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MATHEMATICAL MODELING RESULTS OF PROPOSED MICROWAVE LANDING SYSTEMS FOR RUNWAYS 32R AND 14L AT MOFFETT FIELD, MOUNTAIN VIEW, CALIFORNIA

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BACKGROUND

This Microwave Landing System (MLS) math modeling study was requested by the Aircraft Operations Division of the NASA-Ames Research Center as an aid in the selection of a precision landing system to be installed on runway 32R or 14L at Moffett Field, Mountain View, California.

SCENARIO DESCRIPTION

The Airport at Moffett Field consists of two parallel runways. Precision landing guidance is desired for an approach to runway 32R or alternatively the opposite end (runway 14L). A site visit to Moffett Field disclosed that the primary sources of multipath interference to an MLS system serving either of these runways would be the three large airship hangars. These hangars consist of very wide sloped and curved sides rising to about 200 feet above the ground. The chain link fence around the end of runway 14L is also a possible source of derogatory effects. Figure 1 is a drawing of the airport showing the obstacles modeled (3 hangars and fence) and their relationship to runway 32R/14L.

SCENARIOS MODELED

The MLS system modeled for runway 32R located the Azimuth and Precision Distance Measuring Equipment (DME/P) systems on centerline 1000 feet beyond the stop end of the 9200 foot long runway. The Elevation system for this runway was modeled 950 feet backset from threshold and 400 feet to the pilot's right of runway centerline.

The 14L runway was modeled with the Azimuth and DME/P systems 1180 feet beyond the stop end of the runway on centerline. The Elevation system for this runway was located 868 feet from threshold and 255 feet to the pilot's right.

Typical MLS equipment characteristics (2° beamwidth Azimuth and 1.5° beamwidth Elevation antennas) were assumed for this simulation. A nominal DME/P COS/COS^2 pulse with a 1200 nano-second rise time was also assumed. Although this is one of the first scenarios modeled using our implementation of the DME/P model (originally developed in Germany by DFVLR) which is still being validated, we are confident that the results are a reasonable simulation of the actual effects that would be measured.

The coverage volume for each system was evaluated by simulating a straight in 3° approach and 10 nautical mile (nm) partial orbits at elevation angles of 2°, 3° and 4°. In addition, a 6° 5 nm partial orbit was also simulated.

MODELING RESULTS

Since several surfaces had to be defined to simulate the curved sides of the hangars, the model which is limited to 10 building surfaces per run could not consider all hangars in one run. Therefore, several modeling runs were performed to consider all potential multipath sources. The surfaces from all scenarios which

had the maximum multipath were then included in a "composite" modeling run.

Appendix A shows the composite input file (for a 3° approach) used to model the multipath effects on the Azimuth and DME/P for a runway 32R MLS system. Hangar 3 exhibited little multipath effects in the initial runs and is mostly shadowed by hangar 2, therefore no surfaces from hangar 3 were included in the composite scenario for runway 32R. Surfaces of hangars 1 and 2, as well as portions of the chain link fence, were included in the input file. All multipath levels observed from this scenario were more than 10 decibels (dB) below the direct signal amplitude. No significant errors were generated by this scenario for an approach as shown by the dynamic error plots of figures 2 and 3 for the Azimuth and DME/P, respectively. The Path Following Error (PFE) and Control Motion Noise (CMN) filtered plots for both systems are well within the error tolerances and are not shown. The same obstacles were also used to model a 10 nm orbit at a 3° elevation angle (see Appendix B) and a 5 nm orbit at a 6° elevation angle. Neither orbit simulation exhibited any significant errors.

Appendix C shows the composite input file used to model a 3° approach to runway 14L. During the initial runs, hangar 1 had exhibited little multipath effects. Therefore, only portions of hangars 2 and 3, as well as parts of the fence, were included in this composite input file. On an approach, the lowest part of hangar 2 generated some Azimuth multipath levels within about 4 dB of the direct signal level near threshold. However, no significant errors were generated as indicated by the dynamic error plot of figure 4. No Elevation errors were generated by this scenario, although the effects of the fence on the Elevation signal were considered. The hangar surfaces did cause some DME/P errors near threshold as indicated on the dynamic error plot of figure 5. PFE and CMN filtered errors, however, were well within the tolerances. The 10 nm orbit at a 3° elevation angle modeled for this runway had no significant errors for the Azimuth, Elevation, or DME/P.

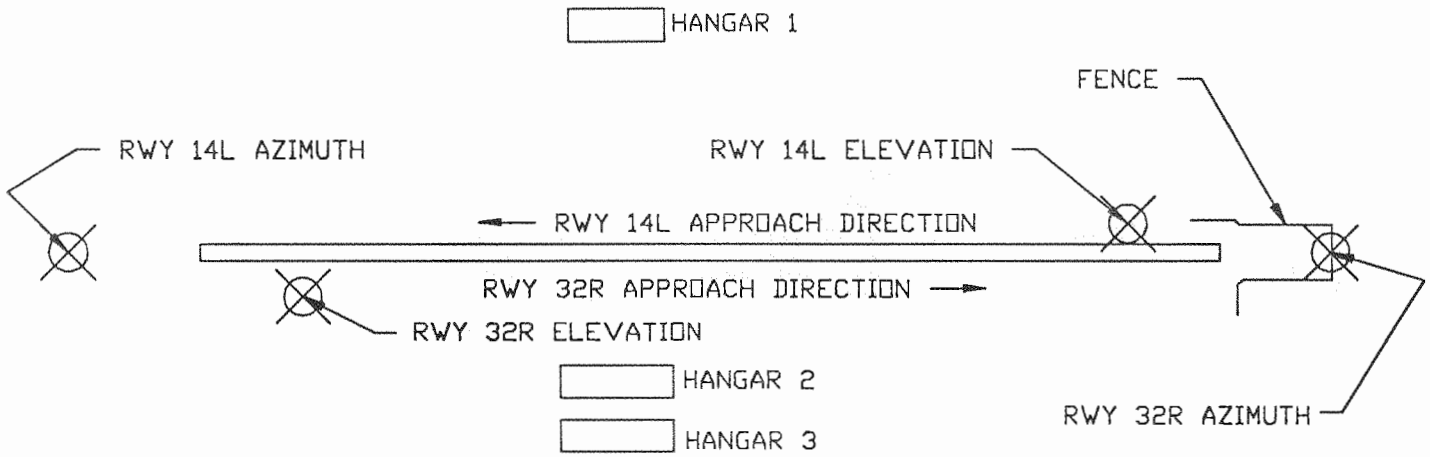

FIGURE 1. AIRPORT DIAGRAM FOR MOFFET FIELD NAS, MOUNTAIN VIEW, CA

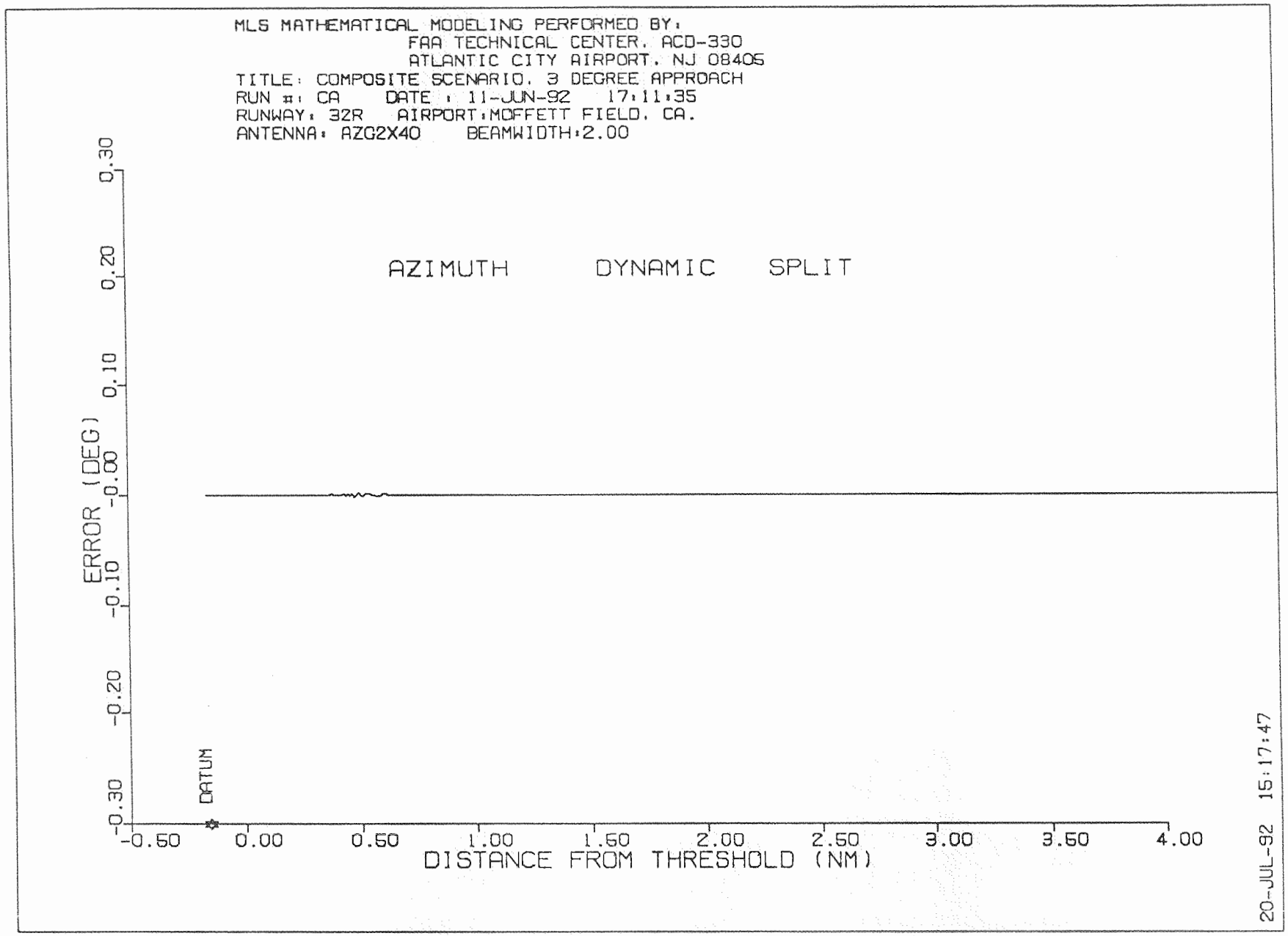

FIGURE 2. RUNWAY 32R AZIMUTH SYSTEM DYNAMIC ERROR FOR A 3 DEGREE APPROACH

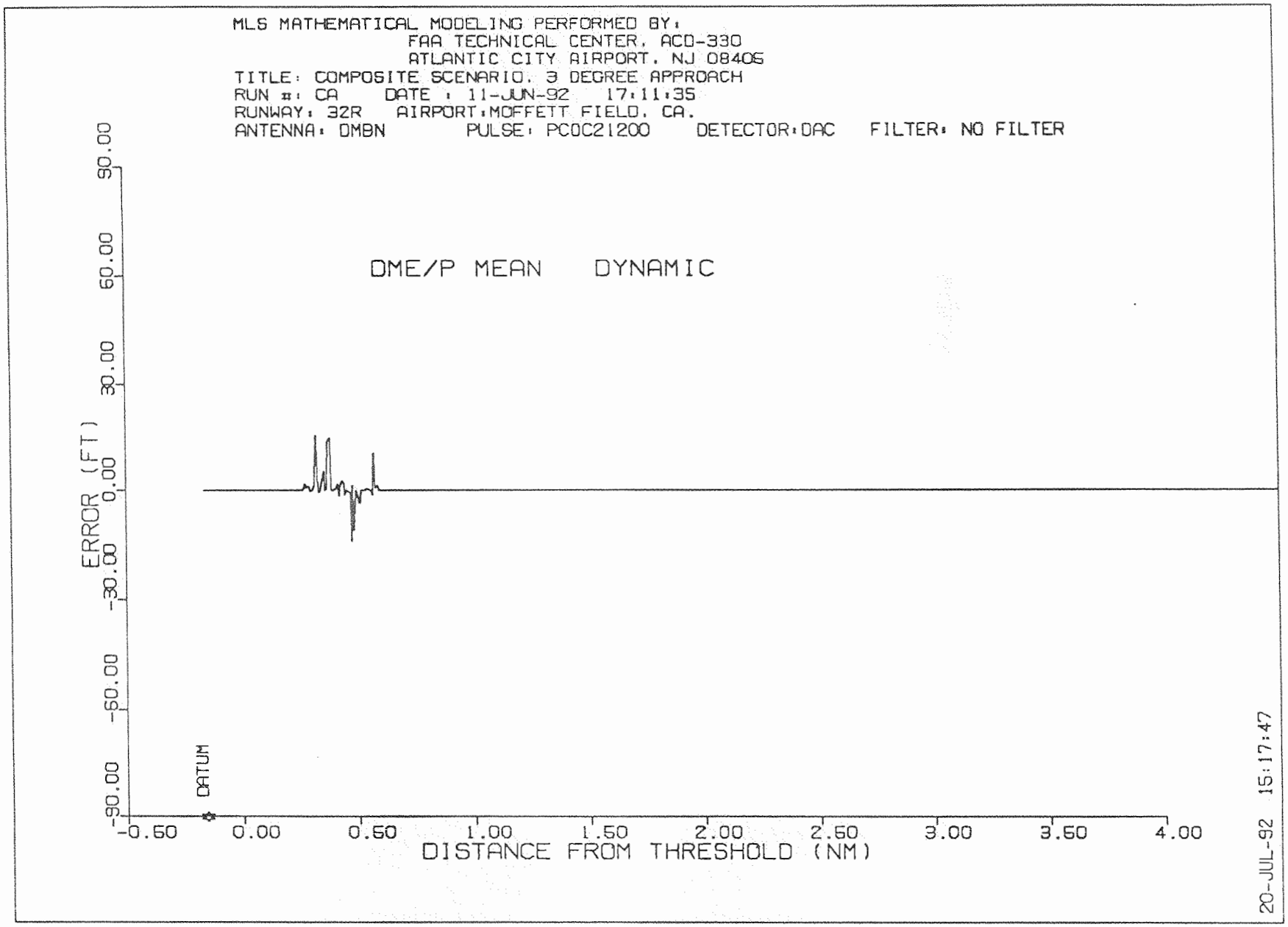

FIGURE 3. RUNWAY 32R DME/P SYSTEM DYNAMIC ERROR FOR A 3 DEGREE APPROACH

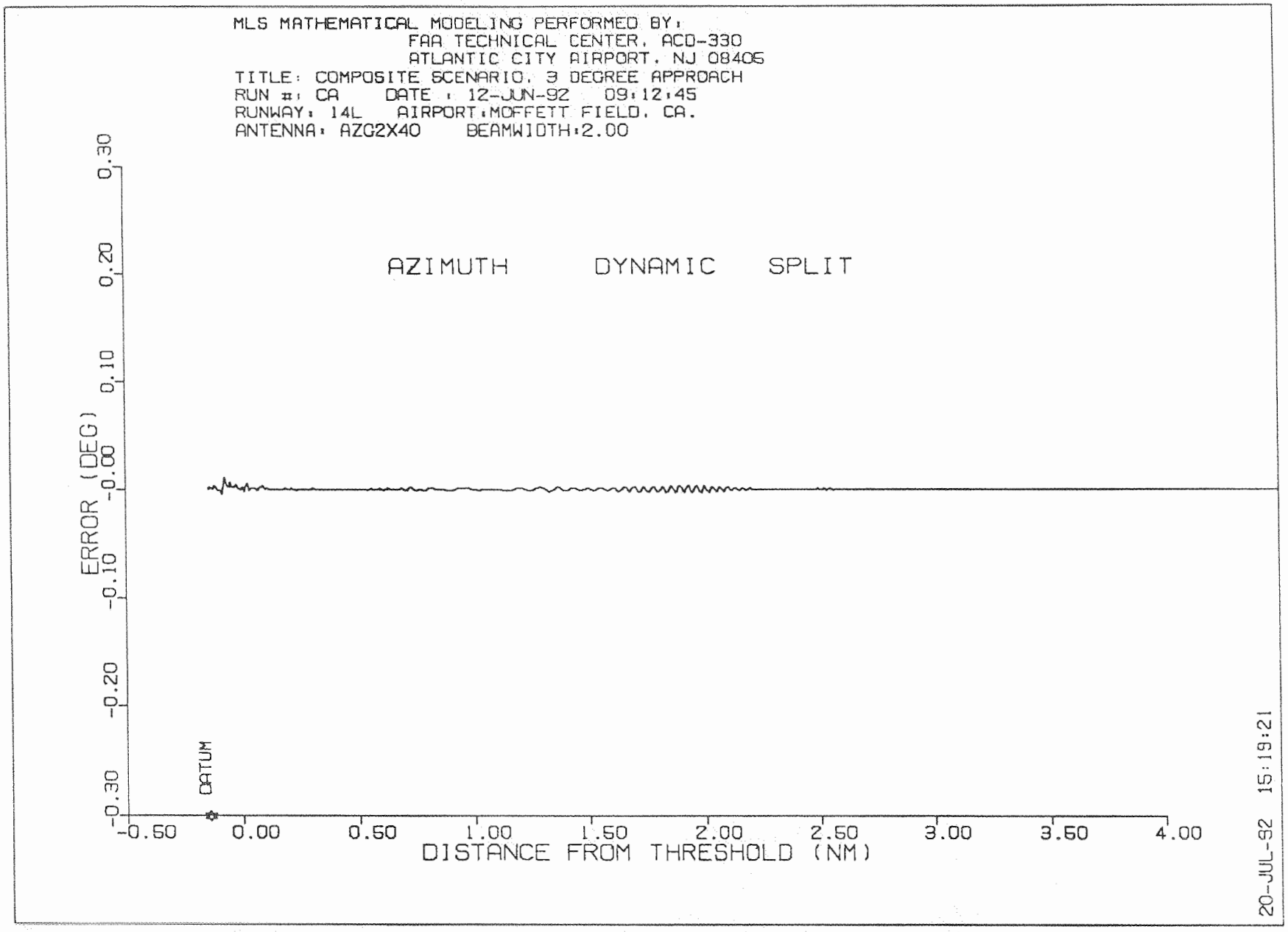

FIGURE 4. RUNWAY 14L AZIMUTH SYSTEM DYNAMIC ERROR FOR A 3 DEGREE APPROACH

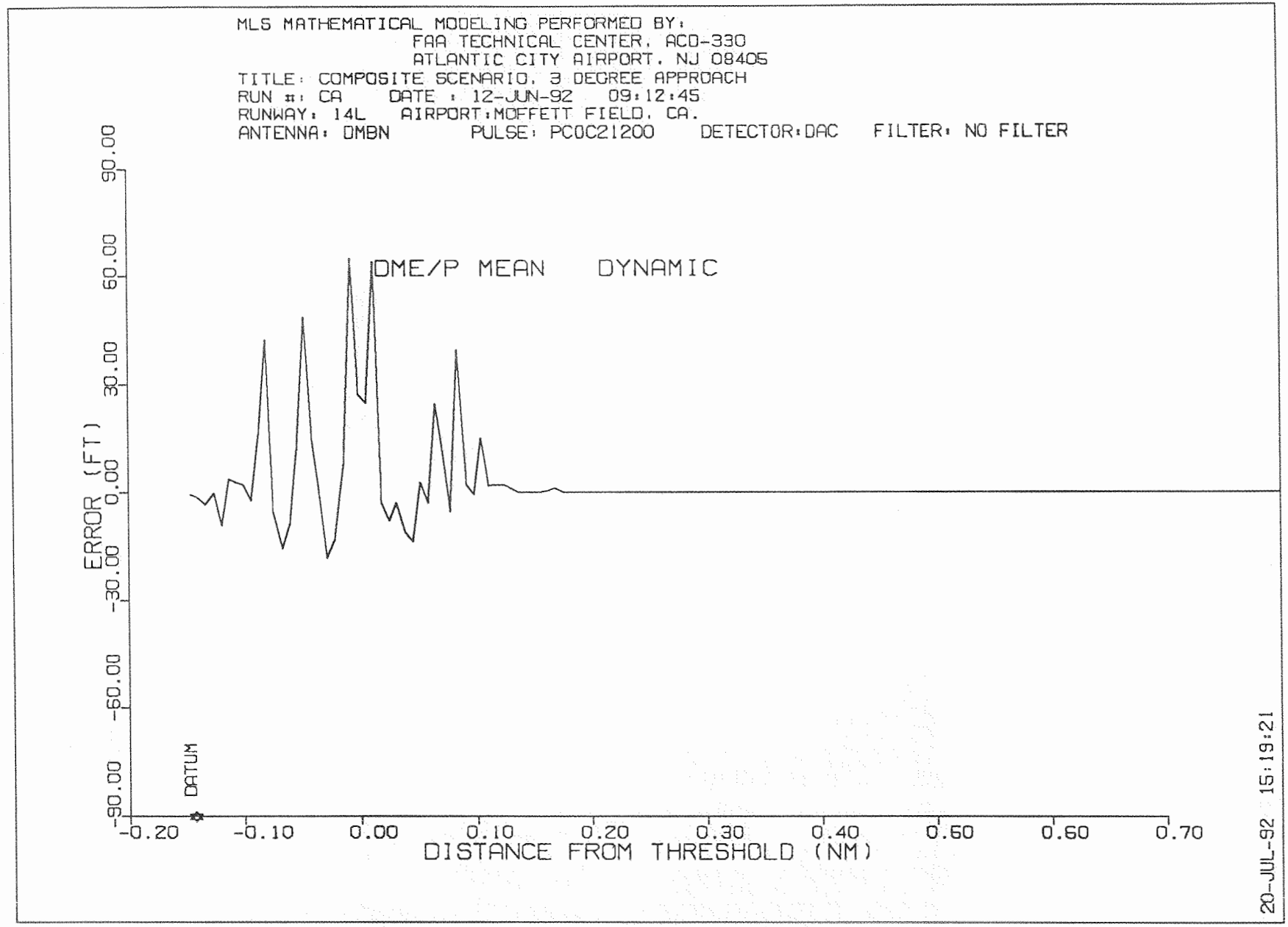

FIGURE 5. RUNWAY 14L DME/P SYSTEM DYNAMIC ERROR FOR A 3 DEGREE APPROACH

APPENDIX A
INPUT FILE FOR
3° APPROACH TO RUNWAY 32R

```
*****************MLS MATHEMATICAL MODEL INPUT DATA FILE**********************
CTION  0
          = SCENARIO DATA
          RUN ID# :CA
          TITLE   :COMPOSITE SCENARIO, 3 DEGREE APPROACH
          AIRPORT :MOFFETT FIELD, CA.
          RUNWAY  :32R
          LENGTH  :9200
          WIDTH   :200
          ARDH    :50
          MGPA    :3.0
          UNITS   :FEET   (feet, meter) FOR ENTRIES IN FILE
CTION 1A
          = ANGLE TRANSMITTER DATA
          PHASE CENTER:  X        Y        Z    FREQ(mhz)  LSL   USL    TYPE
                       -------- -------- -------- --------- ----- ----- --------
          AZIMUTH  :  -1000.0      0.0      7.0    5000.0 -40.0  40.0 AZG2X40
          ELEVATION:   8250.0    400.0     29.0    5000.0   0.9  20.0 ELG15C
CTION 1D
          = DME/P TRANSMITTER DATA
          PHASE CENTER:  X        Y        Z      TYPE
                       -------- -------- -------- --------
          DME/P    :  -1000.0      5.0     12.0 DMBN

          = OTHER DME DATA
                       FREQ(mhz)  SHAPE    TRG  F   SW    AS    TRS  SIGM   RMI
                       --------- --------- --- --- ----- ----- ----- ----- -----
          UPLINK   :     1092.0 PCOC21200 DAC NOF   0.5   0.5 0.125   0.0   0.0
          DOWNLINK :     1029.0 PCOC21200 DAC NOF   0.5   0.5 0.125   0.0   0.0
CTION  2
          NO  - DO ANY GROUND REFLECTION PROCESSING (CALL GREFC) (yes,no)
          NO  - DO FULL INTEGRATION FOR SPECULAR GROUND SCATTERING (yes,no)
          = DEFAULT DIELECTRIC CONSTANT AND ROUGHNESS HEIGHT
          DIELECTRIC CONSTANT : 3.0        -0.9
          ROUGHNESS HEIGHT    : .423469387
         * FOR MULTIPLE SCATTERING PATHS FROM AIRCRAFT AND BUILDINGS
          DIELECTRIC CONSTANT : 3.0        -0.9
          ROUGHNESS HEIGHT    : .423469387
CTION  4
          = SCATTERING FROM BUILDINGS (MAXIMUM OF 10)
          YES - RUN SCATTERING BUILDINGS (yes,no)
     ##  X-LEFT   Y-LEFT   X-RGHT   Y-RGHT   ELV   HGT   TLT   GRCORR   CMP
     -- -------- -------- -------- -------- ----- ----- ----- -------- -----
     nn xxxxxxxx yyyyyyyy xxxxxxxx yyyyyyyy eeeee hhhhh ttttt cccccccc mmmmm
     01   4934.3   1158.5   5938.3   1158.5 185.0  5.22   0.0      5.0 METAL
     02  -1011.6    246.1   -219.0    245.5   0.0   7.0   0.0      0.0 METAL
     03   4934.3   1117.8   5938.3   1117.8 172.9 24.62  67.0      5.0 METAL
     04   -133.3   -286.0    256.7   -286.0   0.0   7.0   0.0      0.0 METAL
     05   -173.6   -246.9  -1011.6   -246.9   0.0   7.0   0.0      0.0 METAL
     06   4998.0  -1875.0   5852.0  -1875.0  17.0 143.0 -22.6      5.0 METAL
     09   4934.3   1032.8   5938.3   1032.8  55.8 24.49  23.4      5.0 METAL
     10   4934.3   1021.8   5938.3   1021.8  26.0 31.72  20.3      5.0 METAL
     12   4934.3   1016.9   5938.3   1016.9  10.0 13.56   0.0      5.0 METAL
```

```
ECTION  9
          = SHADOWING BY BUILDINGS (MAXIMUM OF 10)
          YES - RUN SHADOWING BUILDINGS (yes,no)
       ##  X-LEFT   Y-LEFT   X-RGHT   Y-RGHT   ELV   HGT
       -- -------- -------- -------- -------- ----- -----
       nn xxxxxxxx yyyyyyyy xxxxxxxx yyyyyyyy eeeee hhhhh
       01   -219.0    245.5   -153.9    290.2   0.0   7.0
       02  -1011.6    246.1   -219.0    245.5   0.0   7.0
       03   -133.3   -286.0   -173.6   -246.9   0.0   7.0
       04   -133.3   -286.0    256.7   -286.0   0.0   7.0
       05   -173.6   -246.9  -1011.6   -246.9   0.0   7.0
ECTION 12
          = FLIGHTPATH
          FAF      : 5.0    NAUTICAL MILES
          DATUM    : 8250.0        0.0 23.0
          TYPE     : SEGMENTED   (measured,distance,orbit,radial,
        *                         segmented,straight)
          VELOCITY : 200.0
          INCREMENT: 40.0
          DATA RATE: 0.2
        *  IF "straight" SUFFICIENT DATA ARE AVAILABLE TO COMPUTE FLIGHTPATH
        *  IF "radial" ENTER ANGLE,ELEVATION & STARTING AND ENDING DISTANCES
        *               (nm from dme/p)
          ANGLE: aaaaaaaa
          SDIST: dddddddd
          EDIST: dddddddd
          ELEV : eeeeeeee
        *  IF "orbit" ENTER RADIUS (nm from dme/p) & ELEVATION
          RADIUS: rrrrrrrr
          ELEV  : eeeeeeee
        *  IF "measured" X,Y,Z COORDINATES AND TIME WILL BE READ FROM UNIT 15
        *      WITH VELOCITY AND DATA INCREMENT COMPUTED FROM INPUT
        *  IF "segmented" or "distance" ENTER SEGMENT #,X,Y,Z,VELOCITY AND
        *      INCREMENT
       ##    XS       YS       ZS       VEL      INC
       -- -------- -------- -------- -------- --------
       nn xxxxxxxx yyyyyyyy zzzzzzzz vvvvvvvv iiiiiiii
       01  38630.0      0.0   1621.0    200.0     40.0
       02   8250.0      0.0     29.0      0.0      0.0
ECTION 13
          = FLIGHTPATH AND AIRPORT LAYOUT AXIS LIMITS
        * FLIGHTPATH PLOTS:
                                 X/Y PLOT     X/Z PLOT     D/Z PLOT
                                ----------   ----------   ----------
            MINIMUM X VALUE :  -3000.00 ft  -3000.00 ft     -0.25 nm
            UNITS PER INCH  :   3000.00 ft   3000.00 ft      0.25 nm
            MINIMUM Y VALUE :  -3000.00 ft   -100.00 ft   -100.00 ft
            UNITS PER INCH  :   1000.00 ft    100.00 ft    100.00 ft
        * AIRPORT LAYOUT PLOT:
                                 X/Y PLOT
                                ----------
            MINIMUM X VALUE :  -2000.00 ft
            UNITS PER INCH  :   2000.00 ft
            MINIMUM Y VALUE :  -4000.00 ft
```

UNITS PER INCH : 1000.00 ft

:CTION 14

= ANGLE EQUIPMENT AXIS LIMITS

* MULTIPATH DIAGNOSTIC PLOTS:

	M/D	SEP ANG	SHADOWING
MINIMUM X VALUE :	-50.0 deg	-50.0 deg	-50.0 deg
UNITS PER INCH :	10.0 deg	10.0 deg	10.0 deg
MINIMUM Y VALUE :	-40.0 db	-40.0 deg	-10.0 db
UNITS PER INCH :	10.0 db	10.0 deg	2.0 db

* RECEIVER OUTPUT ERROR & FILTERED ERROR PLOTS:

	RAW	PFE	CMN
MINIMUM X VALUE :	-50.0 deg	-50.0 deg	-50.0 deg
UNITS PER INCH :	10.0 deg	10.0 deg	10.0 deg
MINIMUM Y VALUE :	-0.30 deg	-0.30 deg	-0.30 deg
UNITS PER INCH :	0.10 deg	0.10 deg	0.10 deg

:CTION 15

= DISTANCE MEASURING EQUIPMENT AXIS LIMITS

* MULTIPATH DIAGNOSTIC PLOTS:

	M/D	TIM DELAY	SHADOWING
MINIMUM X VALUE :	-50.0 deg	-50.0 deg	-50.0 deg
UNITS PER INCH :	10.0 deg	10.0 deg	10.0 deg
MINIMUM Y VALUE :	-40.0 db	0.0 ns	-10.0 db
UNITS PER INCH :	10.0 db	100.0 ns	2.0 db

* RECEIVER OUTPUT ERROR & FILTERED ERROR PLOTS:

	RAW	PFE	CMN
MINIMUM X VALUE :	-50.0 deg	-50.0 deg	-50.0 deg
UNITS PER INCH :	10.0 deg	10.0 deg	10.0 deg
MINIMUM Y VALUE :	-90.0 ft	-90.0 ft	-90.0 ft
UNITS PER INCH :	30.0 ft	30.0 ft	30.0 ft

ID DATA

APPENDIX B
INPUT FILE FOR
RUNWAY 32R 3° 10NM ORBIT

```
:******************MLS MATHEMATICAL MODEL INPUT DATA FILE**********************
:CTION  0
          = SCENARIO DATA
          RUN ID# :CO3
          TITLE   :COMPOSITE SCENARIO, 3 DEGREE ORBIT
          AIRPORT :MOFFETT FIELD, CA.
          RUNWAY  :32R
          LENGTH  :9200
          WIDTH   :200
          ARDH    :50
          MGPA    :3.0
          UNITS   :FEET   (feet, meter) FOR ENTRIES IN FILE
:CTION 1A
          = ANGLE TRANSMITTER DATA
          PHASE CENTER:  X         Y         Z    FREQ(mhz)  LSL   USL    TYPE
                      -------- -------- -------- --------- ----- ----- --------
          AZIMUTH  :  -1000.0      0.0      7.0    5000.0 -40.0  40.0 AZG2X40
          ELEVATION:   8250.0    400.0     29.0    5000.0   0.9  20.0 ELG15C
:CTION 1D
          = DME/P TRANSMITTER DATA
          PHASE CENTER:  X         Y         Z      TYPE
                      -------- -------- -------- --------
          DME/P    :  -1000.0      5.0     12.0 DMBN

          = OTHER DME DATA
                      FREQ(mhz)  SHAPE    TRG  F   SW    AS    TRS  SIGM   RMI
                      --------- --------- --- --- ----- ----- ----- ----- -----
          UPLINK   :    1092.0 PCOC21200 DAC NOF   0.5   0.5 0.125   0.0   0.0
          DOWNLINK :    1029.0 PCOC21200 DAC NOF   0.5   0.5 0.125   0.0   0.0
:CTION  2
          NO  - DO ANY GROUND REFLECTION PROCESSING (CALL GREFC) (yes,no)
          NO  - DO FULL INTEGRATION FOR SPECULAR GROUND SCATTERING (yes,no)
          = DEFAULT DIELECTRIC CONSTANT AND ROUGHNESS HEIGHT
          DIELECTRIC CONSTANT : 3.0        -0.9
          ROUGHNESS HEIGHT    : .423469387
        * FOR MULTIPLE SCATTERING PATHS FROM AIRCRAFT AND BUILDINGS
          DIELECTRIC CONSTANT : 3.0        -0.9
          ROUGHNESS HEIGHT    : .423469387
:CTION  4
          = SCATTERING FROM BUILDINGS (MAXIMUM OF 10)
          YES - RUN SCATTERING BUILDINGS (yes,no)
      ##  X-LEFT   Y-LEFT   X-RGHT   Y-RGHT   ELV   HGT   TLT   GRCORR   CMP
      -- -------- -------- -------- -------- ----- ----- ----- -------- -----
      nn xxxxxxxx yyyyyyyy xxxxxxxx yyyyyyyy eeeee hhhhh ttttt cccccccc mmmmm
      01   4934.3   1158.5   5938.3   1158.5 185.0  5.22   0.0      5.0 METAL
      02  -1011.6    246.1   -219.0    245.5   0.0   7.0   0.0      0.0 METAL
      03   4934.3   1117.8   5938.3   1117.8 172.9 24.62  67.0      5.0 METAL
      04   -133.3   -286.0    256.7   -286.0   0.0   7.0   0.0      0.0 METAL
      05   -173.6   -246.9  -1011.6   -246.9   0.0   7.0   0.0      0.0 METAL
      06   4998.0  -1875.0   5852.0  -1875.0  17.0 143.0 -22.6      5.0 METAL
      09   4934.3   1032.8   5938.3   1032.8  55.8 24.49  23.4      5.0 METAL
      10   4934.3   1021.8   5938.3   1021.8  26.0 31.72  20.3      5.0 METAL
      12   4934.3   1016.9   5938.3   1016.9  10.0 13.56   0.0      5.0 METAL
```

```
ECTION  9
          = SHADOWING BY BUILDINGS (MAXIMUM OF 10)
          YES - RUN SHADOWING BUILDINGS (yes,no)
       ##  X-LEFT   Y-LEFT   X-RGHT   Y-RGHT   ELV   HGT
       -- -------- -------- -------- -------- ----- -----
       nn xxxxxxxx yyyyyyyy xxxxxxxx yyyyyyyy eeeee hhhhh
       01   -219.0    245.5   -153.9    290.2   0.0   7.0
       02  -1011.6    246.1   -219.0    245.5   0.0   7.0
       03   -133.3   -286.0   -173.6   -246.9   0.0   7.0
       04   -133.3   -286.0    256.7   -286.0   0.0   7.0
       05   -173.6   -246.9  -1011.6   -246.9   0.0   7.0
ECTION 12
          = FLIGHTPATH
          FAF      : 5.0    NAUTICAL MILES
          DATUM    : 8250.0        0.0 23.0
          TYPE     : SEGMENTED   (measured,distance,orbit,radial,
        *                         segmented,straight)
          VELOCITY : 200.0
          INCREMENT: 40.0
          DATA RATE: 0.2
        *  IF "straight" SUFFICIENT DATA ARE AVAILABLE TO COMPUTE FLIGHTPATH
        *  IF "radial" ENTER ANGLE,ELEVATION & STARTING AND ENDING DISTANCES
        *               (nm from dme/p)
          ANGLE: aaaaaaaa
          SDIST: ddddddddd
          EDIST: ddddddddd
          ELEV : eeeeeeee
        *  IF "orbit" ENTER RADIUS (nm from dme/p) & ELEVATION
          RADIUS: 10.0
          ELEV  : 3215.3
        *  IF "measured" X,Y,Z COORDINATES AND TIME WILL BE READ FROM UNIT 15
        *      WITH VELOCITY AND DATA INCREMENT COMPUTED FROM INPUT
        *  IF "segmented" or "distance" ENTER SEGMENT #,X,Y,Z,VELOCITY AND
        *      INCREMENT
       ##    XS       YS       ZS      VEL      INC
       -- -------- -------- -------- -------- --------
       nn xxxxxxxx yyyyyyyy zzzzzzzz vvvvvvvv iiiiiiii
       40  55523.4  39667.1   3215.3    200.0     40.0
       37  57112.0  37692.8   3215.3    200.0     40.0
       35  58618.3  35655.0   3215.3    200.0     40.0
       32  60039.7  33557.1   3215.3    200.0     40.0
       30  61373.7  31402.5   3215.3    200.0     40.0
       28  62618.1  29195.1   3215.3    200.0     40.0
       25  63770.9  26938.4   3215.3    200.0     40.0
       23  64830.1  24636.3   3215.3    200.0     40.0
       21  65793.8  22292.6   3215.3    200.0     40.0
       18  66660.5  19911.3   3215.3    200.0     40.0
       16  67428.7  17496.5   3215.3    200.0     40.0
       14  68097.1  15052.2   3215.3    200.0     40.0
       11  68664.6  12582.4   3215.3    200.0     40.0
        9  69130.3  10091.5   3215.3    200.0     40.0
        7  69493.3   7583.6   3215.3    200.0     40.0
        4  69753.0   5062.8   3215.3    200.0     40.0
        2  69909.0   2533.5   3215.3    200.0     40.0
```

0	69961.0	0.0	3215.3	200.0	40.0
2	69909.0	-2533.5	3215.3	200.0	40.0
4	69753.0	-5062.8	3215.3	200.0	40.0
7	69493.3	-7583.6	3215.3	200.0	40.0
9	69130.3	-10091.5	3215.3	200.0	40.0
11	68664.6	-12582.4	3215.3	200.0	40.0
14	68097.1	-15052.2	3215.3	200.0	40.0
16	67428.7	-17496.5	3215.3	200.0	40.0
18	66660.5	-19911.3	3215.3	200.0	40.0
21	65793.8	-22292.6	3215.3	200.0	40.0
23	64830.1	-24636.3	3215.3	200.0	40.0
25	63770.9	-26938.4	3215.3	200.0	40.0
28	62618.1	-29195.1	3215.3	200.0	40.0
30	61373.7	-31402.5	3215.3	200.0	40.0
32	60039.7	-33557.1	3215.3	200.0	40.0
35	58618.3	-35655.0	3215.3	200.0	40.0
37	57112.0	-37692.8	3215.3	200.0	40.0
40	55523.4	-39667.1	3215.3	200.0	40.0

CTION 13

= FLIGHTPATH AND AIRPORT LAYOUT AXIS LIMITS

* FLIGHTPATH PLOTS:

	X/Y PLOT	X/Z PLOT	D/Z PLOT
MINIMUM X VALUE :	-3000.00 ft	-3000.00 ft	-0.25 nm
UNITS PER INCH :	3000.00 ft	3000.00 ft	0.25 nm
MINIMUM Y VALUE :	-3000.00 ft	-100.00 ft	-100.00 ft
UNITS PER INCH :	1000.00 ft	100.00 ft	100.00 ft

* AIRPORT LAYOUT PLOT:

	X/Y PLOT
MINIMUM X VALUE :	-2000.00 ft
UNITS PER INCH :	2000.00 ft
MINIMUM Y VALUE :	-4000.00 ft
UNITS PER INCH :	1000.00 ft

CTION 14

= ANGLE EQUIPMENT AXIS LIMITS

* MULTIPATH DIAGNOSTIC PLOTS:

	M/D	SEP ANG	SHADOWING
MINIMUM X VALUE :	-50.0 deg	-50.0 deg	-50.0 deg
UNITS PER INCH :	10.0 deg	10.0 deg	10.0 deg
MINIMUM Y VALUE :	-40.0 db	-40.0 deg	-10.0 db
UNITS PER INCH :	10.0 db	10.0 deg	2.0 db

* RECEIVER OUTPUT ERROR & FILTERED ERROR PLOTS:

	RAW	PFE	CMN
MINIMUM X VALUE :	-50.0 deg	-50.0 deg	-50.0 deg
UNITS PER INCH :	10.0 deg	10.0 deg	10.0 deg
MINIMUM Y VALUE :	-0.30 deg	-0.30 deg	-0.30 deg
UNITS PER INCH :	0.10 deg	0.10 deg	0.10 deg

ECTION 15

= DISTANCE MEASURING EQUIPMENT AXIS LIMITS

* MULTIPATH DIAGNOSTIC PLOTS:

	M/D	TIM DELAY	SHADOWING
MINIMUM X VALUE :	-50.0 deg	-50.0 deg	-50.0 deg
UNITS PER INCH :	10.0 deg	10.0 deg	10.0 deg
MINIMUM Y VALUE :	-40.0 db	0.0 ns	-10.0 db
UNITS PER INCH :	10.0 db	100.0 ns	2.0 db

* RECEIVER OUTPUT ERROR & FILTERED ERROR PLOTS:

	RAW	PFE	CMN
MINIMUM X VALUE :	-50.0 deg	-50.0 deg	-50.0 deg
UNITS PER INCH :	10.0 deg	10.0 deg	10.0 deg
MINIMUM Y VALUE :	-90.0 ft	-90.0 ft	-90.0 ft
UNITS PER INCH :	30.0 ft	30.0 ft	30.0 ft

ND DATA

APPENDIX C
INPUT FILE FOR
3° APPROACH TO RUNWAY 14L

```
*****************MLS MATHEMATICAL MODEL INPUT DATA FILE**********************
CTION  0
          = SCENARIO DATA
          RUN ID# :CA
          TITLE   :COMPOSITE SCENARIO, 3 DEGREE APPROACH
          AIRPORT :MOFFETT FIELD, CA.
          RUNWAY  :14L
          LENGTH  :9200
          WIDTH   :200
          ARDH    :50
          MGPA    :3.0
          UNITS   :FEET   (feet, meter) FOR ENTRIES IN FILE
CTION 1A
          = ANGLE TRANSMITTER DATA
          PHASE CENTER:  X        Y        Z    FREQ(mhz)  LSL   USL    TYPE
                       -------- -------- -------- --------- ----- ----- --------
          AZIMUTH  :  -1180.0      0.0     38.5    5000.0 -40.0  40.0 AZG2X40
          ELEVATION:   8332.0    255.0      7.0    5000.0   0.9  20.0 ELG15C
CTION 1D
          = DME/P TRANSMITTER DATA
          PHASE CENTER:  X        Y        Z      TYPE
                       -------- -------- -------- --------
          DME/P    :  -1180.0      5.0     43.5 DMBN

          = OTHER DME DATA
                       FREQ(mhz)  SHAPE    TRG  F   SW    AS    TRS  SIGM   RMI
                       --------- --------- --- --- ----- ----- ----- ----- -----
          UPLINK   :     1092.0 PCOC21200 DAC NOF   0.5   0.5 0.125   0.0   0.0
          DOWNLINK :     1029.0 PCOC21200 DAC NOF   0.5   0.5 0.125   0.0   0.0
CTION  2
          NO  - DO ANY GROUND REFLECTION PROCESSING (CALL GREFC) (yes,no)
          NO  - DO FULL INTEGRATION FOR SPECULAR GROUND SCATTERING (yes,no)
          = DEFAULT DIELECTRIC CONSTANT AND ROUGHNESS HEIGHT
          DIELECTRIC CONSTANT : 3.0        -0.9
          ROUGHNESS HEIGHT    : .423469387
         * FOR MULTIPLE SCATTERING PATHS FROM AIRCRAFT AND BUILDINGS
          DIELECTRIC CONSTANT : 3.0        -0.9
          ROUGHNESS HEIGHT    : .423469387
CTION  4
          = SCATTERING FROM BUILDINGS (MAXIMUM OF 10)
          YES - RUN SCATTERING BUILDINGS (yes,no)
      ##  X-LEFT   Y-LEFT   X-RGHT   Y-RGHT   ELV   HGT   TLT   GRCORR   CMP
      -- -------- -------- -------- -------- ----- ----- ----- -------- -----
      nn xxxxxxxx yyyyyyyy xxxxxxxx yyyyyyyy eeeee hhhhh ttttt cccccccc mmmmm
      01   9333.3    286.0   8943.3    286.0   0.0   7.0   0.0      0.0 METAL
      02   9333.3    286.0   9373.6    246.9   0.0   7.0   0.0      0.0 METAL
      03   9373.6    246.9  10211.6    246.9   0.0   7.0   0.0      0.0 METAL
      05  10211.6   -246.1   9419.0   -245.9   0.0   7.0   0.0      0.0 METAL
      06   3261.7  -1158.5   4265.7  -1158.5 185.0  5.22   0.0      5.0 METAL
      07   3261.7  -1021.8   4265.7  -1021.8  26.0 31.72 -20.3      5.0 METAL
      08   3261.7  -1016.9   4265.7  -1016.9  10.0 13.56   0.0      5.0 METAL
      09   3261.7  -1640.5   4265.7  -1640.5 185.0  5.22   0.0      5.0 METAL
      10   3261.7  -1503.8   4265.7  -1503.8  26.0 31.72 -20.3      5.0 METAL
      11   3261.7  -1498.9   4265.7  -1498.9  10.0 13.56   0.0      5.0 METAL
```

```
ECTION  9
          = SHADOWING BY BUILDINGS (MAXIMUM OF 10)
          YES - RUN SHADOWING BUILDINGS (yes,no)
        ##  X-LEFT   Y-LEFT   X-RGHT   Y-RGHT   ELV   HGT
        -- -------- -------- -------- -------- ----- -----
        nn xxxxxxxx yyyyyyyy xxxxxxxx yyyyyyyy eeeee hhhhh
        01   9333.3    286.0   8943.3    286.0   0.0   7.0
        02   9333.3    286.0   9373.6    246.9   0.0   7.0
        03   9373.6    246.9  10211.6    246.9   0.0   7.0
        04  10211.6   -246.1  10211.6    246.9   0.0   7.0
        05  10211.6   -246.1   9419.0   -245.9   0.0   7.0
        06   9419.0   -245.5   9353.9   -290.2   0.0   7.0
        07   9353.9   -290.2   9354.0   -556.8   0.0   7.0
ECTION 12
          = FLIGHTPATH
          FAF      : 5.0    NAUTICAL MILES
          DATUM    : 8332.0        0.0 1.5
          TYPE     : SEGMENTED   (measured,distance,orbit,radial,
        *                         segmented,straight)
          VELOCITY : 200.0
          INCREMENT: 40.0
          DATA RATE: 0.2
        *  IF "straight" SUFFICIENT DATA ARE AVAILABLE TO COMPUTE FLIGHTPATH
        *  IF "radial" ENTER ANGLE,ELEVATION & STARTING AND ENDING DISTANCES
        *                (nm from dme/p)
          ANGLE: aaaaaaaa
          SDIST: ddddddddd
          EDIST: ddddddddd
          ELEV : eeeeeeee
        *  IF "orbit" ENTER RADIUS (nm from dme/p) & ELEVATION
          RADIUS: rrrrrrrr
          ELEV  : eeeeeeee
        *  IF "measured" X,Y,Z COORDINATES AND TIME WILL BE READ FROM UNIT 15
        *      WITH VELOCITY AND DATA INCREMENT COMPUTED FROM INPUT
        *  IF "segmented" or "distance" ENTER SEGMENT #,X,Y,Z,VELOCITY AND
        *      INCREMENT
        ##    XS       YS       ZS      VEL      INC
        -- -------- -------- -------- -------- --------
        nn xxxxxxxx yyyyyyyy zzzzzzzz vvvvvvvv iiiiiiii
        01  38712.0      0.0   1599.0    200.0     40.0
        02   8332.0      0.0      7.0      0.0      0.0
ECTION 13
          = FLIGHTPATH AND AIRPORT LAYOUT AXIS LIMITS
        * FLIGHTPATH PLOTS:
                                 X/Y PLOT     X/Z PLOT     D/Z PLOT
                                ----------   ----------   ----------
            MINIMUM X VALUE :  -3000.00 ft  -3000.00 ft     -0.25 nm
            UNITS PER INCH  :   3000.00 ft   3000.00 ft      0.25 nm
            MINIMUM Y VALUE :  -3000.00 ft   -100.00 ft   -100.00 ft
            UNITS PER INCH  :   1000.00 ft    100.00 ft    100.00 ft
        * AIRPORT LAYOUT PLOT:
                                 X/Y PLOT
                                ----------
            MINIMUM X VALUE :  -2000.00 ft
```

```
          UNITS PER INCH  :   2000.00 ft
          MINIMUM Y VALUE :  -4000.00 ft
          UNITS PER INCH  :   1000.00 ft
ECTION 14
        = ANGLE EQUIPMENT AXIS LIMITS
      * MULTIPATH DIAGNOSTIC PLOTS:
                                M/D          SEP ANG     SHADOWING
                              ---------    ---------    ---------
          MINIMUM X VALUE :    -0.50 nm     -0.50 nm     -0.50 nm
          UNITS PER INCH  :     0.50 nm      0.50 nm      0.50 nm
          MINIMUM Y VALUE :    -40.0 db     -40.0 deg    -10.0 db
          UNITS PER INCH  :     10.0 db      10.0 deg      2.0 db
      * RECEIVER OUTPUT ERROR & FILTERED ERROR PLOTS:
                                RAW           PFE          CMN
                              ---------    ---------    ---------
          MINIMUM X VALUE :    -0.50 nm     -0.50 nm     -0.50 nm
          UNITS PER INCH  :     0.50 nm      0.50 nm      0.50 nm
          MINIMUM Y VALUE :    -0.30 deg    -0.30 deg    -0.30 deg
          UNITS PER INCH  :     0.10 deg     0.10 deg     0.10 deg
ECTION 15
        = DISTANCE MEASURING EQUIPMENT AXIS LIMITS
      * MULTIPATH DIAGNOSTIC PLOTS:
                                M/D         TIM DELAY   SHADOWING
                              --------     ---------   ---------
          MINIMUM X VALUE :    -0.50 nm     -0.50 nm     -0.50 nm
          UNITS PER INCH  :     0.50 nm      0.50 nm      0.50 nm
          MINIMUM Y VALUE :    -40.0 db       0.0 ns     -10.0 db
          UNITS PER INCH  :     10.0 db     100.0 ns       2.0 db
      * RECEIVER OUTPUT ERROR & FILTERED ERROR PLOTS:
                                RAW           PFE          CMN
                              ---------    ---------    ---------
          MINIMUM X VALUE :    -0.50 nm     -0.50 nm     -0.50 nm
          UNITS PER INCH  :     0.50 nm      0.50 nm      0.50 nm
          MINIMUM Y VALUE :    -90.0 ft     -90.0 ft     -90.0 ft
          UNITS PER INCH  :     30.0 ft      30.0 ft      30.0 ft
ID DATA
```

APPENDIX D
INPUT FILE FOR
RUNWAY 14L 3° 10NM ORBIT

```
******************MLS MATHEMATICAL MODEL INPUT DATA FILE**********************
ECTION  0
          = SCENARIO DATA
          RUN ID# :CO3
          TITLE   :COMPOSITE SCENARIO, 3 DEGREE ORBIT, 10 NMI.
          AIRPORT :MOFFETT FIELD, CA.
          RUNWAY  :14L
          LENGTH  :9200
          WIDTH   :200
          ARDH    :50
          MGPA    :3.0
          UNITS   :FEET   (feet, meter) FOR ENTRIES IN FILE
ECTION 1A
          = ANGLE TRANSMITTER DATA
          PHASE CENTER:  X         Y         Z    FREQ(mhz)  LSL   USL    TYPE
                       -------- -------- -------- --------- ----- ----- --------
          AZIMUTH  :  -1180.0      0.0     38.5    5000.0 -40.0  40.0 AZG2X40
          ELEVATION:   8332.0    255.0      7.0    5000.0   0.9  20.0 ELG15C
ECTION 1D
          = DME/P TRANSMITTER DATA
          PHASE CENTER:  X         Y         Z      TYPE
                       -------- -------- -------- --------
          DME/P    :  -1180.0      5.0     43.5 DMBN

          = OTHER DME DATA
                       FREQ(mhz)  SHAPE    TRG  F   SW    AS    TRS  SIGM   RMI
                       --------- --------- --- --- ----- ----- ----- ----- -----
          UPLINK   :     1092.0 PCOC21200 DAC NOF   0.5   0.5 0.125   0.0   0.0
          DOWNLINK :     1029.0 PCOC21200 DAC NOF   0.5   0.5 0.125   0.0   0.0
ECTION  2
          NO  - DO ANY GROUND REFLECTION PROCESSING (CALL GREFC) (yes,no)
          NO  - DO FULL INTEGRATION FOR SPECULAR GROUND SCATTERING (yes,no)
          = DEFAULT DIELECTRIC CONSTANT AND ROUGHNESS HEIGHT
          DIELECTRIC CONSTANT : 3.0        -0.9
          ROUGHNESS HEIGHT    : .423469387
        * FOR MULTIPLE SCATTERING PATHS FROM AIRCRAFT AND BUILDINGS
          DIELECTRIC CONSTANT : 3.0        -0.9
          ROUGHNESS HEIGHT    : .423469387
ECTION  4
          = SCATTERING FROM BUILDINGS (MAXIMUM OF 10)
          YES - RUN SCATTERING BUILDINGS (yes,no)
      ##  X-LEFT   Y-LEFT   X-RGHT   Y-RGHT   ELV   HGT   TLT   GRCORR   CMP
      -- -------- -------- -------- -------- ----- ----- ----- -------- -----
      nn xxxxxxxx yyyyyyyy xxxxxxxx yyyyyyyy eeeee hhhhh ttttt cccccccc mmmmm
      01   9333.3    286.0   8943.3    286.0   0.0   7.0   0.0      0.0 METAL
      02   9333.3    286.0   9373.6    246.9   0.0   7.0   0.0      0.0 METAL
      03   9373.6    246.9  10211.6    246.9   0.0   7.0   0.0      0.0 METAL
      05  10211.6   -246.1   9419.0   -245.9   0.0   7.0   0.0      0.0 METAL
      06   3261.7  -1158.5   4265.7  -1158.5 185.0  5.22   0.0      5.0 METAL
      07   3261.7  -1021.8   4265.7  -1021.8  26.0 31.72 -20.3      5.0 METAL
      08   3261.7  -1016.9   4265.7  -1016.9  10.0 13.56   0.0      5.0 METAL
      09   3261.7  -1640.5   4265.7  -1640.5 185.0  5.22   0.0      5.0 METAL
      10   3261.7  -1503.8   4265.7  -1503.8  26.0 31.72 -20.3      5.0 METAL
      11   3261.7  -1498.9   4265.7  -1498.9  10.0 13.56   0.0      5.0 METAL
```

```
CTION  9
          = SHADOWING BY BUILDINGS (MAXIMUM OF 10)
          YES - RUN SHADOWING BUILDINGS (yes,no)
       ##  X-LEFT   Y-LEFT   X-RGHT   Y-RGHT   ELV   HGT
       -- -------- -------- -------- -------- ----- -----
       nn xxxxxxxx yyyyyyyy xxxxxxxx yyyyyyyy eeeee hhhhh
       01   9333.3    286.0   8943.3    286.0   0.0   7.0
       02   9333.3    286.0   9373.6    246.9   0.0   7.0
       03   9373.6    246.9  10211.6    246.9   0.0   7.0
       04  10211.6   -246.1  10211.6    246.9   0.0   7.0
       05  10211.6   -246.1   9419.0   -245.9   0.0   7.0
       06   9419.0   -245.5   9353.9   -290.2   0.0   7.0
       07   9353.9   -290.2   9354.0   -556.8   0.0   7.0
CTION 12
          = FLIGHTPATH
          FAF       : 5.0    NAUTICAL MILES
          DATUM     : 8332.0        0.0 1.5
          TYPE      : SEGMENTED    (measured,distance,orbit,radial,
        *                          segmented,straight)
          VELOCITY : 200.0
          INCREMENT: 40.0
          DATA RATE: 0.2
        *  IF "straight" SUFFICIENT DATA ARE AVAILABLE TO COMPUTE FLIGHTPATH
        *  IF "radial" ENTER ANGLE,ELEVATION & STARTING AND ENDING DISTANCES
        *                (nm from dme/p)
          ANGLE: aaaaaaaa
          SDIST: ddddddddd
          EDIST: ddddddddd
          ELEV : eeeeeeee
        *  IF "orbit" ENTER RADIUS (nm from dme/p) & ELEVATION
          RADIUS: 10.0
          ELEV  : 3193.8
        *  IF "measured" X,Y,Z COORDINATES AND TIME WILL BE READ FROM UNIT 15
        *      WITH VELOCITY AND DATA INCREMENT COMPUTED FROM INPUT
        *  IF "segmented" or "distance" ENTER SEGMENT #,X,Y,Z,VELOCITY AND
        *      INCREMENT
       ##    XS       YS       ZS      VEL      INC
       -- -------- -------- -------- -------- --------
       nn xxxxxxxx yyyyyyyy zzzzzzzz vvvvvvvv iiiiiiii
       40  55542.6  39614.4   3193.8    200.0     40.0
       37  57129.1  37642.7   3193.8    200.0     40.0
       35  58633.4  35607.6   3193.8    200.0     40.0
       32  60052.9  33512.5   3193.8    200.0     40.0
       30  61385.1  31360.8   3193.8    200.0     40.0
       28  62627.9  29156.3   3193.8    200.0     40.0
       25  63779.1  26902.6   3193.8    200.0     40.0
       23  64836.9  24603.5   3193.8    200.0     40.0
       21  65799.3  22263.0   3193.8    200.0     40.0
       18  66664.9  19884.9   3193.8    200.0     40.0
       16  67432.1  17473.2   3193.8    200.0     40.0
       14  68099.6  15032.2   3193.8    200.0     40.0
       11  68666.4  12565.7   3193.8    200.0     40.0
        9  69131.4  10078.1   3193.8    200.0     40.0
        7  69493.9   7573.5   3193.8    200.0     40.0
```

4	69753.3	5056.1	3193.8	200.0	40.0
2	69909.0	2530.2	3193.8	200.0	40.0
0	69961.0	0.0	3193.8	200.0	40.0
2	69909.0	-2530.2	3193.8	200.0	40.0
4	69753.3	-5056.1	3193.8	200.0	40.0
7	69493.9	-7573.5	3193.8	200.0	40.0
9	69131.4	-10078.1	3193.8	200.0	40.0
11	68666.4	-12565.7	3193.8	200.0	40.0
14	68099.6	-15032.2	3193.8	200.0	40.0
16	67432.1	-17473.2	3193.8	200.0	40.0
18	66664.9	-19884.9	3193.8	200.0	40.0
21	65799.3	-22263.0	3193.8	200.0	40.0
23	64836.9	-24603.5	3193.8	200.0	40.0
25	63779.1	-26902.6	3193.8	200.0	40.0
28	62627.9	-29156.3	3193.8	200.0	40.0
30	61385.1	-31360.8	3193.8	200.0	40.0
32	60052.9	-33512.5	3193.8	200.0	40.0
35	58633.4	-35607.6	3193.8	200.0	40.0
37	57129.1	-37642.7	3193.8	200.0	40.0
40	55542.6	-39614.4	3193.8	200.0	40.0

ECTION 13

= FLIGHTPATH AND AIRPORT LAYOUT AXIS LIMITS

* FLIGHTPATH PLOTS:

	X/Y PLOT	X/Z PLOT	D/Z PLOT
MINIMUM X VALUE :	-3000.00 ft	-3000.00 ft	-0.25 nm
UNITS PER INCH :	3000.00 ft	3000.00 ft	0.25 nm
MINIMUM Y VALUE :	-3000.00 ft	-100.00 ft	-100.00 ft
UNITS PER INCH :	1000.00 ft	100.00 ft	100.00 ft

* AIRPORT LAYOUT PLOT:

	X/Y PLOT
MINIMUM X VALUE :	-2000.00 ft
UNITS PER INCH :	2000.00 ft
MINIMUM Y VALUE :	-4000.00 ft
UNITS PER INCH :	1000.00 ft

ECTION 14

= ANGLE EQUIPMENT AXIS LIMITS

* MULTIPATH DIAGNOSTIC PLOTS:

	M/D	SEP ANG	SHADOWING
MINIMUM X VALUE :	-50.0 deg	-50.0 deg	-50.0 deg
UNITS PER INCH :	10.0 deg	10.0 deg	10.0 deg
MINIMUM Y VALUE :	-40.0 db	-40.0 deg	-10.0 db
UNITS PER INCH :	10.0 db	10.0 deg	2.0 db

* RECEIVER OUTPUT ERROR & FILTERED ERROR PLOTS:

	RAW	PFE	CMN
MINIMUM X VALUE :	-50.0 deg	-50.0 deg	-50.0 deg
UNITS PER INCH :	10.0 deg	10.0 deg	10.0 deg
MINIMUM Y VALUE :	-0.30 deg	-0.30 deg	-0.30 deg
UNITS PER INCH :	0.10 deg	0.10 deg	0.10 deg

ECTION 15

= DISTANCE MEASURING EQUIPMENT AXIS LIMITS

* MULTIPATH DIAGNOSTIC PLOTS:

	M/D	TIM DELAY	SHADOWING
MINIMUM X VALUE :	-50.0 deg	-50.0 deg	-50.0 deg
UNITS PER INCH :	10.0 deg	10.0 deg	10.0 deg
MINIMUM Y VALUE :	-40.0 db	0.0 ns	-10.0 db
UNITS PER INCH :	10.0 db	100.0 ns	2.0 db

* RECEIVER OUTPUT ERROR & FILTERED ERROR PLOTS:

	RAW	PFE	CMN
MINIMUM X VALUE :	-50.0 deg	-50.0 deg	-50.0 deg
UNITS PER INCH :	10.0 deg	10.0 deg	10.0 deg
MINIMUM Y VALUE :	-90.0 ft	-90.0 ft	-90.0 ft
UNITS PER INCH :	30.0 ft	30.0 ft	30.0 ft

ND DATA