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PERFORMANCE PREDICTIONS FOR PROPOSED ILS FACILITIES AT ST. LOUIS MUNICIPAL AIRPORT

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16 Abstract

The results of computer simulations of performance of proposed ILS facilities on Runway 12L/30R at St. Louis Municipal Airport (Lambert Field) are reported. These simulations indicate that an existing industrial complex located near the runway is compatible with acceptable performance of the proposed facilities. Strict adherence to FAA standards for site grading is suggested to insure satisfactory performance of the glide slope systems.

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PREFACE

This report presents the results of computer simulation of performance of proposed ILS facilities on Runway 12L/30R at St. Louis Municipal Airport (Lambert Field). This work was undertaken under the direction of the project sponsor, H. H. Butts of the Systems Research and Development Service ARD 321, in response to a request from Gus Sandors, Airway Facilities Service, AAF 420. Pursuant to this request, which was initially communicated to TSC on April 23, 1975, a liaison was established with Clyde Humphries, Central Region FAA, ACE 420, for the purpose of obtaining necessary input descriptions of the St. Louis Airport for exercise of the TSC localizer and glide slope simulation models. The TSC Project Manager, L. Jordan, conferred with Regional FAA and St. Louis Airport Officials on May 14, at which time a visual inspection was made and photographs were taken of all structures around the airfield posing any evident threat of significant multipath interference with signals from the proposed ILS facilities. The requirements of an aerial survey to provide the data for prediction of glide slope facilities performance were discussed. A special problem noted was the position of "Building 45" of the McDonnell Douglas complex in relation to the siting of the glide slope array for the 12L approach.

Airport descriptive data derived from the photographs, layout maps and aerial survey were input to TSC's localizer and glide slope performance simulation programs. Preliminary reports of the computer-predicted performance were included in the TSC Significant Items Reports of July 31 and October 14, 1975, and were communicated verbally to AAF 420 and ACE 420. This report documents the basis for the findings communicated earlier.

The localizer and glide slope simulation programs were written by David Newsom of Kentron Hawaii Limited, who also contributed valuable technical input in the model development.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

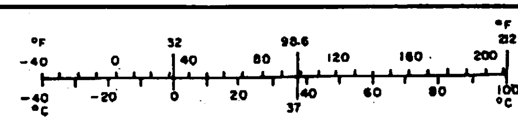


TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (CONTINUED)

LIST OF TABLES

1. INTRODUCTION

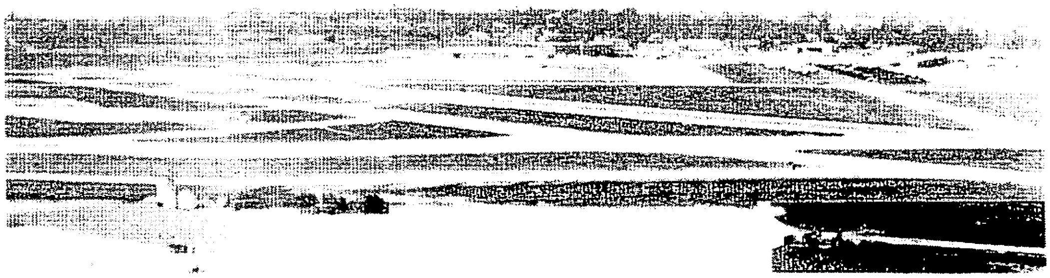
The development of Runway 12L/30R at St. Louis Municipal Airport has been proposed as part of a plan for meeting the projected demand for commercial airport capacity in the Greater St. Louis region over the next two decades. The proposed development includes construction of extensions and installation of ILS facilities at each end of the above runway. A critical consideration for the evaluation of the foregoing proposal is whether the anticipated environment of industrial and airport structures and unlevel terrain renders operation of conventional ILS facilities unfeasible. This report presents estimated system performance for the contemplated facilities obtained by application of TSC-developed computer models for ILS performance simulation.

Figure 1 shows a computer reconstruction of the St. Louis Airport along with a panoramic view of the airport composed from photographs taken from the control tower located on the Southwest edge of the airport. The prominent runway seen in the foreground is Runway 12R/30L, one of two major runways presently instrumented. Runway 12R/30R extends parallel to the former runway from approximately the middle of the view to the Southeast boundary of the airfield. The proposed development plan calls for adding 1700-ft. extensions to each end of this existing runway.

A common source of localizer signal derogation is the placement of hangars and other large buildings near a runway in such positions that strong beams of off-course ILS signals are reflected across the glide path near the runway threshold. The possibility of encountering this difficulty was a serious concern of this study because of the presence of the large complex of buildings near the proposed threshold of the extended Runway 12L. Since a portion of the complex is positioned forward from the proposed glide slope antenna sites for 12L at only a small off-course angle, there was also concern that reflections from these buildings would degrade glide slope signals in the vicinity of the threshold. Other buildings presently located in the proposed approach clear zone are scheduled for removal and hence are given no further consideration in this study.

The remaining principal concern for ILS performance is the possible adverse effect of irregular terrain in the approach zone at either end of the runway. Though extensive earth movement and grading are planned, the proposed final terrain profiles of both approaches are characterized by large upslope areas. Such upslope approach terrain is frequently the cause of poor flyability with conventional glide slope systems.

In each of the following three sections, the application of computer simulation of ILS performance under one of the isolated problem conditions described above is discussed.

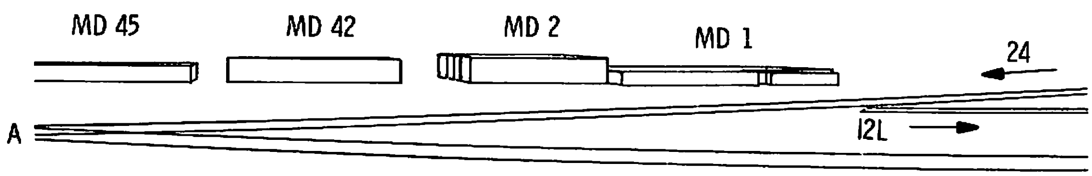


NOTE:
BUILDING TENANT CODES
MD McDONNELL DOUGLAS
NAR NORTH AMERICAN ROCKWELL

a.

FIGURE 1. COMPUTER RECONSTRUCTION OF ST. LOUIS MUNICIPAL AIRPORT LAYOUT AND PANORAMIC VIEW OF AIRPORT COMPOSED OF PHOTOGRAPHS TAKEN FROM THE CONTROL TOWER. (1 of 4)

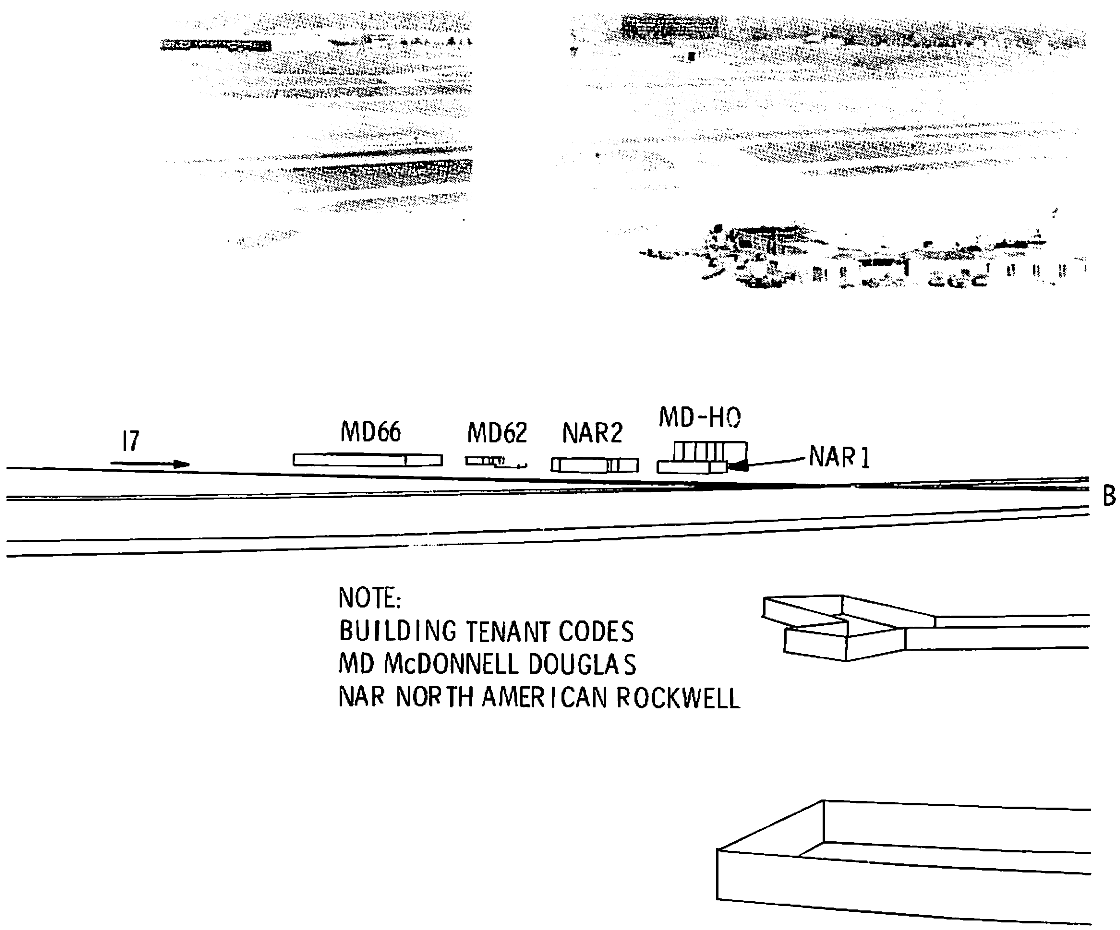
Figure 1a can be joined to Figure 1b at point A.



NOTE:
BUILDING TENANT CODES
MD McDONNELL DOUGLAS
NAR NORTH AMERICAN ROCKWELL

b.

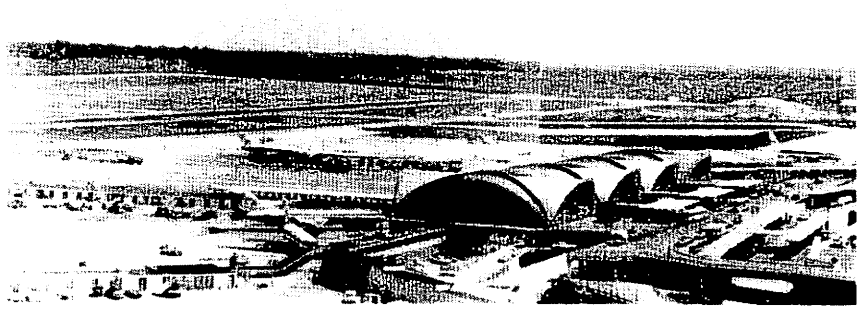
FIGURE 1. COMPUTER RECONSTRUCTION OF ST. LOUIS MUNICIPAL AIRPORT LAYOUT AND PANORAMIC VIEW OF AIRPORT COMPOSED OF PHOTOGRAPHS TAKEN FROM THE CONTROL TOWER. (2 of 4)

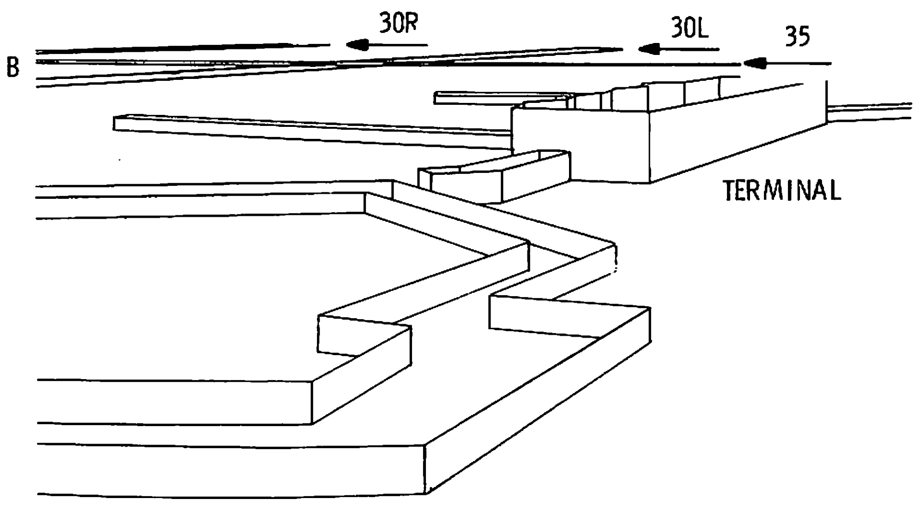


c.

FIGURE 1. COMPUTER RECONSTRUCTION OF ST. LOUIS MUNICIPAL AIRPORT LAYOUT AND PANORAMIC VIEW OF AIRPORT COMPOSED OF PHOTOGRAPHS TAKEN FROM THE CONTROL TOWER. (3 of 4)

Figure 1d can be joined to Figure 1c at point B.





d.

FIGURE 1. COMPUTER RECONSTRUCTION OF ST. LOUIS MUNICIPAL AIRPORT LAYOUT AND PANORAMIC VIEW OF AIRPORT COMPOSED OF PHOTOGRAPHS TAKEN FROM THE CONTROL TOWER. (4 of 4)

2. LOCALIZER SIGNAL SCATTERING FROM BUILDINGS

The computer program ILSLOC* is specifically designed to simulate localizer signal derogation caused by multipath interference from buildings and other fixed structures. To generate the simulated ILS signal reflections the program requires the description of building surfaces represented by combinations of rectangular and triangular flat plates. To simplify input data collection and facilitate rapid calculations, an assumption is made that the building and ground surfaces are perfectly reflecting. The ground surface is also assumed to be perfectly flat. These idealizations, which may be closely approximated by actual circumstances, are justified in part by their correspondence to the worst case conditions for ILS signal derogation. An example of comparison of an ILSLOC prediction with actual flyability data is given in Appendix A.

The required building data were derived from airport layout maps furnished by the St. Louis Airport Authority and from building photographs taken during the visit of TSC personnel to the airport. The airport layout plan shown in Figure 2 was measured on a digitizing table to determine the base outlines of all major buildings directly visible from the proposed localizer antenna sites. Detailed features of buildings were generally ignored. The equivalent full-scale accuracy of the digitized building coordinates thus measured is estimated at ± 10 feet. A computer-generated plot of the measured building outlines reproduced from the digitized coordinates is shown in Figure 3. The building descriptions were completed by height estimates determined by measurement of front-view photographs of the individual structures. Relative height to base ratios apparent from the photographs were scaled by the measured wall base lengths determined from the layout map. Consistency of the estimates was checked by comparing the dimensions of standard features, i.e., doorways, etc. Buildings made up of sections of greatly different heights were broken up

* Chin, G., Jordon, L., et al., Users' Manual for ILSS (Revised ILSLOC): Simulation for Derogation Effects on the Instrument Landing System, Final Report, No. FAA-RD-76-217, Transportation Systems Center, Cambridge MA, December 1976.

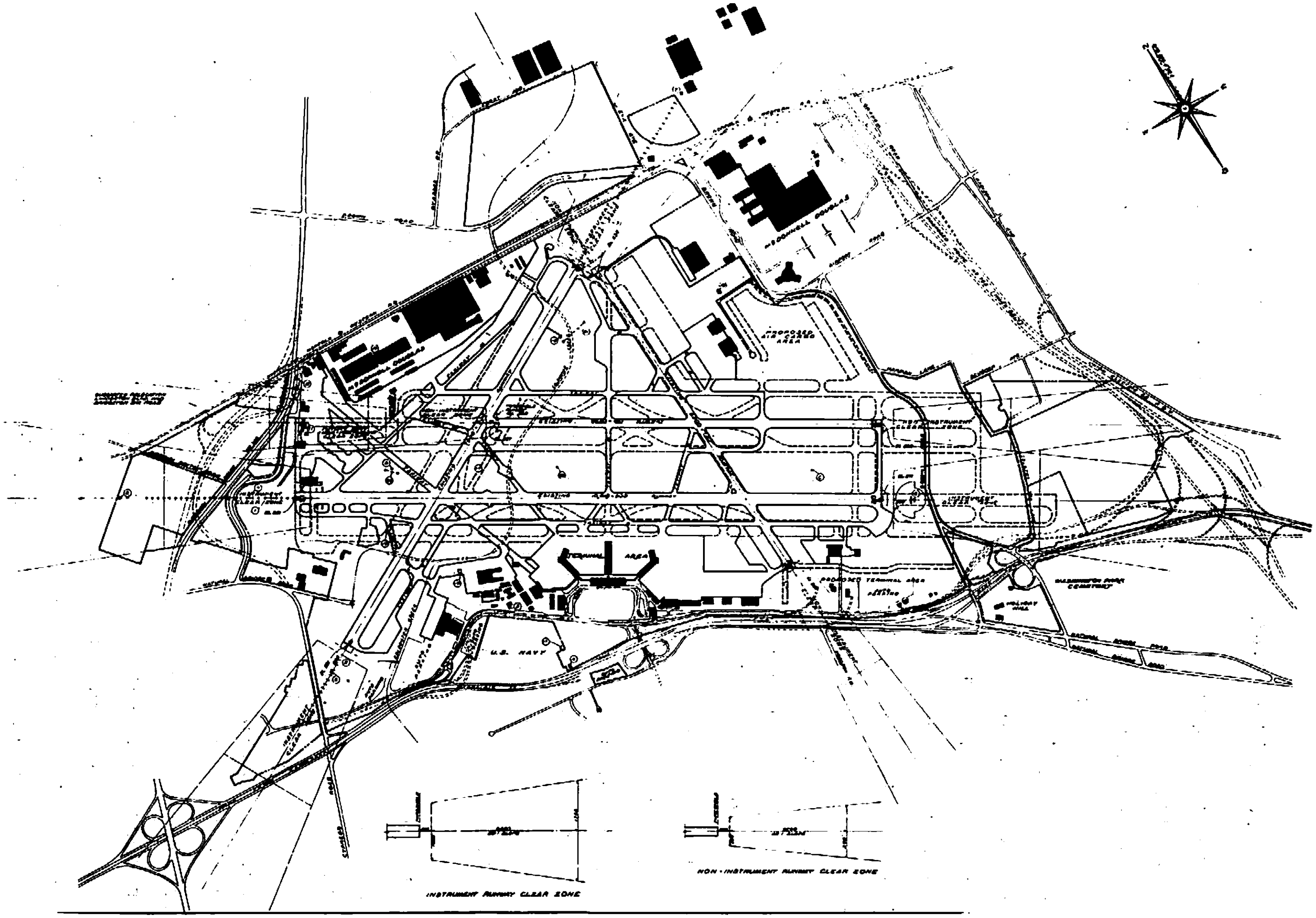


FIGURE 2. LAYOUT PLAN MAP OF ST. LOUIS AIRPORT.

FIGURE 3. LAYOUT OF MAJOR BUILDINGS NEAR ST. LOUIS AIRPORT RECONSTRUCTED BY COMPUTER FROM MEASUREMENTS OF LAYOUT PLAN MAP.

into abutting buildings, each of a distinct uniform height. During this process, a number of buildings which were considered not likely to be serious multipath contributors were eliminated from further consideration. This helped eventually to reduce the maximum length of computer runs to a manageable time limit of approximately one hour. Among the buildings retained for further analysis were: the larger buildings of the McDonnell Douglas industrial complex and headquarters, the North American Rockwell hangar, and the Main Terminal building. (See the computer reconstruction of these buildings in Figure 1.)

Input data sets for the ILSLOC computer program were prepared from the building data for six runway/localizer combinations. Runs of ILSLOC applied to these input data produced simulations of course structure to be observed along the nominal glide paths of the respective approaches. Examples of the localizer flyability curves thus obtained are shown in Figures 4, 5, and 6. An evaluative summary is given in Table 1.

The implications of these localizer simulations can be stated quite simply: the performance of a V-ring installation on either the existing or an extended Runway 12L is predicted to be satisfactory. On Runway 30R V-ring performance would not be adequate. The alternate selection of a double traveling wave array capture effect localizer (14/6 element combination) should provide acceptable Category II performance with either runway length option. Localizer flyability is predicted to be best for the extended runway.

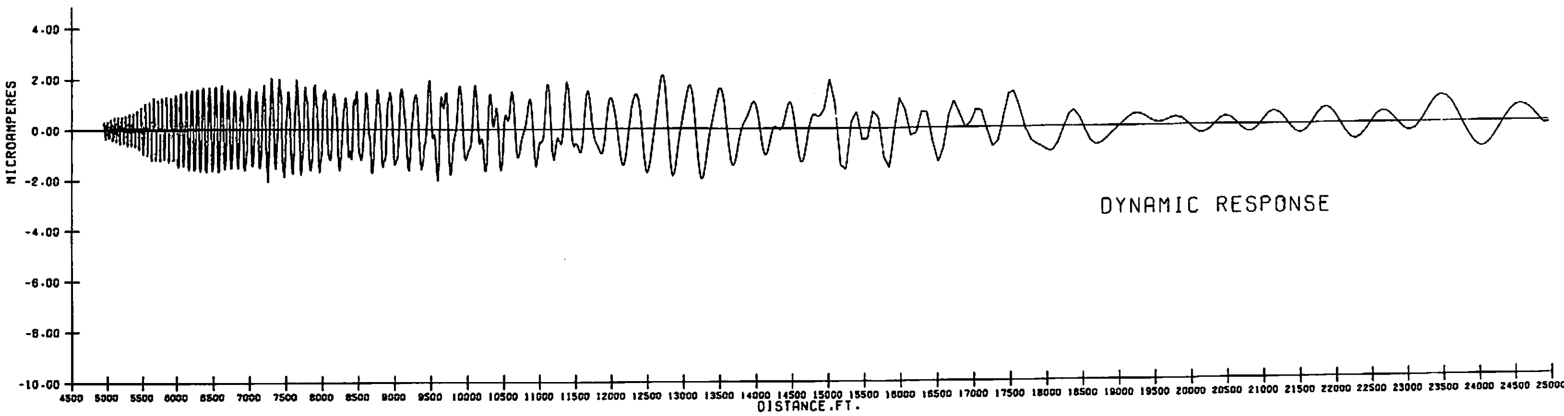


FIGURE 4A. CDI PREDICTED BY SIMULATION FOR EXISTING RUNWAY 12L AT ST. LOUIS AIRPORT WITH V-RING LOCALIZER.

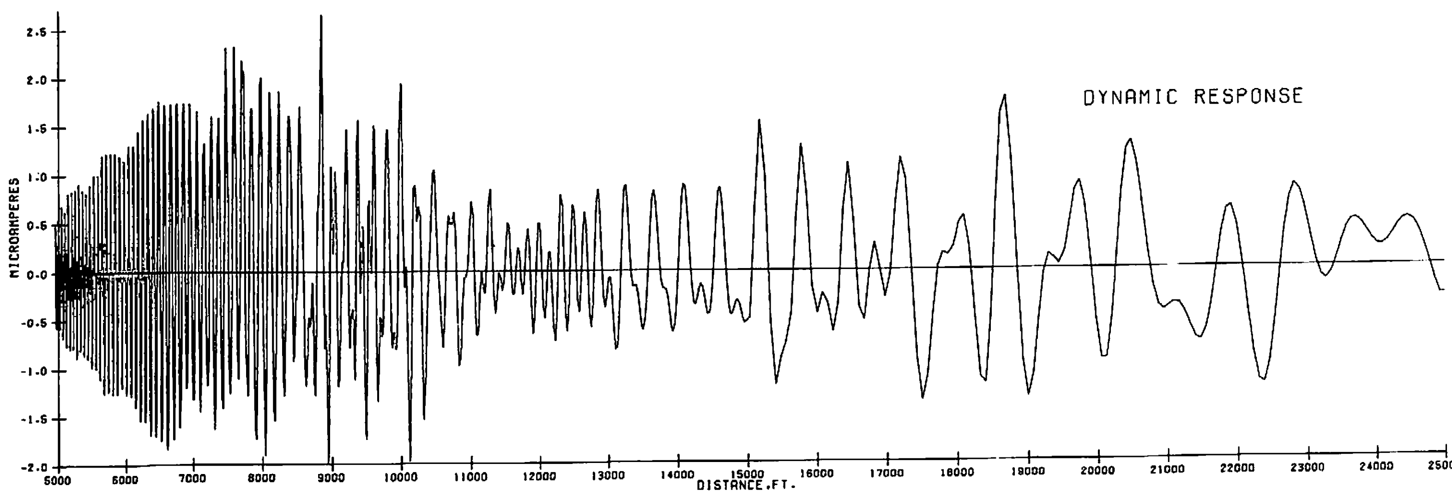


FIGURE 4B. CDI PREDICTED BY SIMULATION FOR EXTENDED RUNWAY 12L AT ST. LOUIS AIRPORT WITH V-RING LOCALIZER.

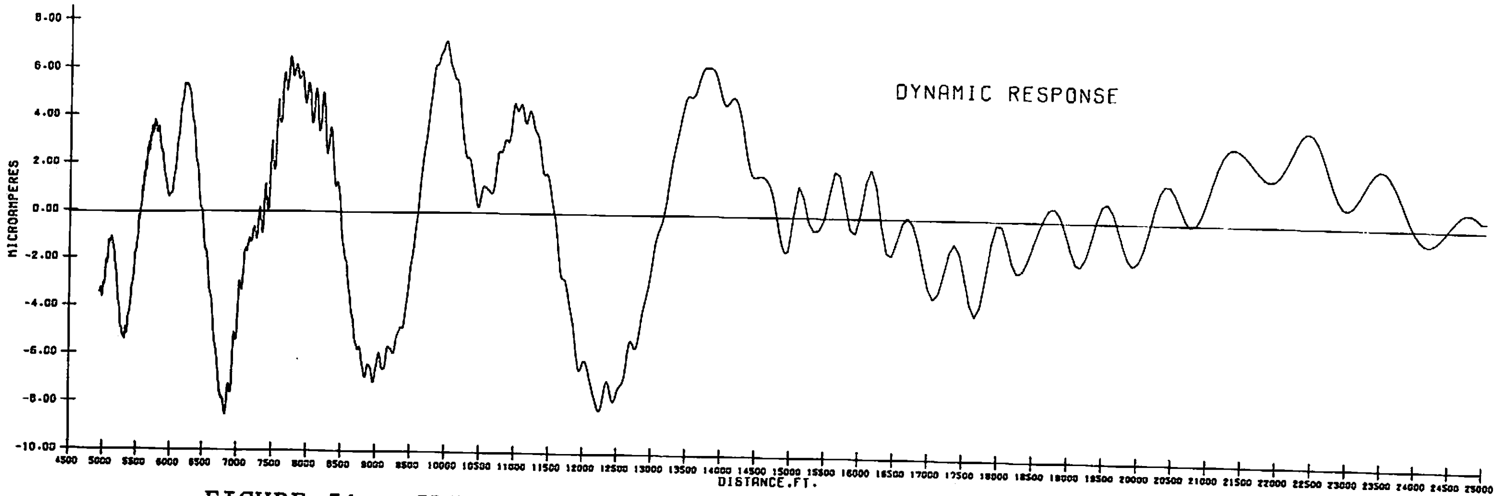


FIGURE 5A. CDI PREDICTED BY SIMULATION FOR EXISTING RUNWAY 30R AT ST. LOUIS AIRPORT WITH V-RING LOCALIZER.

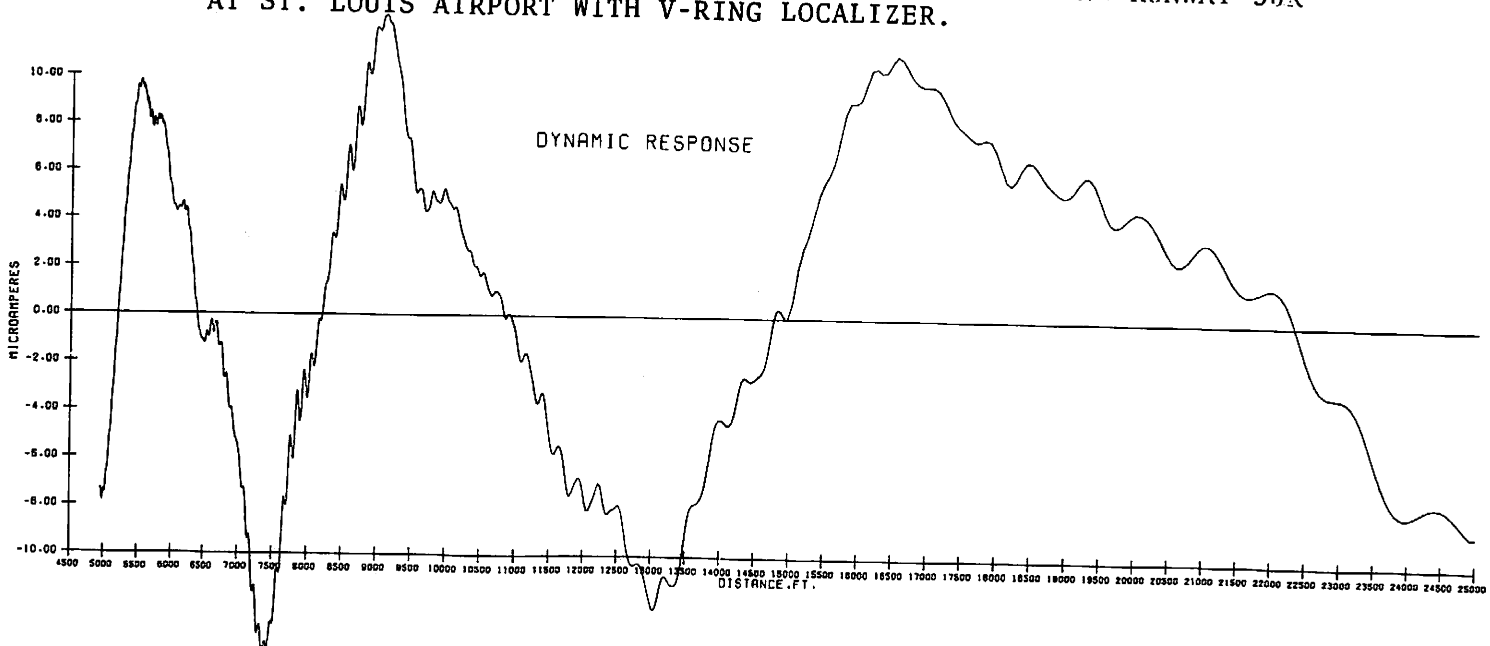


FIGURE 5B. CDI PREDICTED BY SIMULATION FOR EXTENDED RUNWAY 30R AT ST. LOUIS AIRPORT WITH V-RING LOCALIZER.

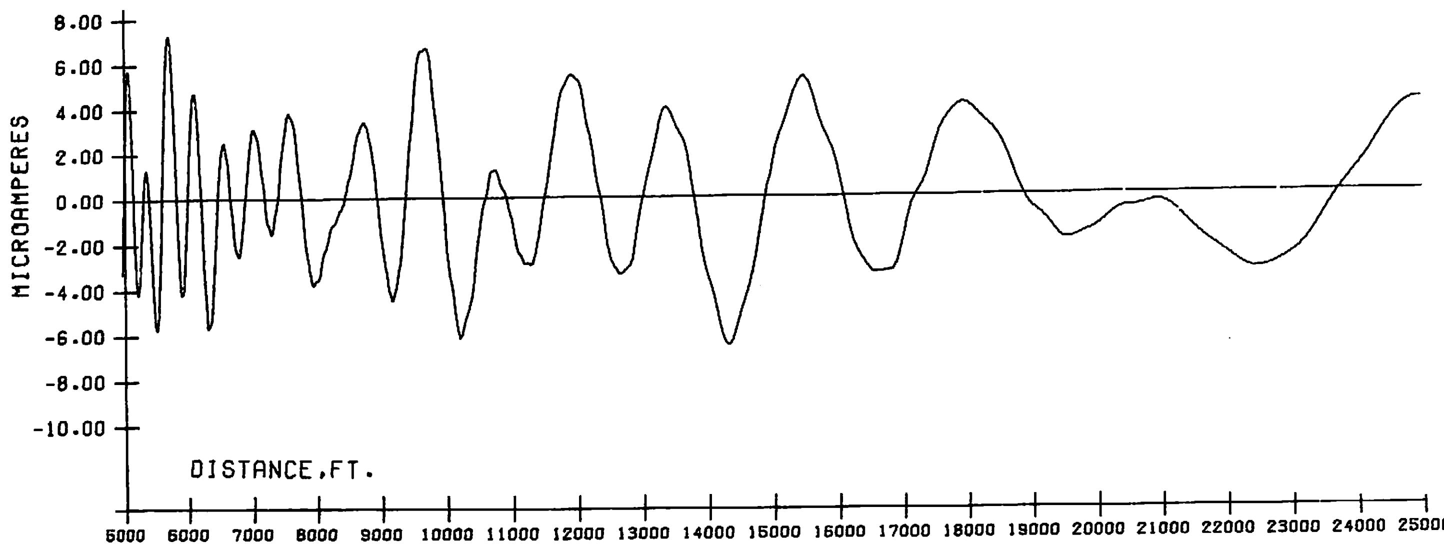


FIGURE 6A. CDI PREDICTED BY SIMULATION FOR EXISTING RUNWAY 30R AT ST. LOUIS AIRPORT WITH 14/6 ELEMENT TRAVELING WAVE LOCALIZER.

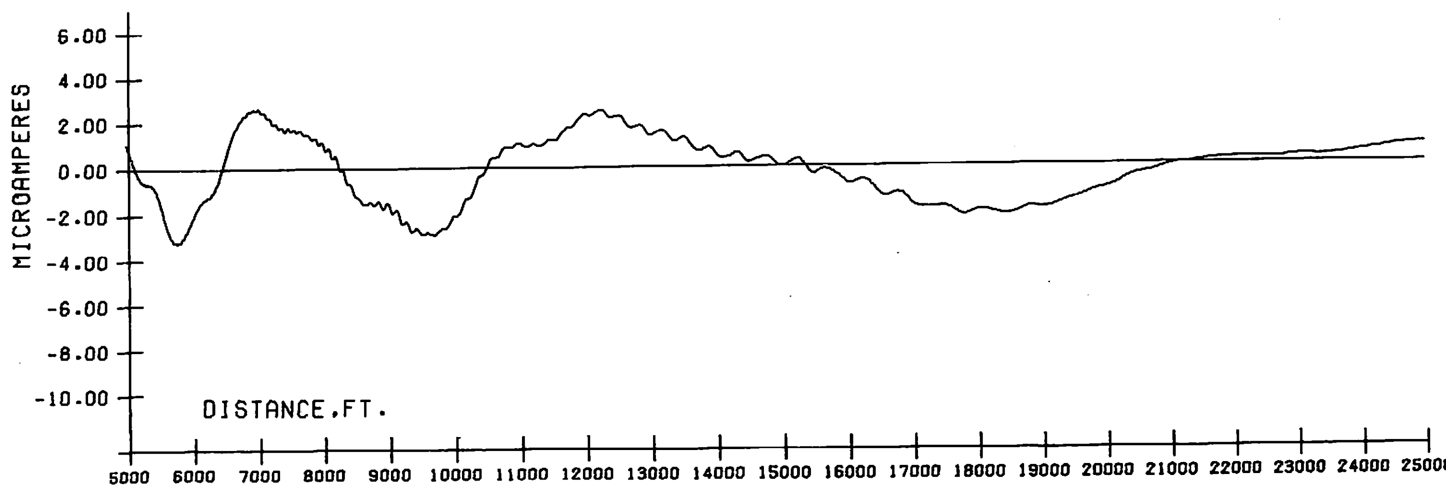


FIGURE 6B. CDI PREDICTED BY SIMULATION FOR EXTENDED RUNWAY 30R AT ST. LOUIS AIRPORT WITH 14/6 ELEMENT TRAVELING WAVE LOCALIZER.

TABLE 1. SIMULATION OF LOCALIZER PERFORMANCE ON PROPOSED RUNWAY 12L/30R AT ST. LOUIS MUNICIPAL AIRPORT.

RUNWAY	LENGTH	ANTENNA	MAX. CDI (ZONE 3)
12L	6620 feet	V-Ring	2μA
	10020 feet	V-Ring	2μA
30R	6620 feet	V-Ring	8μA
	6620 feet	TW-14/6	<7μA
	10020 feet	V-Ring	12μA
	10020 feet	TW-14/6	<3μA

3. INFLUENCE OF BUILDINGS ON THE 12L GLIDE SLOPE SIGNAL

The proximity of the McDonnell Douglas complex to proposed sites for the 12L glide slope installation and particularly the forward position of "Building 45" gave rise to concern for possible building influences on glide slope flyability. In fact, several existing smaller buildings and aircraft sheds violate the proposed instrument runway clear zone. The airport development plan calls for removal of these structures. To further alleviate the problem, consideration is being given to reconstructing the runway on a center line translated 150 feet away from the buildings which remain. To avoid possible problems of restricted taxiway use during periods of Instrument Flight Rules (IFR) weather conditions, the glide slope installation would ideally be located on the side of the runway away from the terminal building. Such a placement, however, would conflict with the desire to minimize the deleterious effects of scattering from the industrial complex.

To aid in the choice of runway side for glide slope antenna placement, simulation of expected glide slope signal scattering from the McDonnell Douglas complex was undertaken. To accomplish this, an extended version of ILSLOC, called ILSS, was developed, which has the capability of simulating all standard glide slope antenna patterns as well as any required localizer patterns. ILSS is a generalized program for estimating ILS signal scattering from buildings or other reflecting structures of limited size. Its capabilities do not include terrain scattering, which at present must be treated separately.

The ILSS program was used to simulate two cases of the performance of a narrow-beam capture effect glide slope array. In each case the array was placed 500 feet off center line at the glide path intercepts (GPI) of the existing or the extended 12L approaches, and was placed on the side away from the terminal. No ILSS simulations of cases for Runway 30R were performed since no prominent buildings are positioned so as to threaten significant interference with this glide slope approach. The results of simulations of cases for Runway 12L are summarized in Table 2 and typical examples are presented graphically in Figures 7 and 8. Note: the ILSS program simulates a straight line trajectory. Therefore these figures show a strong "fly up" signal in the region of trajectory flare.

TABLE 2. SUMMARY OF CAPTURE EFFECT GLIDE SLOPE SIGNAL SCATTERING FROM BUILDINGS.

POSITION	ZONE 3 MAXIMUM CDI ROUGHNESS
Existing Rwy 12L - Hangar side	± 5μA
- Terminal side	less than ± 5μA
Extended Rwy 12L - Hangar side	± 7μA
- Terminal side	± 5μA

Table 2 implies that no serious derogation of the 12L course due to building-scattered glide slope signals is to be expected.

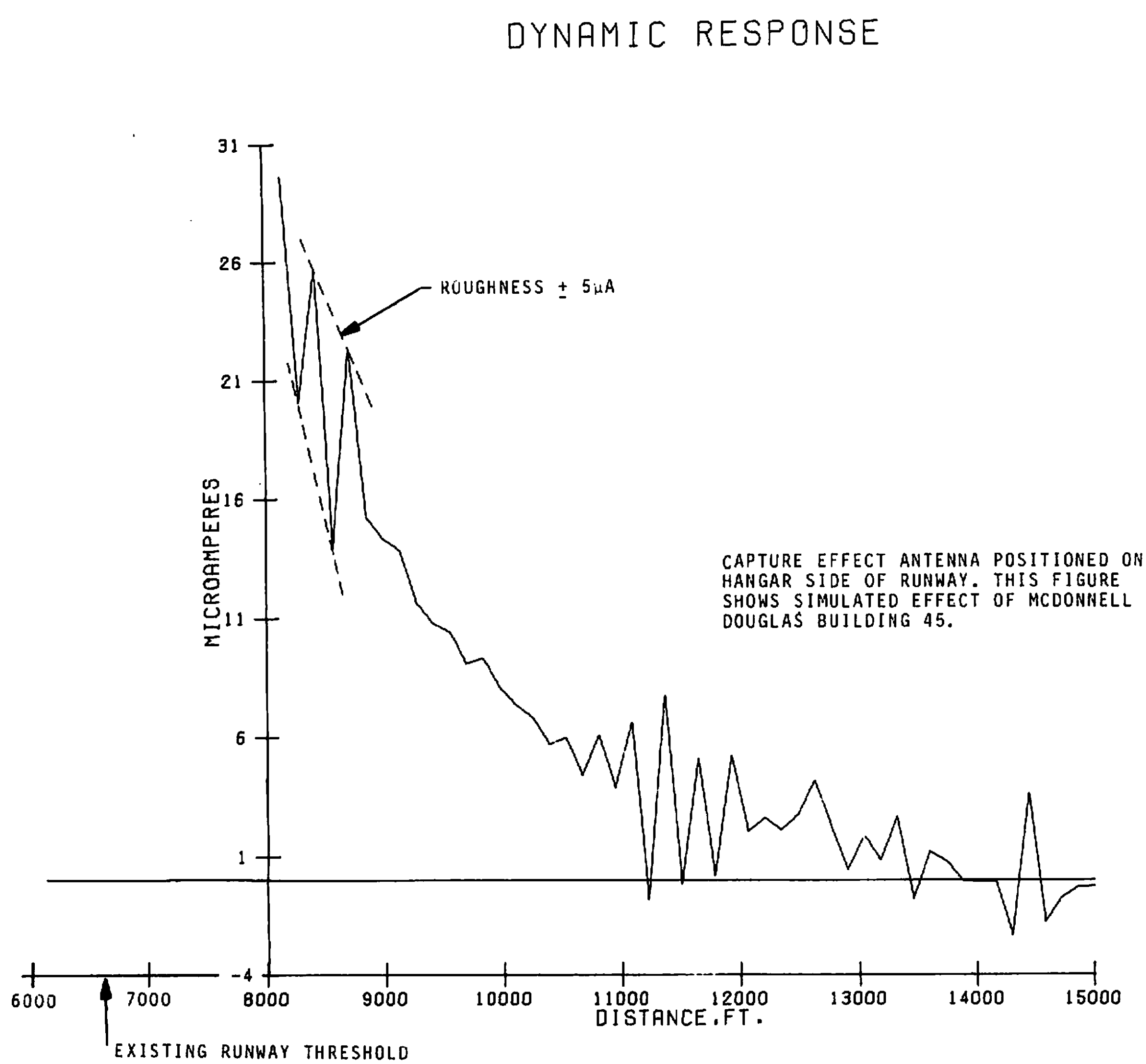


FIGURE 7. GLIDE SLOPE CDI FOR EXISTING RUNWAY 12L AT ST. LOUIS AIRPORT.

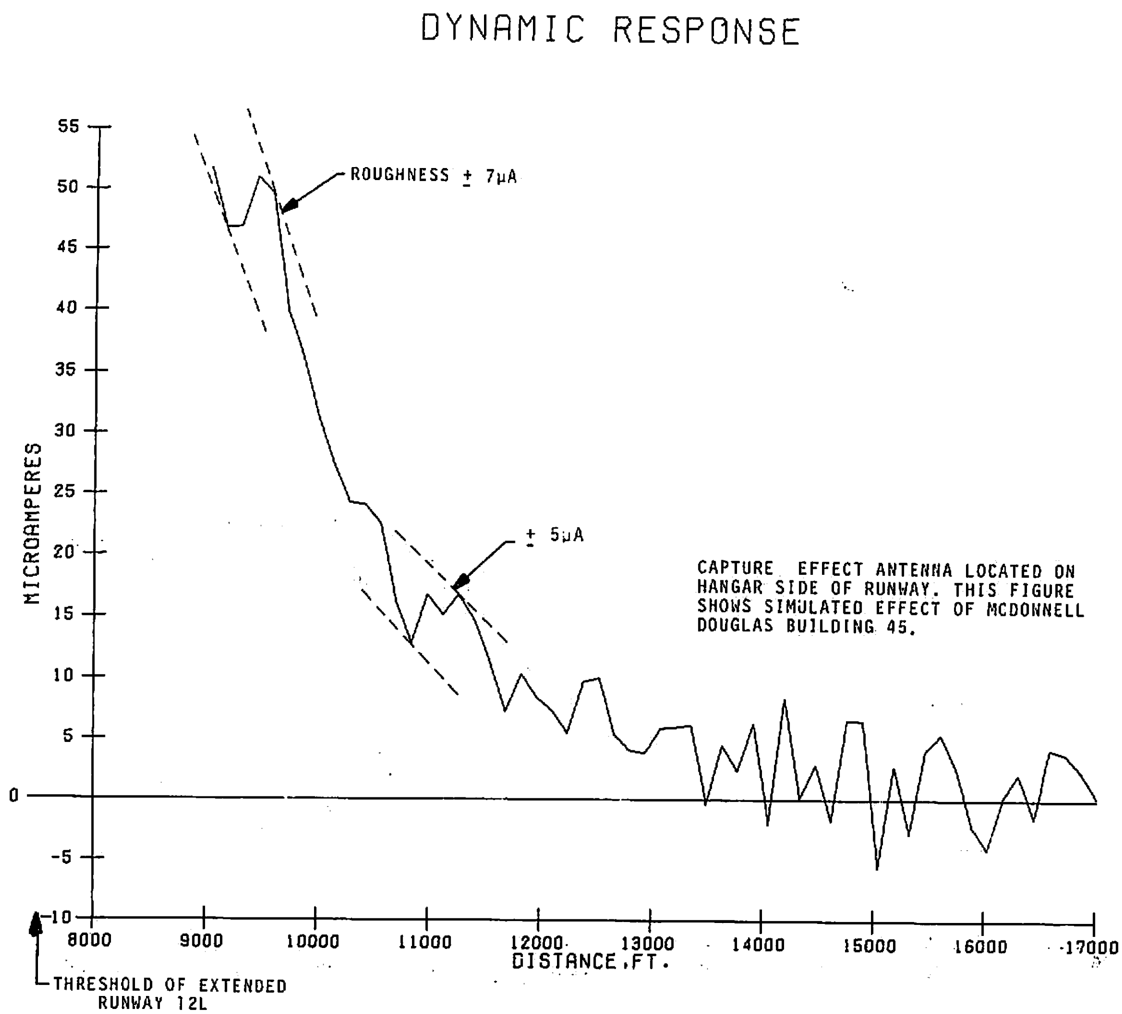


FIGURE 8. GLIDE SLOPE CDI FOR EXTENDED RUNWAY 12L AT ST. LOUIS AIRPORT.

4. GLIDE SLOPE SIGNAL SCATTERING FROM TERRAIN

Since conventional glide slope antenna systems depend on the ground plane image for formation of the on-course signal, the dominant source of GS course derogation is scattering from terrain irregularities. While the same theoretical principles apply to signal scattering from both a limited number of buildings and an irregular terrain of large extent, the estimation of signal scattering from an arbitrary irregular terrain is a computational task of much larger magnitude. As of this writing, no program is available that can simulate general terrain scattering in reasonable computer times; however, a program called "ILSGLD"* has been developed which treats a restricted "one-dimensional" case of terrain scattering efficiently.

For the one-dimensional approximation, the terrain is assumed to consist of flat strips which extend on lines of constant elevation to arbitrarily large distances perpendicular to the runway. The elevation of the surface varies then only in the direction parallel to the runway center line. Use of the one-dimensional terrain model is appropriate for simulation of glide slope signal scattering dominated by the terrain structure near the extended runway center line. This might be the case, for instance, where a narrow pattern array is used and where terrain is characterized by general slopes rather than by prominent isolated features. The views of the approach zones shown in Figure 1 give the impression that the general features of the terrain environment of the 12L-30R approaches at St. Louis Airport can be reasonably approximated by the one-dimensional model.

The input to the ILSGLD program includes a sequence of point coordinates which describe the contour of the ground over the extended center line. The region of primary interest is usually from the GPI (glide slope intercept point) to the vicinity of

*Morin, S., Newsom, D., et al., ILS Slope Performance Prediction: Version A, Final Report No. FAA-RD-74-157A, Transportation Systems Center, Cambridge MA, September 1974.

the middle marker. For the present study, inputs to ILSGLD were prepared by determining the ground elevations of 20 points on the extended center line which best approximated the profile in each approach direction. Simulations of expected glide slope course structure were obtained for several antenna siting/runway length options. The results are summarized in Table 3 and a sample plot is shown in Figure 9. Simulations of level flight course width checks were also obtained. These showed unsatisfactory bends in the cases of null reference simulation, but acceptable performance for capture effect installations.

TABLE 3. SUMMARY OF ILSGLD SIMULATION OF GLIDE SLOPE SIGNAL DEROGATION BY TERRAIN SCATTERING.

RUNWAY	ANTENNA	FINDING
12L existing	NULL REF.	± 30μA bends at 7000 ft.*
12L existing	CAP. EFF.	<±5μA bends
12L extended	NULL REF.	±30μA bends - 6k ft. to 14k ft.
12L extended	CAP. EFF.	<±5μA bends
30R existing	NULL REF.	±50μA bends
30R existing	SIDEBAND REF.	±25μA bends
30R existing	CAP. EFF.	±12μA bends at 6500 ft.
30R extended	CAP. EFF.	<3μA bends at 7000 ft.

* Distances are the projected range along the approach from the threshold.

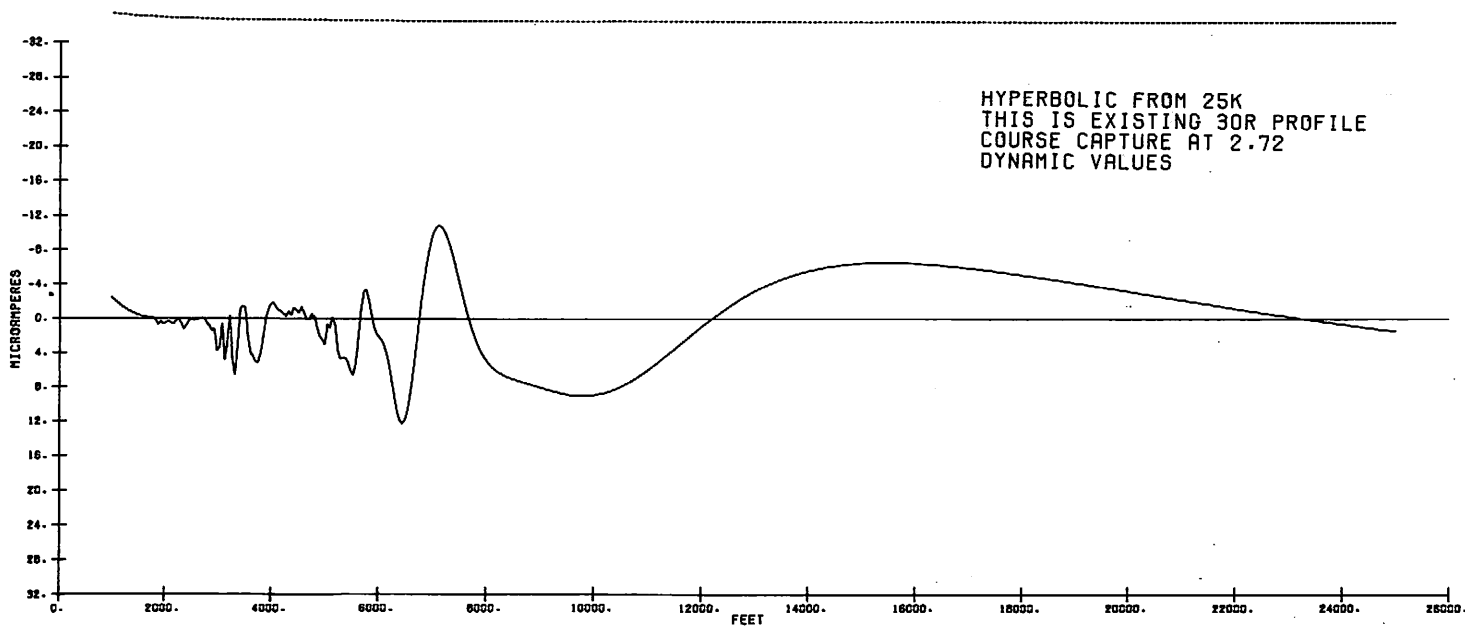


FIGURE 9. SIMULATED EFFECT OF APPROACH PATH TERRAIN ON GLIDE SLOPE SIGNAL FOR EXISTING RUNWAY 30R AT ST. LOUIS AIRPORT WITH CAPTURE EFFECT ANTENNA.

The implications of these simulations are that:

1. Satisfactory Category II performance on Runway 12L should be obtained with installation of a capture effect system.
2. Performance on the existing Runway 30R is predicted to be marginal at best for any conventional image type glide slope array with the present terrain profile. Category II performance on an extended 30R graded to meet FAA criteria should be satisfactory.

Also with additional grading, satisfactory Category II performance should be obtained on the existing Runway 30R as well. Examples of satisfactory grading were not tested because of lack of budget and time.

APPENDIX

MODEL VALIDATION FOR HANCOCK AIRPORT, SYRACUSE, NEW YORK

For purposes of validating the localizer model, TSC obtained a set of flight recordings for Hancock Airport at Syracuse, New York, showing the results of inspections conducted during 1971 and 1972.

At that time, Hancock Airport had a Category I Eight - Loop Localizer on Runway 28 operating with a nominal 4° course width and elevated 19 feet above ground level at its location 2000 feet beyond the end of the runway. The Localizer was used as the origin for the location of airport structures in the model. The airport structures in the vicinity of Runway 28 are shown in Figure A1. All structures used in the model validation study, some two dozen buildings, are delineated in Figure A1 by the different numbers assigned to them. Based on the sizes and locations of these reflecting structures, the model predicted a course deviation indication (CDI) on the runway center line as shown in Figure A2, where the flight recorded and theoretical CDI's are compared. For the theoretical model the aircraft was assumed to be on a glide path of 2.5°, the antenna course width was taken as 3.64° (FAA specs) and the antenna height as 12 feet (which is an approximation to account for the bulge in the runway ahead of the actual 19-foot antenna elevation).

Theoretical and flight test data are in good agreement in both the magnitude and phase of the derogation, (Figure A2). The validation could have been more precise had we known how far off center line the pilot actually flew (the theoretical results are presented for a center line flight only), whether hangar doors were open, partially open or closed during the flight test (the theoretical results are for the conservative case of closed hangar doors) and the precise speed of the aircraft*. Therefore, it is recommended that for future validation studies these kinds of information be obtained and recorded.

* In Figure A2, the middle marker location, 14,250 feet, on the theoretical and on the flight data graphs was lined up. If the aircraft had maintained a constant speed of 200 ft./sec., all other points on the two graphs would also have lined up. They do not and therefore precise comparison of the phase of the derogation is not directly possible.

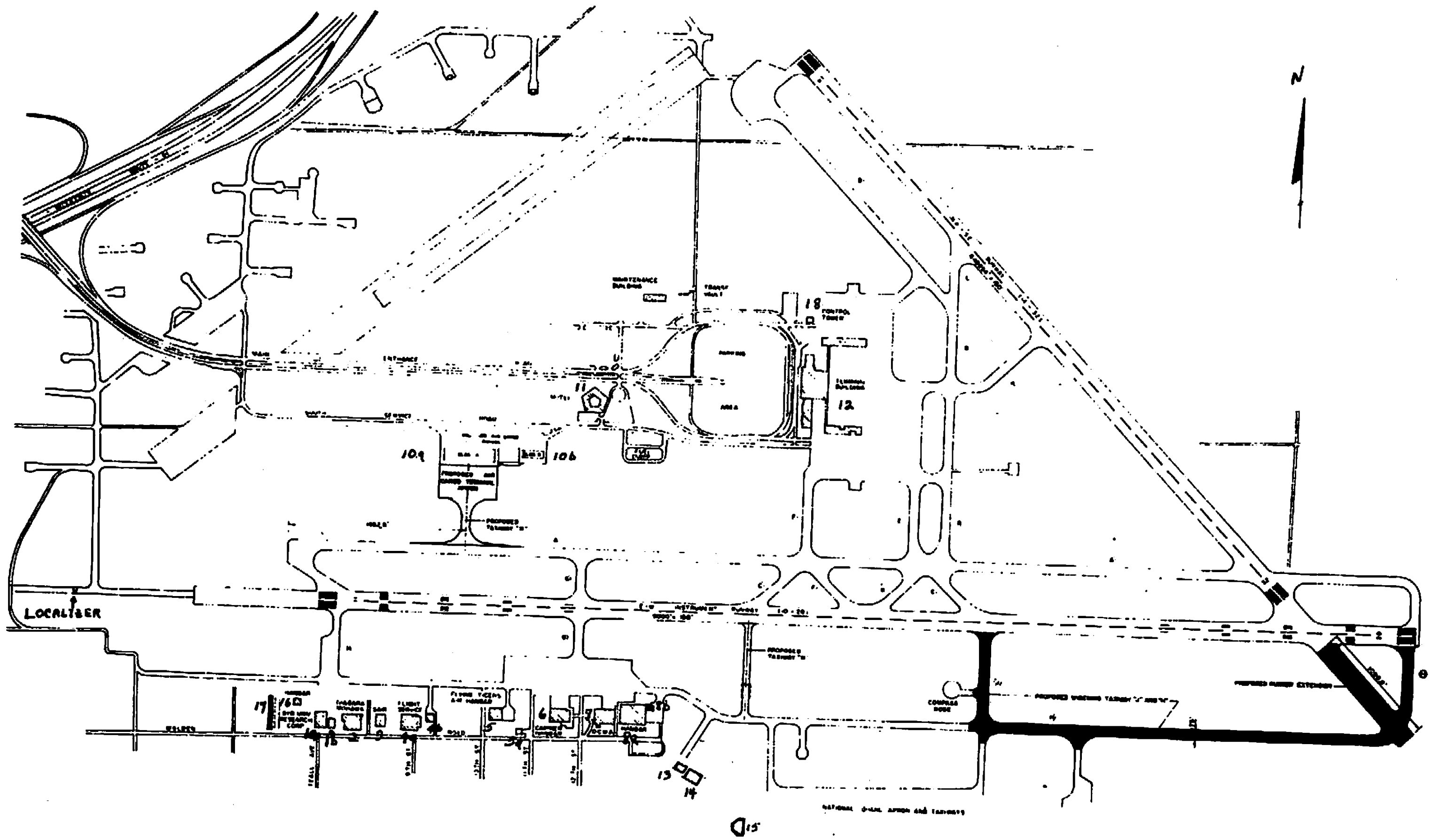


FIGURE A1. AIRPORT STRUCTURES IN VICINITY OF RUNWAY 28. ALL STRUCTURES USED IN MODEL VALIDATION STUDY ARE NUMBERED FOR IDENTIFICATION.

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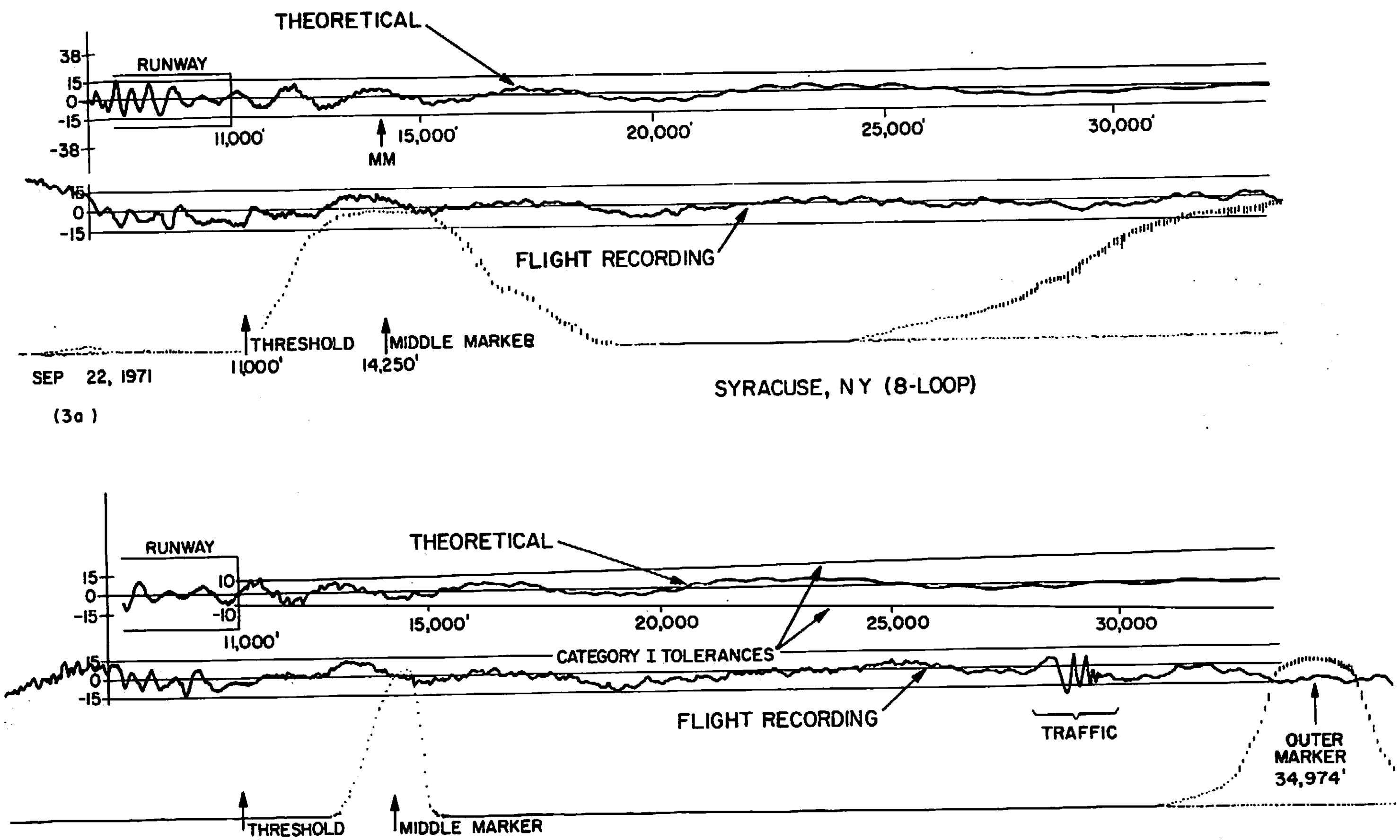

Jan 8, 1972

FIGURE A2. CDI PREDICTED BY SIMULATION FOR RUNWAY CENTERLINE.

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U. S. DEPARTMENT OF TRANSPORTATION
518