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ILS Mathematical Modeling Study of an ILS Glide Slope Proposed for Runway 19L at the Meridian Naval Air Station, Mississippi

James D. Rambone

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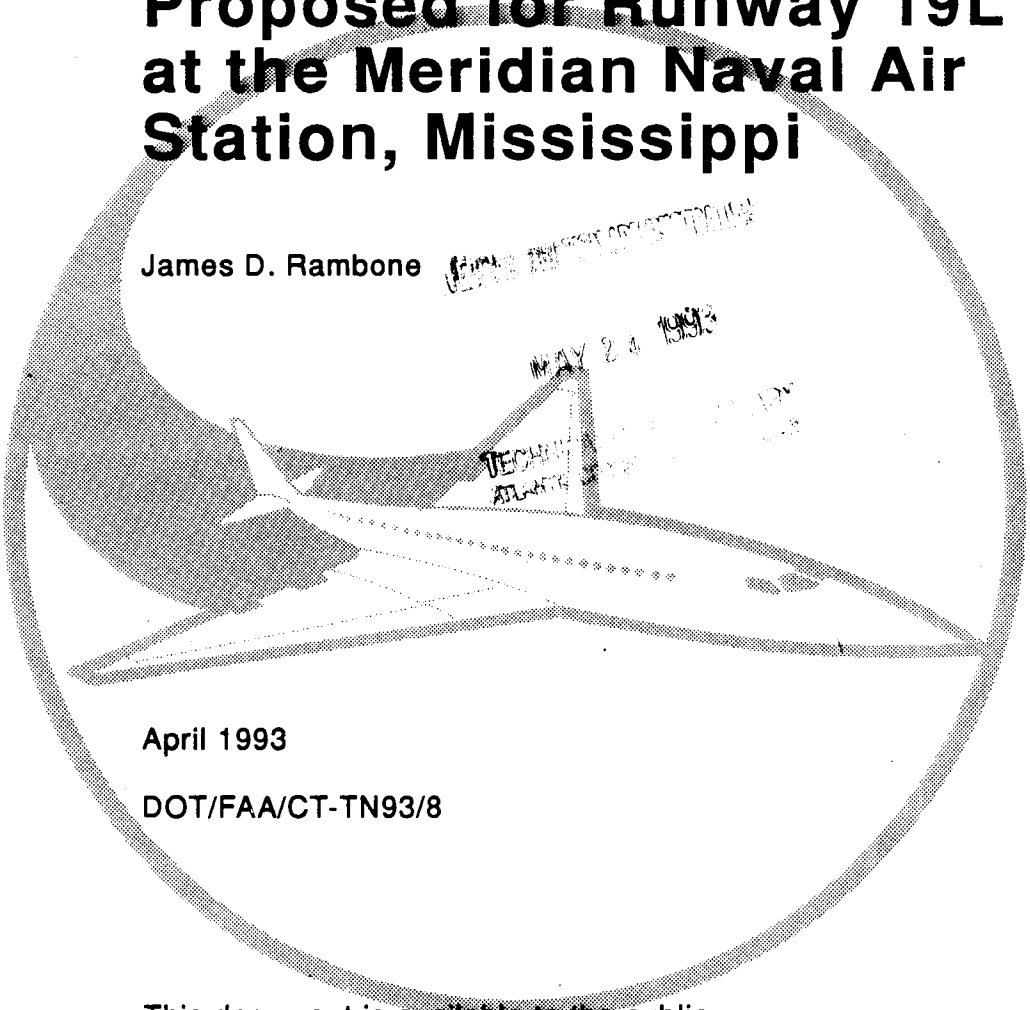

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16. Abstract

This Technical Note describes the Instrument Landing System (ILS) math modeling performed by the Federal Aviation Administration (FAA) Technical Center at the request of the Naval Command, Control, and Ocean Surveillance Center In-Service Engineering (NISE). Data arepresented showing the computed performance for a glide slope proposed for runway 19L at the Meridian Naval Air Station (NAS). As requested, capture effect and null reference systems were modeled at the proposed glide slope site. The proposed site is located 783 feet back from runway threshold and 400 feet left offset of centerline. NISE is concerned that severe terrain gradients in front of the site may adversely affect glide slope performance. Glide slope modeling was conducted using physical optics computations in the Geometric Theory of Diffraction-3D (GTD-3D) model. The GTD computations in the GTD-3D model could not accommodate a triple diffraction occurrence caused by sharp terrain gradients in front of the glide slope site. Glide slope modeling computed only the effect of the proposed terrain on glide slope performance. Preliminary modeling results for both the capture effect and null reference antennas with the proposed terrain grade indicated an out-of-tolerance excursion occurring approximately 3,000 feet in front of threshold. The first 1,000 foot section of proposed terrain grade in front of the antenna was modified slightly to eliminate this excursion in the final modeling runs. Modeled path structure and level run plots are provided for the proposed capture effect and null reference systems. Results indicate that the capture effect and null reference systems modeled with the modified proposed terrain grade should meet Category I path structure, linearity, and symmetry tolerances.

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EXECUTIVE SUMMARY

This instrument landing system (ILS) math modeling study was performed at the request of the Naval Command, Control, and Ocean Surveillance Center In-Service Engineering (NISE). NISE requested modeling of capture effect and null reference antennas at the proposed glide slope site for runway 19L at the Meridian Naval Air Station (NAS). The glide slope antenna will be located 783 feet back from runway threshold and 400 feet left offset of centerline. NISE is concerned that severe terrain gradients in front of the site may adversely affect glide slope performance. Glide slope modeling was conducted using physical optics computations in the Geometric Theory of Diffraction-3D (GTD-3D) model. The GTD computations in the GTD-3D model could not accommodate a triple diffraction occurrence caused by sharp terrain gradients in front of the glide slope site. Glide slope modeling computed only the effect of the proposed terrain grade on glide slope performance. Preliminary modeling results for both the capture effect and null reference antennas with the proposed terrain grade indicated an out-of-tolerance excursion occurring approximately 3,000 feet from threshold. The first 1,000-foot section of proposed terrain grade in front of the antenna was modified slightly to eliminate this excursion in the final modeling runs. Modeled path structure and level run plots are provided for the proposed capture effect and null reference systems. Results indicate that the capture effect and null reference systems modeled at the proposed site with the modified proposed terrain grade should meet Category I path structure, linearity, and symmetry tolerances.

INTRODUCTION

PURPOSE.

The purpose of this math modeling study was to provide computer modeled performance data for an instrument landing system (ILS) glide slope proposed for runway 19L at the Meridian Naval Air Station (NAS), Mississippi.

BACKGROUND.

The Naval Command, Control, and Ocean Surveillance Center In-Service Engineering (NISE) will be installing an ILS glide slope to serve runway 19L at the Meridian NAS. In support of this project, NISE has requested a math modeling study to be performed by the Federal Aviation Administration (FAA) Technical Center. Glide slope math modeling was requested for capture effect and null reference systems proposed to serve runway 19L. The proposed site is located 783 feet backset from threshold and 400 feet left offset of centerline. There is concern that severe terrain gradients in front of the antenna site may adversely affect glide slope performance. NISE provided maps showing a proposed terrain grade for the area in front of the glide slope site. This modeling effort was performed under project T0603S. The Technical Program Manager is Mr. Edmund A. Zyzys. Additional information regarding this study may be obtained by contacting Mr. James D. Rambone at (609) 485-5373.

DISCUSSION

ILS MATH MODELS.

The FAA Technical Center conducts ILS mathematical computer model studies through application of physical optics or geometric theory of diffraction techniques to compute anticipated ILS performance. The modeling for the runway 19L glide slope was performed using the Ohio University Geometrical Theory of Diffraction (OUGTD) model, which was obtained from Ohio University under an FAA Technical Center contract. This program was written for Ohio University by Mr. Vichate Ungvichian to account for the interactions of electromagnetic waves when reflected and/or diffracted from the terrain between an ILS antenna and an aircraft (reference 1). The OUGTD program utilizes the Geometrical Theory of Diffraction (GTD) and the Uniform Theory of Diffraction (UTD) as the basic theories when computing the diffraction of the electromagnetic waves. The GTD and UTD theories both treat electromagnetic waves as rays. This is acceptable due to the localized nature of wave interactions at very high frequencies (above 100 megahertz (MHz)). This treatment allows one to include the multiple interaction (i.e., doubly diffracted, etc.) between neighboring ground plates with little computational effort. This is a very difficult task when using the Physical Optics theory. The UTD theory is used to calculate the fields in the transition areas; the GTD theory is used in all other areas.

The GTD-3D model has a limitation. The GTD computation in the model cannot accommodate occurrences of triple diffraction caused by several sharp

terrain gradients. If triple diffraction is encountered, erroneous results can occur.

The physical optics computation in the GTD-3D model, a less accurate technique used in computing wave propagation, does not have the capability to compute multiple reflections and diffractions of signals. This glide slope modeling study was performed using physical optics techniques due to occurrences of triple diffraction errors in the GTD computations.

The pseudo-3D version of the model was used for this modeling effort. This version uses a matrix of X, Y, and Z coordinates for the terrain to compute a new terrain profile for each observation point (simulated aircraft position). The term "pseudo-3D" is used to emphasize the fact that the model is not truly 3-dimensional, but rather considers the terrain to be invariant in the X direction. For each observation point and its associated terrain profile, the simulated Course Deviation Indicator (CDI) deflection is computed from the various combinations of rays. The subroutine that determines the profile was modified by FAA Technical Center engineers to eliminate some restrictions on establishing the origin and selection of coordinates.

Input data required by the 3-D model consists of two data files: the terrain matrix file and the input/control file. The terrain matrix file consists of X (distance perpendicular to the runway), Y (distance along the runway centerline extended), and Z (elevation values referenced to the base of the antenna mast). The computer model applies an interpolation process to the terrain matrix file to determine a new terrain profile for each observation point along the flightpath. The new profile is that of the terrain directly below a line drawn from the ILS antenna to the observation point. This profile is the surface used in the computation of the glide slope radio frequency (RF) energy at the observation point. The input/control file consists of data describing the antenna system (location, amplitude, and phase of each antenna element), along with other pertinent site and flightpath data. Antenna heights were computed to produce actual path angles of approximately 3.0 degrees. Antenna current phasing for all simulations were computed using a simulation of the airborne phasing techniques detailed in the Flight Inspection Manual OAP 8200.1 (reference 2). In the simulation, samples of antenna current phase are recorded while flying the simulated aircraft along an approach angle of 1.5 degrees from 8 to 4 nautical miles (nmi) with respect to the site. Ten samples of antenna current phase are recorded for each antenna. Using average phase values, the phase of the upper antenna is adjusted for zero phase difference with respect to the lower antenna for sideband reference or capture effect systems. For the capture effect system, the phases of the lower and upper antennas are adjusted to result in zero phase difference with respect to the middle antenna. This technique is similar to the method originated by the Ohio University Avionics Center for their modeling applications.

ILS MATH MODELING PERFORMED.

Figure 1 shows the general orientation of the runway with the proposed and modified terrain grade. The physical optics computation in the GTD-3D model was used to model the effects of terrain on glide slope performance. The

GTD computation in the model could not accommodate a triple diffraction occurrence produced by sharp terrain gradients in front of the site. Figure 2 shows a composite of terrain profiles with the proposed grade for simulated aircraft positions in the distance interval from 35,000 to 1,000 feet from runway point of intercept (RPI) in increments of 1,000 feet. A 1,000-foot section of the proposed terrain grade in front of the antenna was modified to eliminate an out-of-tolerance excursion occurring approximately 3,000 feet from threshold. A low area located between the runway and glide slope site which runs parallel to the runway was removed by grading the terrain at a constant slope to a point beyond the glide slope site, as shown in figure 1. Figure 3 shows a composite of terrain profiles with this modified proposed terrain grade. As requested, a capture effect antenna and a null reference antenna were modeled at the proposed glide slope site. A summary of the model input data describing the antenna systems at the proposed site is provided in table 1. Glide slope level and path structure computer runs were made with these data.

DATA PRESENTATION.

Glide slope modeling results are presented in the form of course structure and level run plots. The reference flightpath for a structure plot is the hyperbolic path formed by the intersection of a cone originating at the base of the antenna and a vertical plane located along runway centerline. In the model, this path is determined by the location of the eyepiece of the theodolite. For the data presented, the theodolite eyepiece is positioned at the X and Y coordinates of the glide slope antenna mast, but at the elevation (Z coordinate) of the RPI. Modeled results are given in figures 4 through 9. Modeled path structure results for the capture effect system and null reference system installed at the proposed site with the proposed terrain grade are shown in figures 4 and 5, respectively. Figure 6 shows the modeled path structure run result for the capture effect antenna with the modified proposed terrain grade. Modeled path structure results for the null reference antenna with the modified proposed grade are shown in figure 7. Figures 8 and 9 are the modeled level run results with the modified proposed terrain grade for the capture effect and null reference antennas, respectively.

DATA ANALYSIS.

Glide slope modeling path structure results for the capture effect and null reference antennas (figures 4 and 5) with the proposed terrain grade show a path structure for both antennas, which exceed Category I tolerance limits approximately 3,000 feet in front of threshold. Modeled path structure results for the capture effect antenna with the modified proposed terrain grade (figure 6) shows a path structure which meets Category I tolerances. Modeled path structure results for the null reference antenna with the modified proposed terrain grade (figure 7) shows a path structure which also meets Category I tolerance limits. The level run results (figures 8 and 9) show a linear crossover and near symmetrical glidepath which meets Category I tolerances for both the capture effect and null reference antennas.

CONCLUSIONS

Modeled glide slope results using the physical optics computation in the Geometric Theory of Diffraction-3D model indicate that satisfactory Category I glide slope performance should be obtained with the capture effect system or null reference system installed at the proposed site with the modified proposed terrain grade.

REFERENCES

1. User's Manual for the Ohio University Geometric Theory of Diffraction Glide Slope Model, Ohio University, Technical Report Number OU/AEC/ERR 47-7, February 1982.

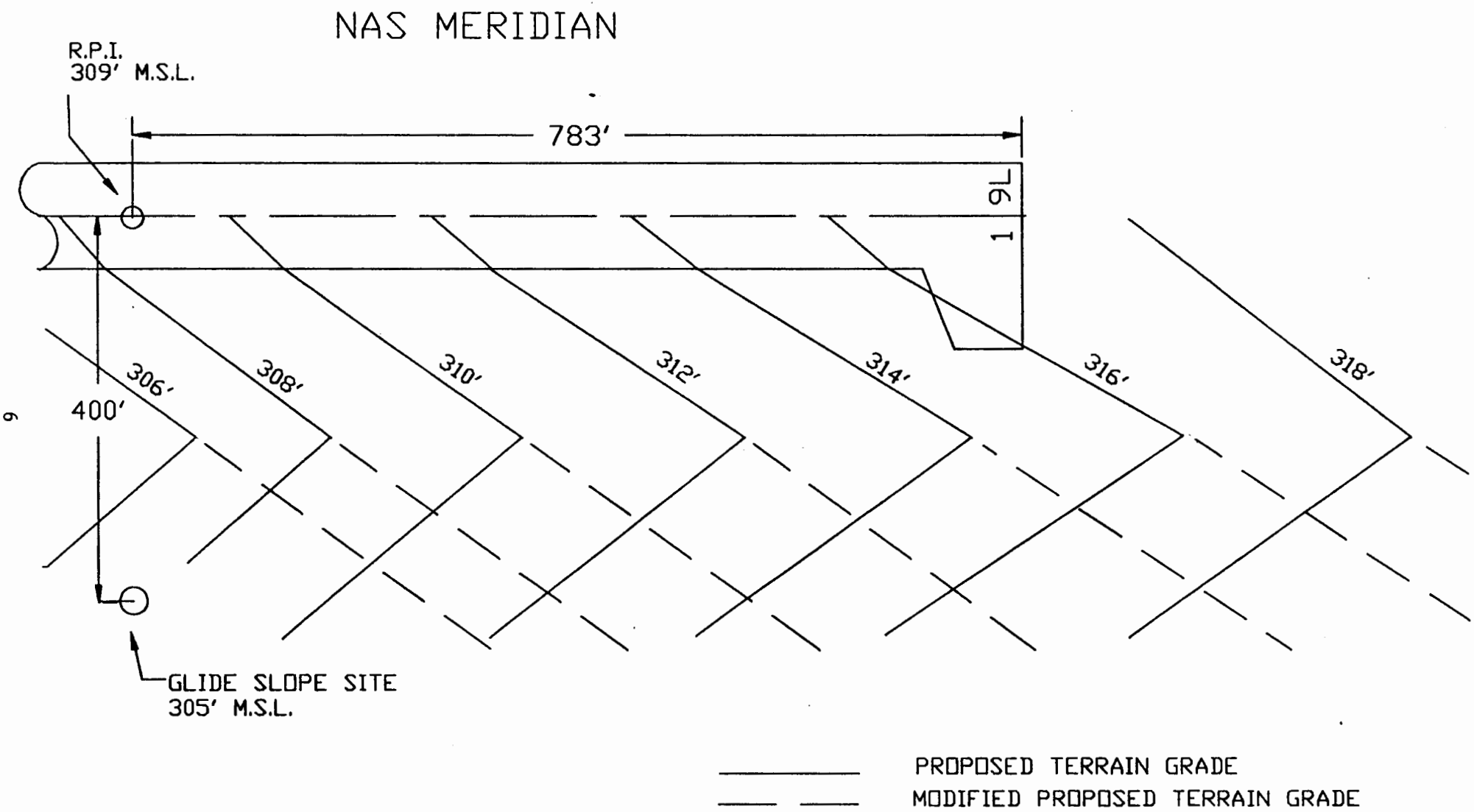
2. United States Flight Inspection Manual, FAA Handbook OAP 8200.1, Change 32, Section 217.

TABLE 1. GLIDE SLOPE DATA SUMMARY

	Capture Effect Antenna Height/Offset (ft/ft)	Null Reference Antenna Height/Offset (ft/ft)
Lower Antenna	16.43/1.013	16.76/0.00
Middle Antenna	32.87/0.000	----------
Upper Antenna	49.30/-1.688	33.51/1.053
A-Ratio *	0.289	0.239

Antenna	
Backset from threshold (ft)	783.00
Offset from centerline (ft)	400.00
Elevation (ft m.s.l.)	305.00
Average Path Angle (deg)	3.00
Path Width (deg)	0.70

* A-Ratio - Ratio of separate sideband signal amplitude to carrier sideband signal amplitude.



* DRAWING NOT TO SCALE

FIGURE 1. MERIDIAN NAS R/W-19L, ILS MATH MODELING LAYOUT

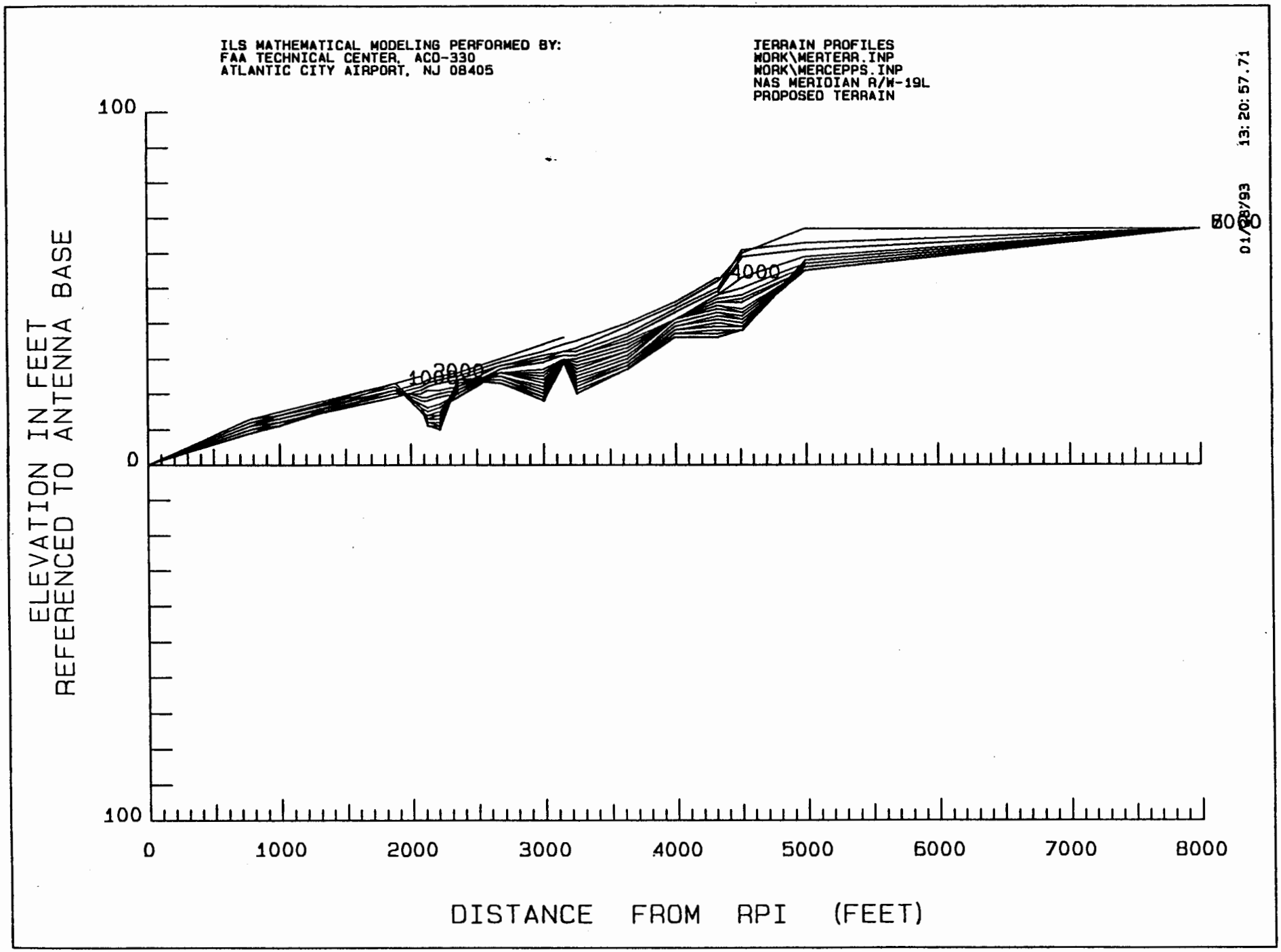


FIGURE 2. PROPOSED TERRAIN PROFILE, R/W-19L

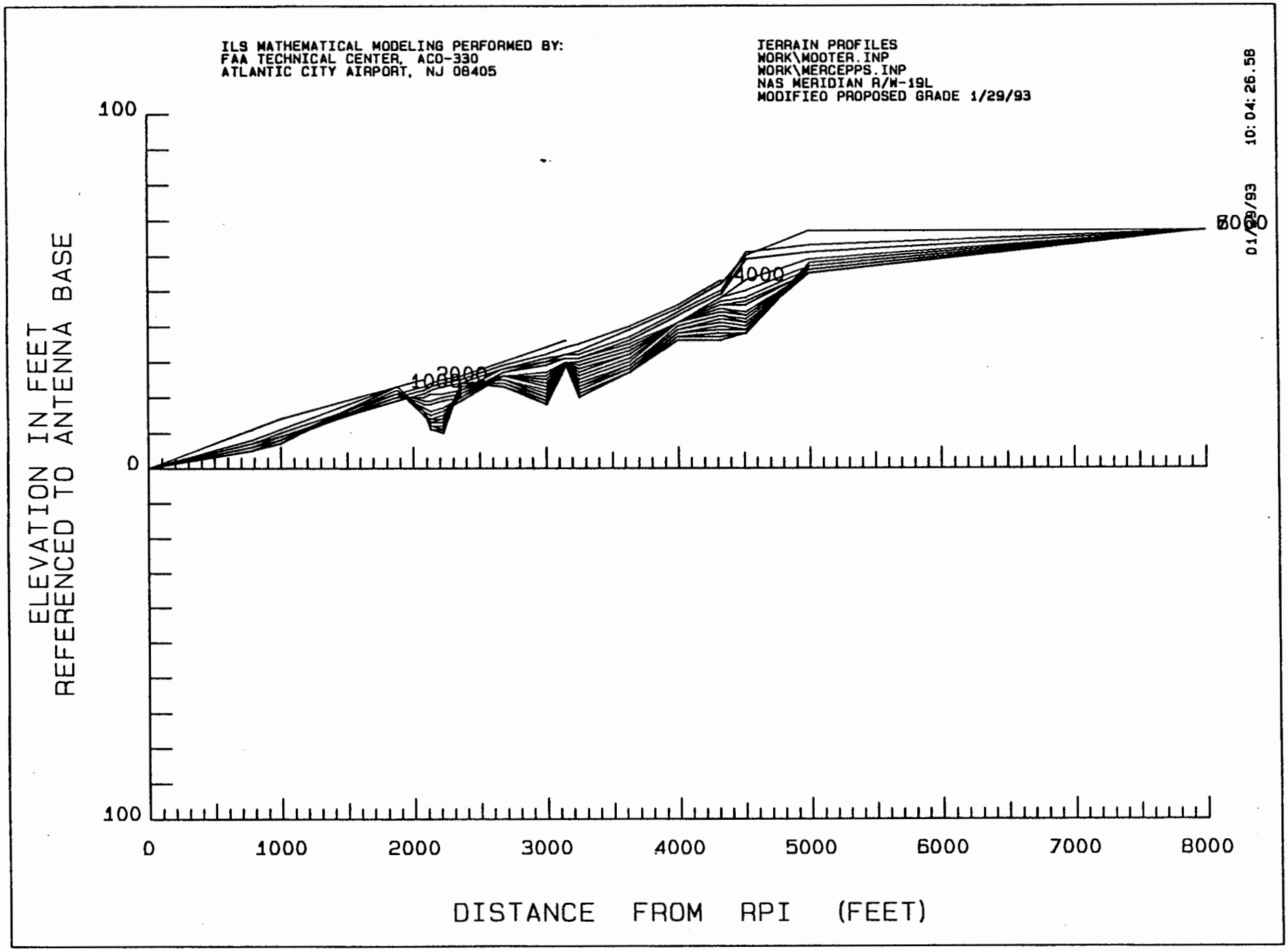


FIGURE 3. MODIFIED PROPOSED TERRAIN PROFILE, R/W-19L

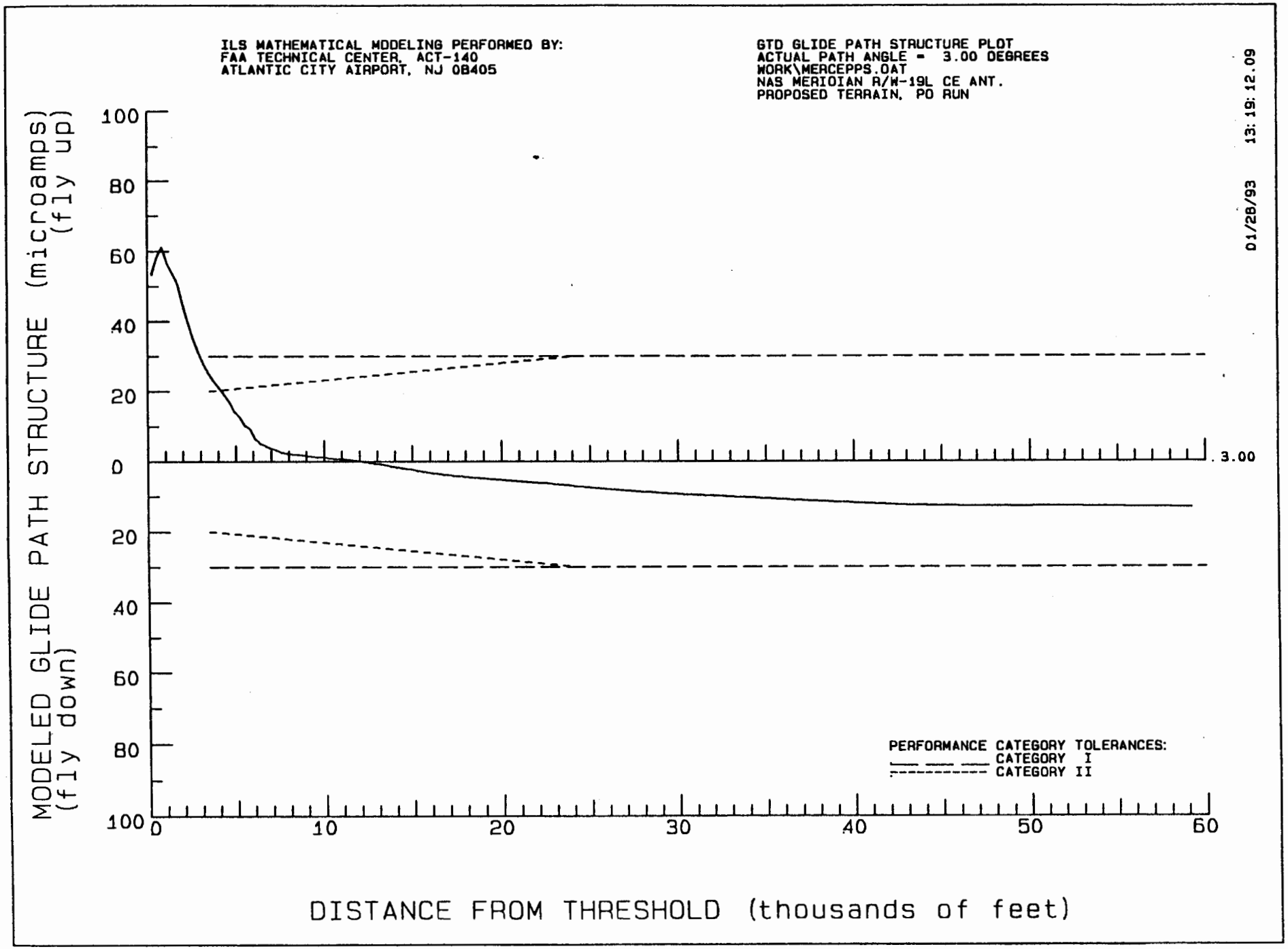


FIGURE 4. MODELED PATH STRUCTURE, PROPOSED TERRAIN GRADE, CAPTURE EFFECT SYSTEM

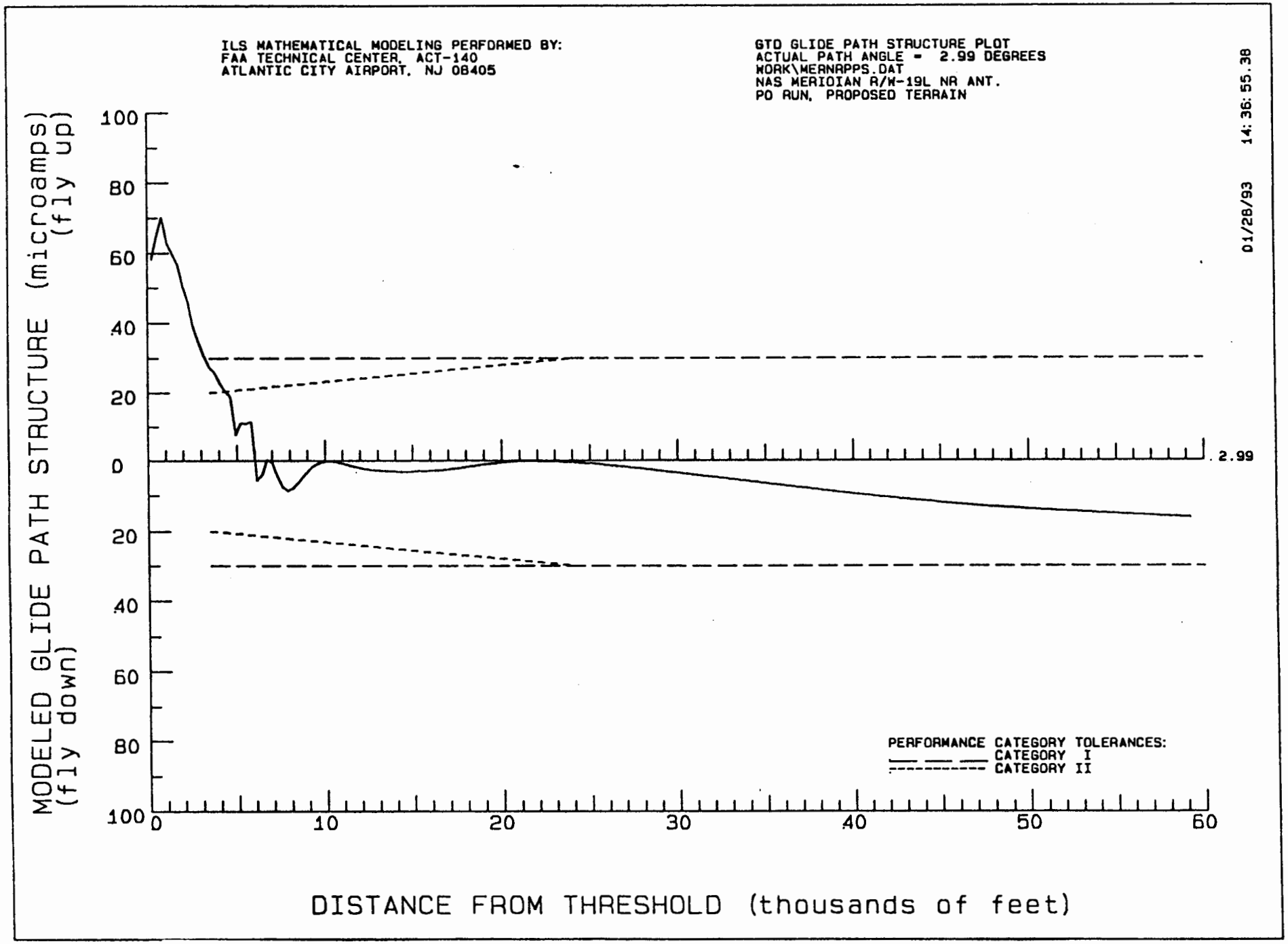


FIGURE 5. MODELED PATH STRUCTURE, PROPOSED TERRAIN GRADE, NULL REFERENCE SYSTEM

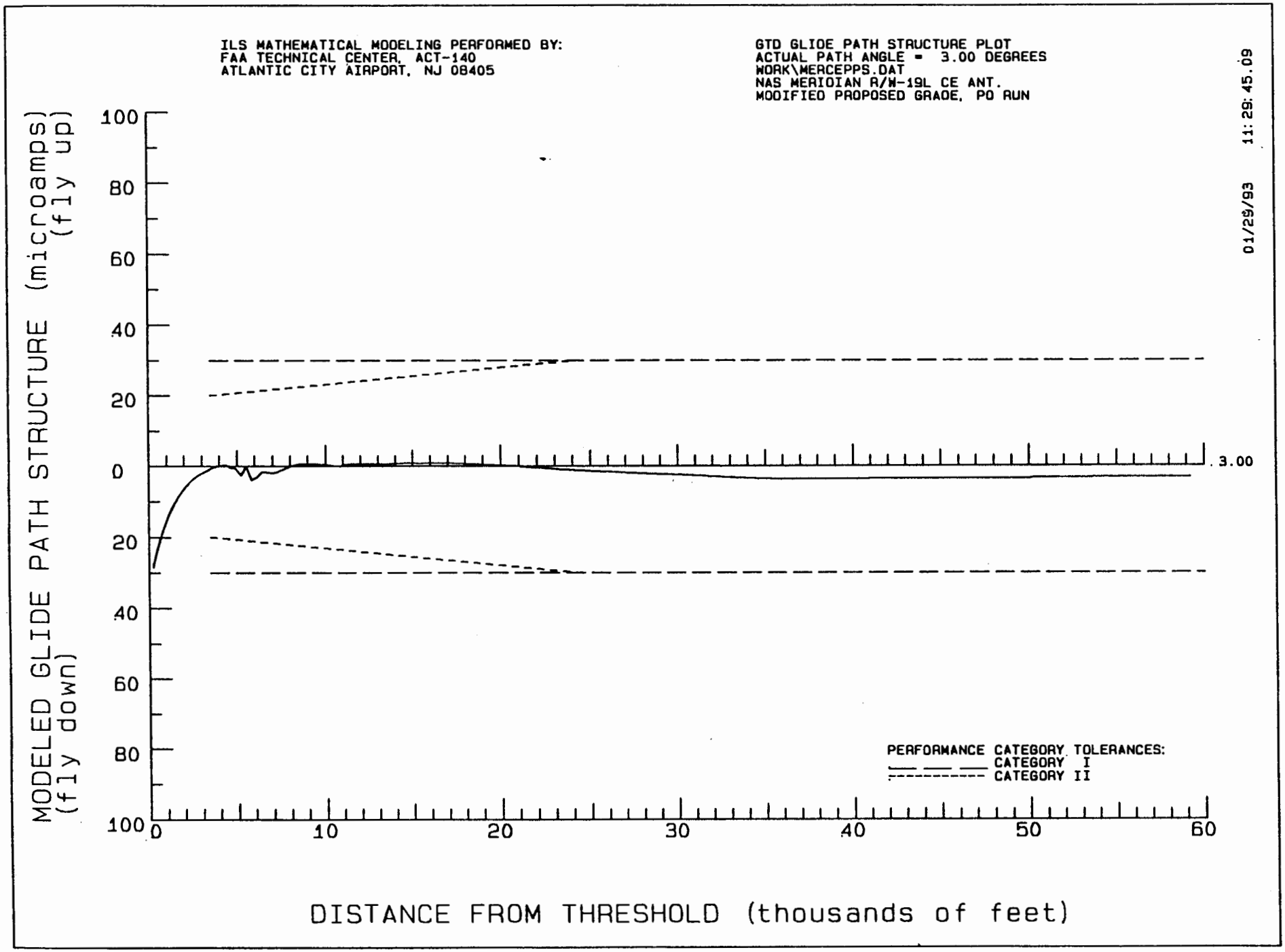


FIGURE 6. MODELED PATH STRUCTURE, MODIFIED PROPOSED GRADE, CAPTURE EFFECT SYSTEM

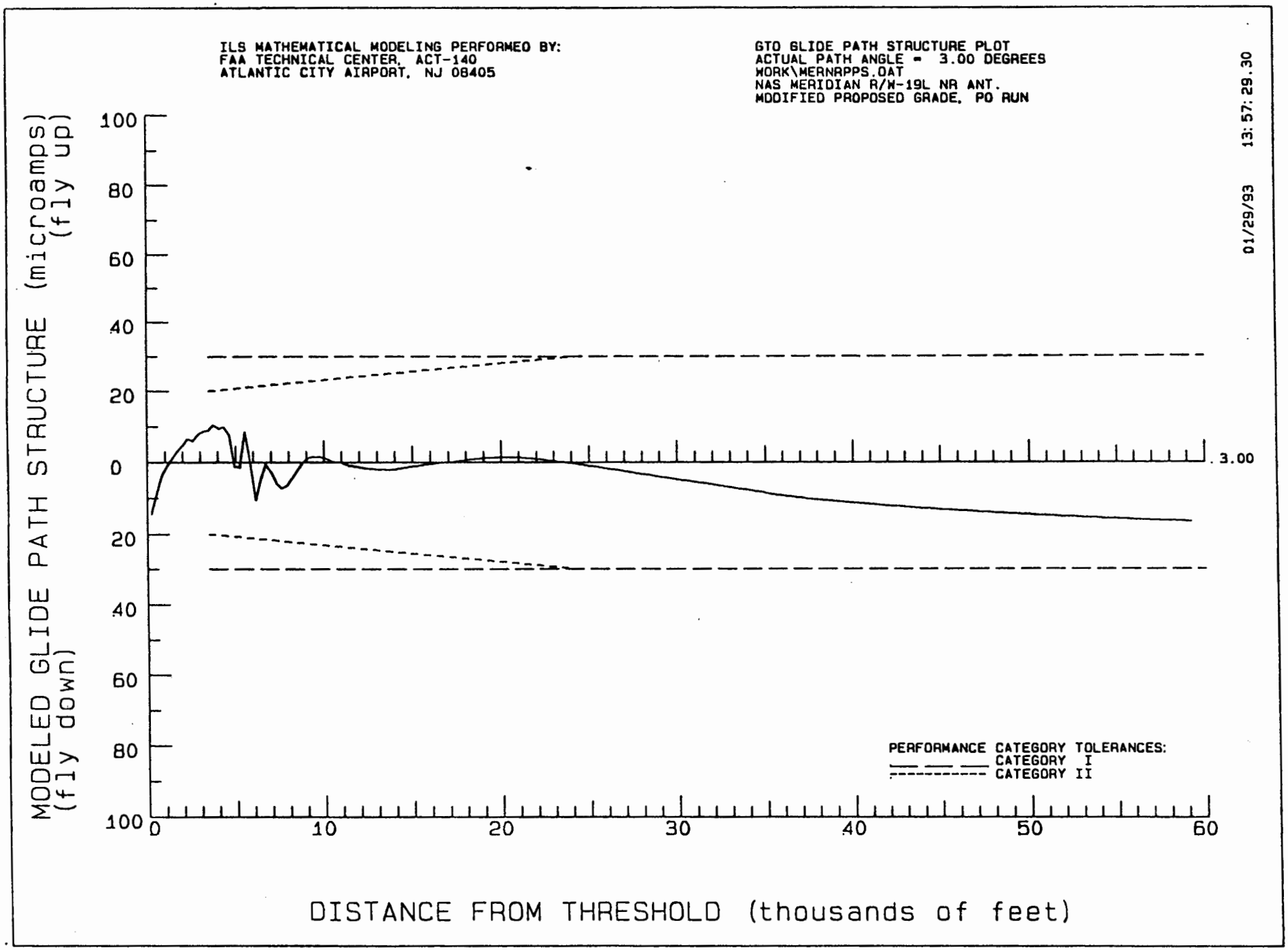


FIGURE 7. MODELED PATH STRUCTURE, MODIFIED PROPOSED GRADE, NULL REFERNCE SYSTEM

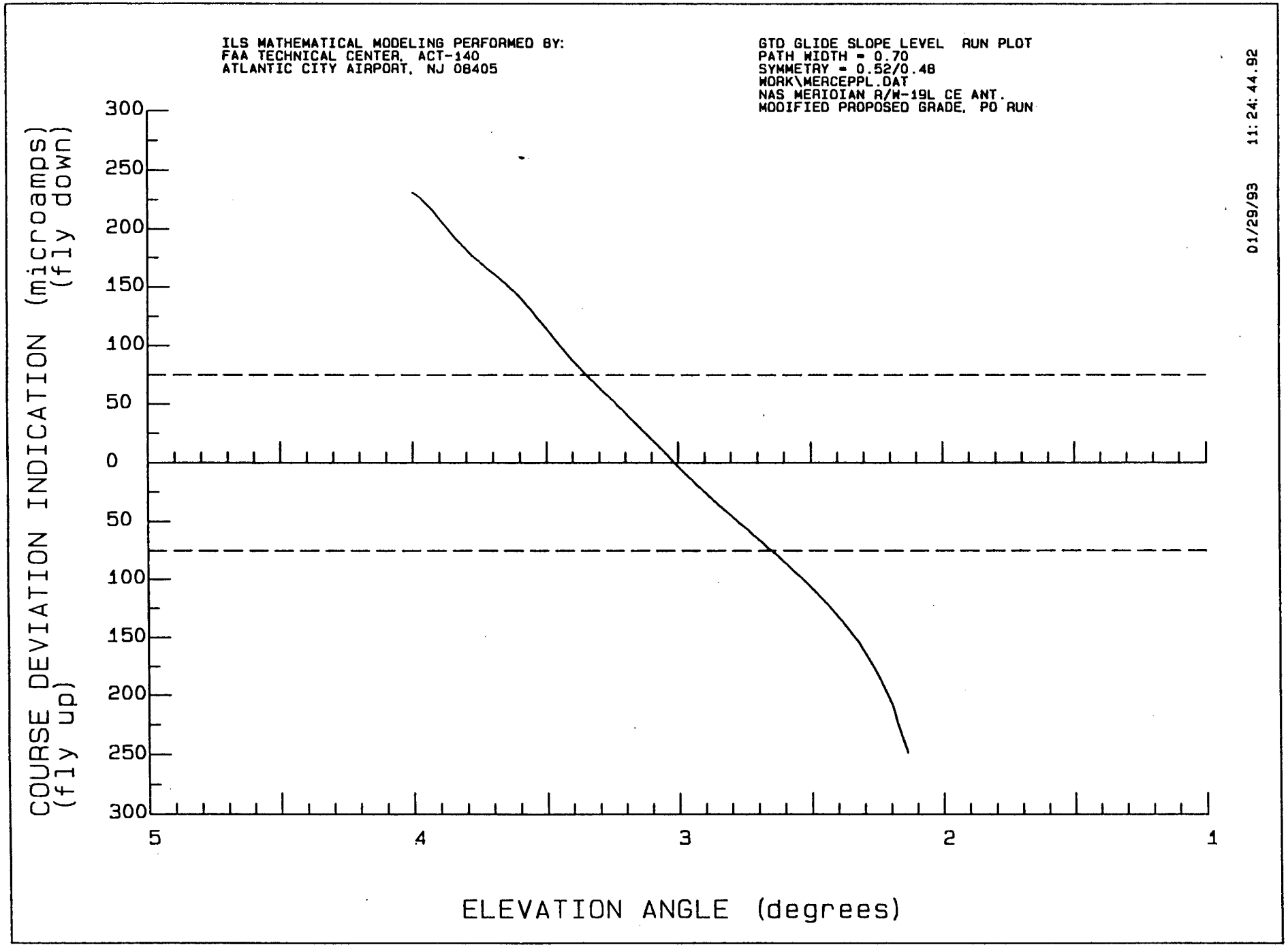


FIGURE 8. MODELED LEVEL RUN, MODIFIED PROPOSED GRADE, CAPTURE EFFECT SYSTEM

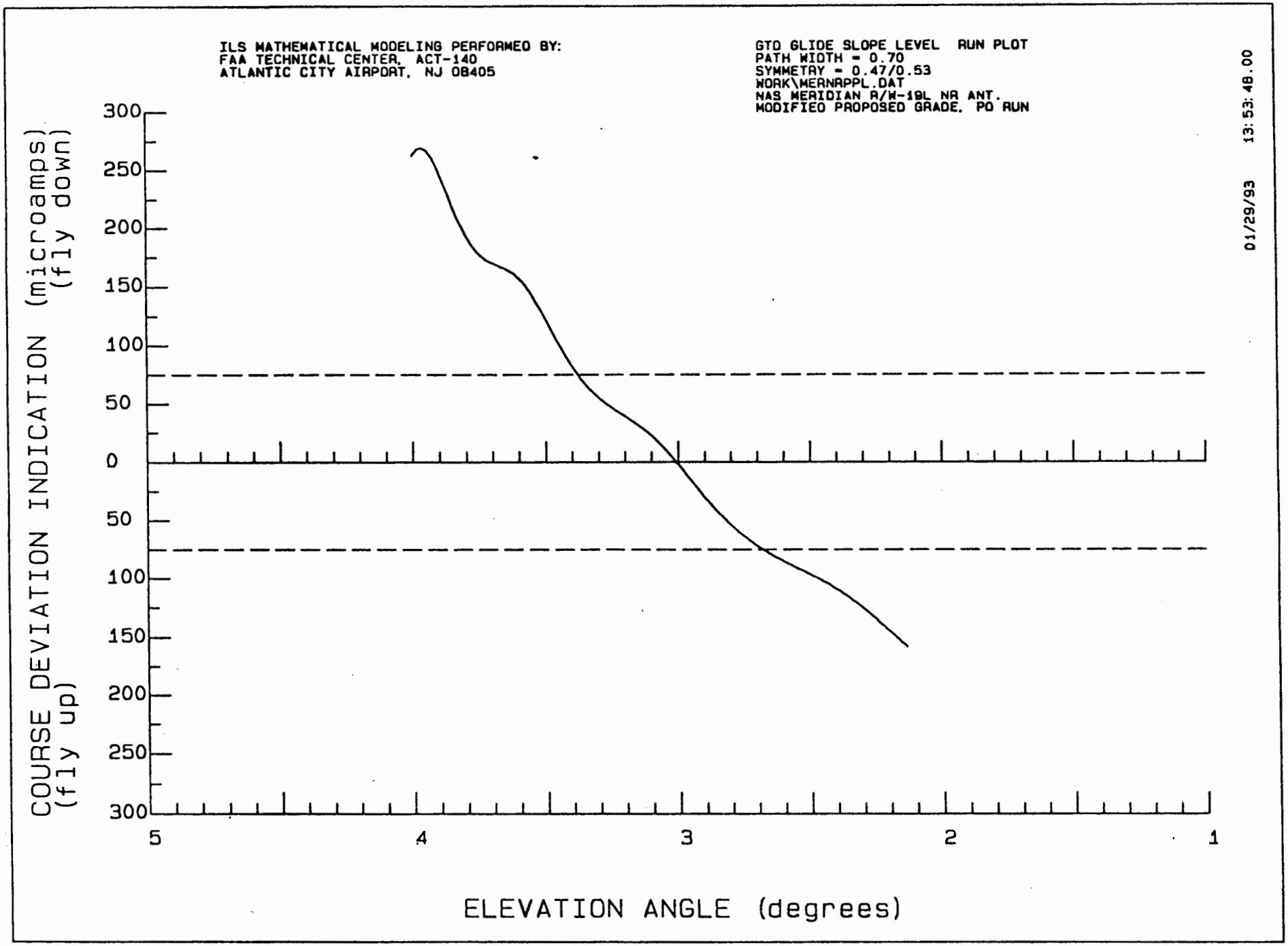


FIGURE 9. MODELED LEVEL RUN, MODIFIED PROPOSED GRADE, NULL REFERENCE SYSTEM