands per physical record	100	5
Data type per plot command	30 Bytes	26 Decimals
No. of computer words per plot command	7.5	6
Edit, print, or terminal viewing of data	No	Yes
Disc space usage, referenced to PLT2	-	30% less
If tape is used - track and parity	9,Odd	9,Odd
File transmission through 'PROCOMM/KERMIT'	*	No problem

* 1. ASCII record, but data stored in binary bytes.
  2. Since the record length is 3000 bytes, a format of (750A4) is sufficient.
  3. Data transmission of the PLT2 file using standard PROCOMM/KERMIT software is difficult, if not impossible.

Two samples of NASTRAN plot commands are presented in Appendix A. The sample from PLT1 file is clearly readable, and provides meaningful information to any user who wants to use the data. The sample from PLT2 file cannot be fully printed, nor edited, because the record is too long. Both samples were taken from a test problem running on a VAX machine.

HIDDEN-LINE AND SHRINK PLOTS

The hidden-line plot and the 2-D and 3-D element shrink plots were added to NASTRAN in 1983 and 1985. They work very well alone, and work well together with other plot options such as label and color. However, the hidden-line plot and the element shrink plot are exclusive to one another. A modification of the plotting source code now allows the merging of the two plot options in the 1991 NASTRAN version.

X-Y-Z COORDINATE SYSTEM

In all previous NASTRAN structural plots, there is no information about how the model structure is oriented in space with respect to the basic rectangular system. A user can specify the viewing angle, vantage point, origin, and scale, and yet the actual plots contain no such information. In the 1991 version, a small x-y-z coordinate is always plotted at the lower right corner of each structural plot frame. This coordinate is rotated exactly

the same way the structural model is when subjected to different view angle, vantage point, and origin. Therefore, it gives the user instant information about the orientation of his structure in space. Of course, the x-y-z coordinate should not be present in all x-y table plots.

Normally there are four lines of labels and sub-labels at the bottom of each plot. The new x-y-z coordinate is placed at the right end of these four lines. Since the character size of the labels and sub-labels can be altered by the CSCALE option, the actual x-y-z coordinate size therefore varies accordingly.

OFFSET PLOT

In NASTRAN element repertoire, three elements, CBAR, CTRIA3 and CQUAD4, have grid point offset capability. In previous NASTRAN structural plots, all elements were treated equally, and they were always connected from grid points to grid points. Offsets were not considered. The argument for this practice is that since the offsets are usually very small, they will have no effect on the overall plot whether the offsets are considered or not. On the other hand, some users want the actual offset to be plotted such that the plots can help to detect any input card error. They argue that if the unintentional error is big enough, it will show on the plot, and corrective action can be taken immediately. The 1991 NASTRAN will satisfy both arguments.

The 1991 version shows the offsets two ways.

1. In an overall structure plot that includes all elements, and the offsets are always included in the plot. The offset absolute distances are computed, but the true offset directions are not. If the offsets are small, they will hardly show on the plot. If an offset is unintentionally large, a line may fly off in an uncontrolled direction.

2. A new 'OFFSET n' option is added to the 1991 NASTRAN PLOT command. If this option is exercised, only the elements with offsets will be plotted. The offset distances are magnified n times each to help bring out the offset magnitudes in plotting. The true offset directions are also computed and applied. If color plot is requested, the offset legs are plotted in different color than the color of the elements. Element label and other plot parameters can be requested simultaneously with the 'OFFSET n' option.

In both (1) and (2), the grid points with offsets are marked by asterisks. For example, a CBAR element with offsets in (2) with large n value will look like a staple, with asterisks at the corners

The "OFFSET n" option is only available for undeformed plot. Default value of n is 1.

CHARACTER SIZE CONTROL

The NASTRAN User's Manual indicates that the character size control, CSCALE n, is used only for the x-y plot. As mentioned above in the x-y-z coordinate discussion,

CSCALE controls also the character size of the labels and sub-labels of the structural plot. The factor 'n' was used to be an integer input. When n was set to 2, the character size on the labels and sub-labels was 4 times larger than normal size. Any increase of n may result in the labels and sub-labels exceeding the plot frame size. In the 1991 NASTRAN, the factor 'n' is changed to real number input with default value of 1.0. When n is set to 1.1, the character size is increased by 10 percent. The character size is double (not four times larger) for n equals 2.0

FIND/NOFIND

The descriptions of FIND, NOFIND, PLOT and ORIGIN in NASTRAN plotting commands are not easily understood. They can be plot commands by themselves, or they (except PLOT) can be options (or parameters) of another plot commnad. Confusion and misuse of these commands or options are quite common.

The FIND command (not used as an option in PLOT command) uses five parameters: SCALE, ORIGIN, VANTAGE POINT, REGION and SET. The PLOT command covers as many as 35 options or parameters, including ORIGIN and NOFIND. NOFIND, used only as an option in PLOT command, has no associated parameter. ORIGIN can be a plot command by itself, or a parameter to FIND, or an option to PLOT. Many of the parameters to FIND, ORIGIN and PLOT are optional and they may or may not have associated default values. The commands FIND and ORIGIN (not used as options) are optional, and need not be present in a series of plot commands. Some of the PLOT options or parameters are themselves linked to other options or other plot commands, which may or may not appear in a series of plot commands. For example, the SCALE and REGION parameters are linked to SCALE (plot size control), CSCALE (character size control), CAMERA, VIEW, and VANTAGE POINTS, any of which may or may nor appear as plot commands.

The FIND-NOFIND-ORIGIN-PLOT picture above seems very complicated and confusing. To make the matter worse, some of the missing plot commands or options have default values, while others have none. However, the following observations, derived from the NASTRAN User's Manual and from actual experimental testing, can be very helpful:

1. If ORIGIN is not defined in a FIND card, ORIGIN ID of zero is used by NASTRAN. It is not a good practice to force NASTRAN to select a zero ORIGIN ID.
2. No matter what ORIGIN ID's the user used in multiple FIND cards, the first ORIGIN ID is the origin no. 1. The second ORIGIN ID, only if it is different from the first, is origin no. 2, and so on. A maximum of ten ORIGIN ID's can be used. If more then ten ORIGIN ID's are used, all the remaining ID's go to the eleventh.
3. ORIGIN ID can be re-used in a sequence of plots. In this case, the plot parameters and controls, such as scale, view, frame size etc., associating to the previous ORIGIN of the same ID, are completely replaced by those of the new ORIGIN data.
4. The ORIGIN ID, requested on a FIND card, defines a number of plotting parameters associating with the current structure orientation in space (such as left, right, upper and bottom plot frame limits, view angle, vantage point, plot scale etc.). These data are saved, and can be recalled by the ORIGIN ID on the PLOT command. Note - if the current PLOT command does not specify this

4

ORIGIN ID, the data saved are not used in the current plot.

5. Therefore, the ORIGIN ID requested in a FIND command, and the ORIGIN ID used by a PLOT card, are unrelated; unless the same ID is specified by both FIND and PLOT. If the PLOT command does not specify any ORIGIN ID, observation (1) above applies. The following example shows that ORIGIN 0 is used by PLOT, not 50:

```
FIND  SCALE, ORIGIN 50, SET 1
PLOT
```

6. NOFIND causes all plotting parameters, including ORIGIN ID, to be the same as the previous plot in a series of plot sequences. The NOFIND option is actually a special case of the PLOT-ORIGIN arrangement. The following examples give identical results in $PLOT 2:

```
$PLOT 1                          $PLOT 1
FIND SCALE, ORIGIN 50, SET 2     FIND SCALE, ORIGIN 50, SET 2
PLOT ORIGIN 50                   PLOT ORIGIN 50


$PLOT 2                          $PLOT 2
PLOT NOFIND                      PLOT ORIGIN 50
```

NOFIND did not work in 1990 and earlier NASTRAN releases as advertised in the user's manual. It always reverted to the first defined ORIGIN ID. Also, each time a FIND card was used, a new AXIS line, plus any old axes previous saved, were printed on the engineering data echo for the current plot. No additional information was printed to indicate which AXIS (or ORIGIN) is being used. The 1991 NASTRAN will print only one AXIS data line, which is the current ORIGIN being used for the current plot.

PROGRAM NASTPLOT
for main-frame, mini, micro and workstation

As mentioned in the PLT1/PLT2 FILE section above, a user needs an external program to read the NASTRAN general plotter tape, interpret the plot commands, and produce the NASTRAN graphic plots. Such a program is usually called a NASTRAN post-processer. Some of the NASTRAN post-processers may be very sophisticated and expensive, and capable of doing many additional things. Some may be relatively simple and cheap, and dedicated only to processing NASTRAN plot file. NASTPLOT is one of the better known products that perform this dedicated task. In fact, there are many versions of NASTPLOT written by various people for different combinations of computer-and-plotter. One common factor of the NASTPLOT programs is that they all use PLT2 file.

A new NASTPLOT program will be included in the 1991 COSMIC/NASTRAN release. This new NASTPLOT program does not necessarily perform better than any existing old ones. However, it has its own virtues:

1. It is FORTRAN written in simple and straightforward program logic.
2. It handles PLT1 or PLT2 tape.
3. It produces Tektronix screen plots, or PostScript files that can be sent to a PostScript printer, or a LaserJet printer (equipped with a PostScript cartridge) for hard-copies.

4. All supporting routines can be easily identified. All Tektronix routines are prefixed by "TX", and all PostScript routines by "PS", (User can easily swap these routines for other plotter requirements).

5. This program was written on a VAX, but the source code is almost machine independent.

BASIC/NASTPLOT
for PC, with MS-DOS and graphic capability

Since the PC is almost a household product nowadays, many offices have a few available already, most PC's come with graphic capability and BASIC language, and since the NASTRAN PLT1 file can be transported easily from one computer system to another, it becomes logical to tap into this vast resource for NASTRAN advantage. To move the plotting to a PC is almost an instant bonus to enhance NASTRAN capability. And it can be done very economically.

A new MS-DOS BASIC/NASTPLOT program was written and tested successfully on a VAX-PC (UNISYS/8080 chip, BASIC 3.2) combination. (Also 286 and 386 PC's.) This BASIC/NASTPLOT program, requiring no special hardware, or software, produces screen plots on a PC just as satisfactory, and just as fast, as any expensive equipment. It even produces color plots if the PC is equipped with a color monitor. 4K byte memory is needed. However, a high resolution monitor is recommended for best results. This program, with complete listing in Appendix B, serves as a demonstration of tapping into the PC world. It can be easily converted to other non MS-DOS systems, such as the Apple and Macintosh.

APPENDIX A

TWO SAMPLES OF NASTRAN PLOT COMMANDS

Sample Plot Commands from a PLT2 file:

```
(3000 bytes/record)
a a a a a a a a A a a a F a a a a a a a a a a a a C a a a a a a a a a a a a F a a a a a a a a a a a a a a a a a a a a a a a a a
a a a a a C a a a a a a a a F a a   a a a a a a a a a a a a a a a a    a D a a a a a a a a a a a a a a a a a a a a a a a a a a a a
a a a a a a a a a a a a a a a a a a A a a a a a a a a a a a a F a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a
a a a a a a A F a a a a a K a a a F a a a a a a  a a a a a a a a a C a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a
a a a C a a a a a D a D a a a a C a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a a
a a a a a a a a a    a a a A a a a a a a a a a a F F a a a a a a a a C a a a   a a a a a a a a a a a a a a a a a a a a a a a a a a
   :
```

Sample Plot Commands from a PLT1 file:

```
(130 columns/record)
1  0    1 1023 1023    0  2  2    0    0    0    0  3  2    0    0    0    0 16  1    0 1015 1019 1015  6  1    0 1012 1019 1012
6  1    0 1009 1019 1009  6  1    0 1006 1019 1006  6  1    0 1003 1019 1003  6  1    0 1000 1019 1000  6  1    0  997 1019  997
6  1    0  994 1019  994  6  1    0  991 1019  991  6  1    0  988 1019  988  6  1    0  985 1019  985  6  1    0  982 1019  982
6  1    0  979 1019  979  6  1    0  976 1019  976  6  1    0  973 1019  973  6  1    0  970 1019  970  6  1    0  967 1019  967
6  1    0  964 1019  964  6  1    0  961 1019  961  6  1    0  958 1019  958  6  1    0  955 1019  955  6  1    0  952 1019  952

   :
6  1    0  604 1019  604  6  1    0  601 1019  601  6  1    0  598 1019  598  6  1    0  595 1019  595  6  1    0  592 1019  592
6  1    0  589 1019  589  6  1    0  586 1019  586  6  1    0  583 1019  583  6  1    0  580 1019  580  6  1    0  577 1019  577
6  1    0  574 1019  574  6  1    0  571 1019  571  6  1    0  568 1019  568 15  1  197  555  199  555  5  1  199  555  198  555
5  1  198  555  198  550  5  1  198  550  197  549  5  1  197  549  195  549  5  1  195  549  194  550  5  1  202  555  202  550
5  1  202  550  203  549  5  1  203  549  206  549  5  1  206  549  207  550  5  1  207  550  207  555  5  1  215  554  214  555
5  1  214  555  211  555  5  1  211  555  210  554  5  1  210  554  210  553  5  1  210  553  211  552  5  1  211  552  214  552

   :
5  1  287  538  286  539  5  1  286  539  283  539  5  1  283  539  282  538  5  1  282  538  282  534  5  1  282  534  283  533
5  1  283  533  286  533  5  1  286  533  287  534  5  1  287  534  287  536  5  1  287  536  285  536 16  1    0    0 1019    0
6  1    0    3 1019    3  6  1    0    6 1019    6  6  1    0    9 1019    9  6  1    0   12 1019   12  6  1    0   15 1019   15
6  1    0   18 1019   18  6  1    0   21 1019   21  6  1    0   24 1019   24  6  1    0   27 1019   27  6  1    0   30 1019   30
6  1    0   33 1019   33  6  1    0   36 1019   36  6  1    0   39 1019   39  6  1    0   42 1019   42  6  1    0   45 1019   45

   :
5  1  121 1012  122 1011  5  1  122 1011  126 1011  5  1  126 1011  127 1012  5  1  127 1012  127 1016  5  1 1017 1016 1018 1017
5  1 1018 1017 1018 1011  5  1 1018 1011 1017 1011  5  1 1017 1011 1019 1011  0  0    0    0    0    0  0  0    0    0    0    0
15 1    9   59   12   59  5  1   12   59   12   53  5  1   12   53   12   59  5  1   12   59   15   59  5  1   22   59   17    5
5  1   17   59   17   56  5  1   17   56   20   56  5  1   20   56   17   56  5  1   17   56   17   53  5  1   17   53   22   53

   :
```

APPENDIX B

BASIC/NASTPLOT PROGRAM LISTING

```
10  'PROGRAM NASTPLOT, MS-DOS PC/BASIC VERSION
20  'BASIC 3.2, WITH EGA OR CGA GRAPHIC CAPABILITY
30  'NO PARTICULAR HARDWARE OR SOFTWARE REQUIRED
40  'INPUT: NASTRAN PLT1 FILE (NOT PLT2 FILE)
50  'WRITTEN BY G.CHAN/UNISYS  11/90
60  'TO RUN THIS PROGRAM    1. BASIC
70  '                       2. LOAD "NASTPLOT
80  '                       3. F2 or RUN "NASTPLOT
90  '                       4. answer all questions asked
100 '            AT END     5. SYSTEM
110 KEY OFF: CLS: PRINT "": PRINT ""
120 ? "                                    ****"
130 ? "                             *          *"
140 ? "                          *                *"
150 ? "                        *   N  A  S  T  P  L  O  T"
160 ? "                          *             *"
170 ? "                             *        *"
180 ? "                                ****"
190 ? ""
200 ? "       PC/BASIC MS-DOS GRAPHIC       SYSTEM RELEASE - NOV. 1990"
210 ? "
220 ? "       WRITTEN BY UNISYS/            FOR COSMIC"
230 ? "       NASTRAN MAINTENANCE GROUP     UNIVERSITY OF GEORGIA"
240 ? "       HUNTSVILLE, ALABAMA           ATHENS, GEORGIA 30602"
250 ? "                                     PHONE: (404) 542-3265"
260 PRINT "": PRINT ""
270 ? "        *** AT THE END OF EACH PLOT, HIT C/R TO CONTINUE ***"
280 ? "                    ===                    ==="
290 PRINT ""
300 DEFINT I-J,Z
310 OPTION BASE 1
320 DIM Z(30)
330 LET YES$="YES":  LET Y$="Y":  LET YSS$="yes":  LET YS$="y"
340 F =0.30
350 JX=640-480: JY=320  '480 & 320 TO CENTER PLOT,  640 TO REVERSE IMAGE
360 '*** CURRENTLY SET UP FOR EGC WITH HI-RESOLUTION MONITOR - SCREEN 9
370 J12=1
380 INPUT "ENTER PLOT FILE FULL NAME: ",FIL$
390 OPEN "I",1,FIL$
400 INPUT "ENTER PLOT NUMBER, ZERO TO QUIT: ",ID
410 IF ID =0 GOTO 880
420 IF J12=2 GOTO 470
430 INPUT#1, Z(1),Z(2),Z(3),Z(4),Z(5),Z(6),Z(7),Z(8),Z(9),Z(10),Z(11),Z(12),Z(
435 '        Z(1),Z(2),...,Z(30) ALL ON ONE LINE
440 IF EOF(1) GOTO 800
450 IF Z(1) <>1 GOTO 420   'NEW PLOT BEGINS WITH ONE IN Z(1)
460 IF Z(19)=16 GOTO 420   'SKIP FIRST ID PLOT IF IT IS PRESENT
470 I3=Z(3)                'SAVE PLOT NUMBER IN I3
480 PRINT " ...WORKING"
```

```
490 IF I3<>ID GOTO 420      'SEARCH FOR REQUESTED PLOT NUMBER
500 I1=7: IE=0
510 CLS
520 IF J12=2 GOTO 590        'WHEN J12=2, CURRENT RECORD IS ALREADY READ
530  SCREEN 9                'EGC with EGD, Advanced screen A (640X350)
535 'SCREEN 2                'CGA and different valus for F,JX and JY
540 COLOR 6,0                'SET COLOR TO ORANGE AND BLACK
550 GOTO 600
560 INPUT#1, Z(1),Z(2),Z(3),Z(4),Z(5),Z(6),Z(7),Z(8),Z(9),Z(10),Z(11),Z(12),Z(
565 '       Z(1),Z(2),...,Z(30) ALL ON ONE LINE
570 IF EOF(1) GOTO 700
580 I1=1
590 J12=1
600 FOR I=I1 TO 30 STEP 6 'LOOP FOR 5 COMMANDS, 6 WORDS EACH
610 IC=Z(I)                  'IC IS PLOT COMMAND
620 IF IC=1  GOTO 710        'A NEW PLOT IF IC IS ONE
630 IF IC>10 THEN IC=IC-10
640 IF IC<>5 AND IC<>6 GOTO 680
650 IP=Z(I+1)                'IP IS PEN CONTROL, SUCH AS COLOR.
660 JR=JX+Z(I+2)*F: JS=JY-Z(I+3)*F: JT=JX+Z(I+4)*F: JU=JY-Z(I+5)*F
670 LINE (JR,JS)-(JT,JU),IP
680 NEXT
690 GOTO 560
700 IE=1                     'EOF ENCOUNTERED AT END OF A PLOT
710 BEEP                     'END OF A PLOT
720 INPUT "",Q$             'C/R TO CONTINUE
730 IF IE=1 GOTO 800
740 CLS                      'CLEAR SCREEN
750 J12=2                    'RESET FLAGS. FIRST RECORD OF NEXT PLOT ALREADY READ
760 GOTO 400                 'LOOP BACK FOR NEXT PLOT
800 IF I3=0 THEN PRINT "EOF ENCOUNTERED. THERE IS NO PLOT IN ";FIL$
810 IF I3=1 THEN PRINT "EOF ENCOUNTERED. THERE IS ONLY ONE PLOT IN ";FIL$
820 IF I3>1 THEN PRINT "EOF ENCOUNTERED. THERE ARE ONLY";I3"PLOTS IN ";FIL$
830 INPUT "START ALL OVER AGAIN";Q$
840 IF Q$<>YES$ AND Q$<>Y$ AND Q$<>YSS$ AND Q$<>YS$ GOTO 880
850 CLOSE #1
860 J12=1: I1 =1
870 GOTO 390                 'CYCLE BACK FOR MORE PLOT
880 PRINT "END OF JOB"
890 COLOR 7,0:  CLS          'RESET COLORS TO BLACK AND WHITE
900 END
```