TECHNICAL DEVELOPMENT REPORT NO. 239

DYNAMIC-SIMULATION TESTS OF SEVERAL TRAFFIC CONTROL SYSTEMS FOR THE FORT WORTH-DALLAS TERMINAL AREA

FOR LIMITED DISTRIBUTION

by

Clair M. Anderson
and
Tirey K. Vickers

Navigational Aids Evaluation Division

August 1954

CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS, INDIANA

DYNAMIC-SIMULATION TESTS OF SEVERAL TRAFFIC CONTROL SYSTEMS FOR THE FORT WORTH-DALLAS TERMINAL AREA

SUMMARY

This report describes the evaluation of several proposed methods for improving the flow of air traffic in the Fort Worth-Dallas terminal area. The investigation was conducted at the Technical Development and Evaluation Center through the use of the dynamic air traffic control simulator.

Tests simulated the operation of the Fort Worth and Dallas Air Route Traffic Control sectors simultaneously with the operation of approach control for the five major airports in the area. Comparative tests comprising 2800 aircraft operations were made, with and without radar, at traffic loads up to 55 per cent higher than the presently encountered traffic peaks. These tests pointed out several methods of simplifying the control of the most difficult local traffic problem; namely, the operation of shuttle flights between Carter and Love Fields. Other tests showed that the flow of terminal area and en route traffic could be improved considerably by the relocation of certain radio aids to establish additional independent flight routes and new jet approach procedures.

Recommendations include a step-by-step plan for the implementation of various changes to take care of future increases in traffic demand.

INTRODUCTION

The new airport known as Amon Carter Field was originally planned as a joint Fort Worth-Dallas terminal airport, and was located slightly east of the midpoint between the two cities. As originally conceived, the idea of a single airline terminal serving both cities was intended to simplify the local air traffic problem by eliminating the necessity for separate stops at each city. However, active support of the joint airport idea was withdrawn by Dallas interests before the new airport was completed.

When Amon Carter Field was commissioned in the spring of 1953, scheduled Fort Worth air carrier operations were transferred from Meacham Field to the new airport. However, because of legal and political reasons sustained by Dallas civic pride, air carriers were still required to furnish service to Love Field. Thus the local traffic problem was not simplified after all. Instead, the new situation made the problem even more complex, because air carriers had to serve two major terminals which were only 12 miles apart, instead of 30 miles as before. The resulting congestion greatly increased traffic delays during IFR (Instrument Flight Rules) conditions. Shuttle operations became a major problem. During IFR conditions, shuttles sometimes took as long as an hour and a quarter to make the 12-mile trip, being forced up to altitudes as high as 7000 feet during the process.

Besides Amon Carter and Love Field, the local terminal area includes three other major airports: Hensley Field (Navy), Carswell Field (Air Forces), and Meacham Field (Municipal). IFR traffic operations are handled by three approach control towers: Love, Amon Carter, and Meacham. These Agencies control all IFR altitude levels up to 5,000 feet MSL inclusive. Altitudes of 6,000 feet and above are controlled by the Fort Worth Air Route Traffic Control Center. With this arrangement, coordination between the various air traffic control agencies becomes a major bottleneck to IFR traffic flow. For example, westbound flights from Love Field or eastbound flights from Meacham may require coordination between all four agencies before takeoff.

In the fall of 1953, the Office of Federal Airways requested the Technical Development and Evaluation Center to conduct a study of the Fort Worth-Dallas traffic problem. Two TDEC air traffic control specialists spent several days at Fort Worth and Dallas, conferring with regional airways operations personnel and gathering first-hand data on the problems. Subsequently, one air traffic control specialist from the Dallas (Love Field) airport traffic control tower and another from the Fort Worth air route traffic control center were detailed to TDEC to assist in setting up and conducting the simulation tests.

The primary objective of the simulation program was to develop methods of increasing the IFR traffic capacity of the terminal area. Consideration was given to the following specific items:

1. Simplification of flight paths to remove as many built-in bottlenecks as possible.

2. Simplification of control procedures to reduce the amount of coordination between agencies and to minimize the amount of controller work load per aircraft operation.

3. Development of procedures which would serve at least two directions of operation at each major airport, and which would continue to function satisfactorily in the event of partial or complete radar failure.

4. Evaluation of various arrangements of radar equipment, including separate surveillance radars at Love and Amon Carter, as well as combined area operations from a single facility.

5. Investigation of the effect of certain changes in the arrangement of terminal area navigation facilities. Changes included the proposed relocation of the Fort Worth VOR, the establishment of an additional VOR, and the possible relocation of certain H facilities and fan markers in order to accomplish the objectives of items 1, 2, and 3 above.

SIMULATION METHODS

Traffic Samples.

Abbreviations used in traffic samples are listed in Table I. Flight progress strips were obtained from the Fort Worth Center, Love tower, and Amon Carter tower, to cover a recent typical day of IFR operations. These records were analyzed to determine the period of heaviest traffic flow in the Fort Worth-Dallas Terminal Area. A 2-1/2 hour peak period, extending from approximately 0830 to 1100 CST, was selected to form the input for the first traffic problem tested. Details of this actual traffic sample, known as Sample 1, are listed in Table II.

Sample 1 had a traffic density of only 30 operations per hour for the entire terminal area. When run through the simulator, this was hardly enough traffic to load the system to the point where system bottlenecks became apparent. Therefore, a number of additional aircraft, comprising 18 operations, were added to the original sample. The new sample, known as Sample 2, is detailed in Table III.

While testing various shuttle procedures, it became desirable to have a somewhat shorter sample with a fairly high density of shuttle flights. For this purpose, the last part of Sample 2 was dropped; the first 61 flights of Sample 2, including 17 shuttle flights, were used. This sample was known as Sample 2B.

In order to demonstrate how the traffic problem could be simplified if shuttle flights were eliminated, another sample was constructed by omitting all shuttles from Sample 2. The resulting sample was known as Sample 2 A.

One consideration in running these simulation tests was to obtain a maximum amount of significant information about the flow characteristics of the various systems in a minimum number of working hours. Since potential bottlenecks are not as apparent in light traffic conditions, it was desirable to test the various systems in sustained heavy traffic. In order to maintain a heavier traffic density throughout the test period, a number of flights comprising 25 operations were added to the lighter periods of Sample 2. The new sample, known as Sample 3, is detailed in Table IV.

The actual traffic sample obtained from the original flight progress strips contained a number of flights which passed through the terminal area without landing. These flights were run through the system whenever the Fort Worth Center was simulated in the tests to build up the center sector work loads to a reasonable figure. Details of these flights are listed in Table V.

To test the feasibility of proposed jet letdown and departure procedures, several jet flights were inserted into Sample 3. Details of these entries are listed in Table VI.

TABLE I

Legend for All Traffic Samples

AIRCRAFT IDENTIFICATIONS

A - American Airlines
AF - Air Force
AJ - Central Airlines
D - Delta Airlines
PA - Pioneer Airlines
TT - Trans-Texas Airlines
V - Navy
X - Civilian

OPERATIONS

A - Arrival
D - Departure
S - Shuttle

AIRCRAFT TYPES AND CHARACTERISTICS

DESIGNATION	SPEEDS (MPH)			CLIMB OR DESCENT RATE (FPM)
	CRUISE	INTERMEDIATE	APPROACH	
S - Slow	180	150	120	500
M - Medium	240	190	140	1000
F - Fast	290	220	150	1000
J - Jet	400	290	180	3000

From/To:

ABI Abilene, Texas
ABQ Albuquerque, New Mexico
ACF Amon Carter Field
ACT Waco, Texas
AMA Amarillo, Texas
ARD Ardmore, Oklahoma
AUS Austin, Texas
BAD Barksdale Field, Louisiana
BWD Brownwood, Texas
DAL Love Field
ELM Little Elm, Texas
ELP Elpaso, Texas
EVV Evansville, Indiana
FNY Forney, Texas
FRS Fort Worth Range Station
FTW Meacham Field
FWH Carswell Field
GVT Greenville, Texas
HNY Hensley Field
HOU Houston, Texas
ICH Wichita Falls, Texas
JUS Justin, Texas
LAX Los Angeles, California
LGA LaGuardia Airport, New York
LIT Little Rock, Arkansas
MAF Midland, Texas
MIV Millville, New Jersey
MKC Kansas City, Missouri
MSY New Orleans
OKC Oklahoma City, Oklahoma
PRX Paris, Texas
RSW Roswell, New Mexico
SHV Shreveport, Louisiana
WEB Webb, Texas
WXE Waxahachie, Texas
WYL Wylie, Texas

TABLE II

SAMPLE 1

AIRCRAFT IDENTIFI-CATION	AIRCRAFT TYPE	OPERATION	FROM FIX	FROM TIME	TO	AIRCRAFT IDENTIFI-CATION	AIRCRAFT TYPE	OPERATION	FROM FIX	FROM TIME	TO
PA61	S	A	WXE	0832	DAL	B94	M	D	DAL	0952	AMA
X57B	S	D	FTW	0838	OKC	B15	M	S	DAL	0956	ACF
A100	F	S	ACF	0841	DAL	T142	S	A	FRS	0956	ACF
AJ32	S	S	FTW	0842	ACF	A100	F	D	DAL	0958	LGA
X7996	S	A	WYL	0842	DAL	AJ32	S	D	DAL	1005	PRX
A842	M	A	FRS	0846	DAL	D310	S	D	DAL	1007	SHV
A499	M	A	ELM	0852	DAL	AF2400	F	D	FWH	1008	RSW
B21	M	D	DAL	0849	AUS	PA42	S	S	ACF	1008	DAL
B25	F	D	DAL	0852	HOU	B28B	M	D	ACF	1011	SPS
B669	F	D	ACF	0854	ARD	AF1806	S	D	DAL	1013	FWH
AF8008	S	D	HNY	0858	ELP	AF4246	M	A	WXE	1012	FWH
AF1674	S	D	FWH	0901	ELP	A499	M	S	DAL	1016	ACF
TT50	S	A	FNY	0902	DAL	A402	M	S	ACF	1017	DAL
A222	F	S	ACF	0903	DAL	AJ21	S	A	JUS	1020	ACF
B803	F	D	DAL	0908	HOU	PA61	S	S	DAL	1021	ACF
AJ32	S	S	ACF	0909	DAL	TT42	S	S	ACF	1024	DAL
D908	F	D	DAL	0903	MSY	AF9994	S	D	FWH	1024	BAD
AF1820	S	D	HNY	0918	AMA	TT41	S	S	DAL	1025	ACF
X54D	S	D	FTW	0920	BWV	D307	S	A	FNY	1030	DAL
AF0140	M	A	WXE	0920	FTW	B15	M	D	ACF	1031	ACT
X2916B	S	D	DAL	0924	HOU	B678	M	D	DAL	1032	OKC
X22T	S	S	FTW	0926	DAL	A484	M	D	DAL	1035	OKC
B28B	M	S	DAL	0927	ACF	A111	F	D	ACF	1036	ELP
A484	M	S	ALF	0929	DAL	B325	M	D	DAL	1040	HOU
PA42	S	A	FRS	0932	ACF	D125X	S	A	FNY	1041	DAL
A841	M	D	DAL	0936	LAX	X1666	M	D	DAL	1048	MIV
B20	F	D	DAL	0950	MKC	A499	M	D	ACF	1053	MAF
B28	M	A	WXE	0943	DAL	PA61	S	D	ACF	1058	ABl
B747	F	D	DAL	0944	OKC	TT41	S	D	ACF	1100	BWD
AF8018	S	S	FTW	0945	DAL	X7996	S	D	DAL	1103	AMA
AF8780	S	A	FNY	0946	FWH	D307	S	S	DAL	1107	ACF
						A402	M	D	DAL	1107	LIT

TABLE III

Details of Sample 2, 2A, and 2S

AIRCRAFT IDENTIFICATION	TYPE	OPERATION	SAMPLE 2 FROM		TO	OPERATION	SAMPLE 2A FROM		TO
			FIX	TIME			FIX	TIME	
PA61	S	A	WXE	0832	DAL	A	WXE	0832	DAL
X57B	S	D	FTW	0838	OKC	D	FTW	0838	OKC
A100	F	S	ACF	0841	DAL				
AJ32	S	S	FTW	0842	ACF				
X7996	S	A	WYL	0842	DAL	A	WYL	0842	DAL
B30	M	A	WXE	0845	DAL	A	WXE	0845	DAL
A842	M	A	JUS	0846	DAL	A	JUS	0846	DAL
A499	M	A	ELM	0852	DAL	A	ELM	0852	DAL
B21	M	D	DAL	0849	AUS	D	DAL	0849	AUS
B25	F	D	DAL	0852	HOU	D	DAL	0852	HOU
B669	F	D	ACF	0854	ADM	D	ACF	0854	ADM
A479	F	A	ELM	0856	DAL	A	ELM	0856	DAL
AF8008	S	D	HNY	0858	ELP	D	HNY	0858	ELP
AF1674	S	D	FWH	0901	ELP	D	FWH	0901	ELP
TT50	S	A	FNY	0902	DAL	A	FNY	0902	DAL
A222	F	S	ACF	0903	DAL				
B403	F	D	DAL	0908	HOU	D	DAL	0908	HOU
AJ32	S	S	ACF	0909	DAL	D	ACF	0909	
D908	F	D	DAL	0913	MSY	D	DAL	0913	MSY
AF1820	S	D	HNY	0918	AMA	D	HNY	0918	AMA
B30	M	S	DAL	0920	ACF	D	DAL	0920	
X540	S	D	FTW	0920	EVV	D	FTW	0920	EVV
AF0140	M	A	JSH	0919	FTW	A	JSH	0919	FTW
A655	M	A	WYL	0921	ACF	A	WYL	0921	ACF
X916B	S	D	DAL	0924	HOU	D	DAL	0924	HOU
X9000	S	A	PLO	0925	HNY	A	PLO	0925	HNY
X22T	S	S	FTW	0926	DAL				
B28B	M	S	DAL	0927	ACF	D	DAL	0927	ICH
B600	F	A	JUS	0928	DAL	A	JUS	0928	DAL
A484	M	S	ACF	0929	DAL	D	ACF	0929	OKC
A479	F	S	DAL	0930	ACF	D	DAL	0930	ACT
PA42	S	A	FRS	0932	ACF	A	FRS	0942	ACF
A800	F	A	FNY	0935	DAL	A	FNY	0935	DAL
A841	M	D	DAL	0936	LAX	D	DAL	0936	LAX
PA42	F	A	FRS	0939	ACF	A	FRS	0939	ACF
B20	F	D	DAL	0940	OKC	D	DAL	0940	OKC
B28	M	A	WXE	0943	DAL	A	WXE	0943	DAL
B747	F	D	DAL	0944	OKC	D	DAL	0944	OKC

AF8018	S	S	FTW	0945	DAL				
AF8780	S	A	FNY	0946	FWH	A	FNY	0946	FWH
AF1000	S	A	FNY	0948	HNY	A	FNY	0948	HNY
B94	M	D	DAL	0952	AMA	D	DAL	0952	AMA
B15	M	S	DAL	0956	ACF	D	DAL	0956	ACT
TT42	S	A	FRS	0956	ACF	A	FRS	0956	ACF
A100	F	D	DAL	0958	LGS	D	DAL	0958	LGA
B30	M	D	ACF	1000	OKC	D	ACF	1000	OKC
A655	F	D	ACF	1003	SAT	D	ACF	1003	SAT
AJ32	S	D	DAL	1005	PRX	D	DAL	1005	PRX
D310	S	D	DAL	1007	SHV	D	DAL	1007	SHV
AF2400	F	D	FWH	1008	ROS	D	FWH	1008	ROS
DA42	S	S	ACF	1008	DAL				
A479	F	D	ACF	1010	ACT				
B29B	M	D	ACF	1011	ICH				
PA62	F	S	ACF	1012	DAL	D	ACF	1012	ACT
AF806	S	D	DAL	1013	ABQ	D	DAL	1013	ABQ
AF4246	M	A	DCV	1027	FWH	A	DCV	1027	FWH
A499	M	S	DAL	1016	ACF	D	DAL	1016	MAF
A402	M	S	ACF	1017	DAL	D	ACF	1017	LIT
AJ21	S	A	JUS	1020	ACF	A	JUS	1020	ACF
PA61	S	S	DAL	1021	ACF	D	DAL	1021	AB1
* TT42	S	S	ACF	1024	DAL				
AF994	S	D	FWH	1024	BAD	D	FWH	1024	BAD
TT41	S	S-	DAL	1025	ACF	D	DAL	1025	BWD
D307	S	A	FNY	1030	DAL	A	FNY	1030	DAL
B15	M	D	ACF	1031	ACT				
B678	M	D	DAL	1032	OKC	D	DAL	1032	OKC
A484	M	D	DAL	1035	OKC				
A111	F	D	ACF	1036	ELP	D	ACF	1036	ELP
B325	M	D	DAL	1040	HOU	D	DAL	1040	HOU
D125X	S	A	FNY	1041	DAL	A	FNY	1041	DAL
X1666	M	D	DAL	1048	MIV	D	DAL	1048	MIV
PA62	F	D	DAL	1050	ACT	D	DAL	1050	ACT
A499	M	D	ACF	1053					
PA61	S	D	ACF-	1058	AB1				
TT41	S	D	ACF	1100	BWD	D	ACF	1100	BWD
X7996	S	D	DAL	1103	AMA	D	DAL	1103	AMA

* Sample 2S included all Sample 2 traffic down to this point only

TABLE IV SAMPLE 3

ACFT IDENT	TYPE	OP'N	FROM FIX	FROM TIME	TO	ACFT IDENT	TYPE	OP'N	FROM FIX	FROM TIME	TO
PA61	S	A	WXE	0832	DAL	A100	F	D	DAL	0958	LGA
AJ2	S	S	FTW	0835	ACF	B30	M	D	ACF	1000	OKC
X57B	S	D	FTW	0838	OKC	A910	F	S	DAL	1000	ACF
TT60	S	S	FTW	0838	DAL	A655	F	D	ACF	1003	SAT
AJ32	S	S	FTW	0842	ACF	AJ32	S	D	DAL	1005	PRX
X7996	S	A	WYL	0842	DAL	D310	S	D	DAL	1007	SHV
B30	M	A	WXE	0845	DAL	AF2400	F	D	FWH	1008	ROS
A842	M	A	JUS	0846	DAL	PA42	S	S	ACF	1008	DAL
A499	M	A	ELM	0852	DAL	A479	F	D	ACF	1010	ACT
B21	M	D	DAL	0849	AUS	B29B	M	D	ACF	1011	ICH
B25	F	D	DAL	0852	HOU	PA62	F	S	ACF	1012	DAL
B669	F	D	ACF	0854	ADM	AF806	S	D	DAL	1013	ABQ
A749	F	A	ELM	0856	DAL	AF4246	M	A	DCV	1016	FWH
AF8008	S	D	HNY	0858	ELP	A499	M	S	DAL	1016	ACF
AF1674	S	D	FWH	0901	ELP	A602	M	S	ACF	1017	DAL
TT50	S	A	FNY	0902	DAL	AJ21	S	A	JUS	1020	ACF
A222	F	S	ACF	0903	DAL	A479	F	A	ELM	1020	DAL
B403	F	D	DAL	0908	HOU	PA61	S	S	DAL	1021	ACF
A111	F	A	JUS	0908	DAL	TT42	S	S	ACF	1024	DAL
AJ32	S	S	ACF	0909	DAL	AF994	S	D	FWH	1024	BAD
D908	F	D	DAL	0913	MSY	TT41	S	S	DAL	1025	ACF
AF1820	S	D	HNY	0918	AMA	D315	M	A	FNY	1027	DAL
B30	M	S	DAL	0920	ACF	D307	S	A	FNY	1030	DAL
C540	S	D	FTW	0920	EVV	B15	M	D	ACF	1031	ACT
AF0140	M	A	JSH	0922	FTW	B678	M	D	DAL	1032	OKC
A655	F	A	WYL	0921	ACF	A910	F	S	ACT	1033	DAL
X916B	S	D	DAL	0924	HOU	A484	M	D	DAL	1035	OKC
X9000	S	A	PLO	0924	HNY	AF622	S	A	WYL	1035	HNY
X22T	S	S	FTW	0926	DAL	A111	F	D	ACF	1036	ELP
B28B	M	S	DAL	0927	ACF	B38	M	A	FRS	1036	ACI
B600	F	A	JUS	0928	DAL	B325	M	D	DAL	1040	HOU
A484	M	S	ACF	0929	DAL	D125X	S	A	FNY	1041	DAL
A479	F	S	DAL	0930	ACF	A208	F	A	ELM	1041	DAL
PA42	S	A	FTW	0932	ACF	X1666	M	D	DAL	1048	MTV
A800	F	A	FNY	0935	DAL	PA62	F	D	DAL	1052	ACT
A841	M	D	DAL	0936	LAX	D315	M	S	DAL	1050	ACF
PA62	F	A	JUS	0939	ACF	A499	M	D	ACF	1053	MAF
A900	F	A	JUS	0939	DAL	A479	F	S	DAL	1054	ACF
B20	F	D	DAL	0940	MKC	PA61	S	D	ACF	1058	ABI
B28	M	A	WXE	0943	DAL	AJ4	S	S	ACF	1058	DAL
B747	F	D	DAL	0944	OKC	TT41	S	D	ACF	1100	BWD
AF8018	S	S	FTW	0949	DAL	B41	M	S	DAL	1101	ACF
AF8780	S	A	FNY	0946	FWH	X7996	S	D	DAL	1103	AMA
AF1000	S	A	FNY	0948	HNY	B34	M	A	JUS	1104	DAL
B94	M	D	DAL	0952	AMA	D307	S	S	DAL	1107	ACF
A157	F	A	WYL	0952	ACF	A402	M	D	DAL	1107	LIT
B15	M	S	DAL	0956	ACF						
TT42	S	A	FTW	0956	ACF						

TABLE V

OVER FLIGHTS

AIRCRAFT IDENTIFICATION	TYPE	ENTRY FIX	ENTRY TIME	ENTRY ALTITUDE	AIRWAY	TO
AF8885	M	JUS	0822	9000	A4	SAT
* AF1234	S	ACT	0845	7000	B5	TUL
AF1522	S	ACT	0853	9000	G5	NQA
X13C	S	ACT	0910	11000	V17-77	MKC
X1245N	S	ACT	0956	9000	B5	TUL
AF0133	M	GVT	1016	10000	G5	ELP
AF9919	M	ALT	1033	9000	A4	OKC
AF9211	J	FRS	1045	27000	Direct	MKC

* Included in Sample 3 Runs only

TABLE VI

SAMPLE 3 JET AIRCRAFT

AIRCRAFT IDENTIFICATION	OP'N	ENTRY FIX	ENTRY TIME	ENTRY ALTITUDE	DESTINATION
AF1000	A	WEB	0850	20,000	Hensley NAS
V6969	A	WEB	0912	20,000	Dallas
AF6014	D	HNY	0913	40,000	ElPaso
AF1004	A	WEB	0915	23,000	Hensley NAS
V444	D	HNY	0927	35,000	St. Louis
V6670	A	WEB	0932	20,000	Dallas
AF1065	A	WEB	0940	23,000	Hensley NAS
AF1010	A	WEB	0941	20,000	Hensley NAS

Measurements.

1. Departure Delay

For the purposes of this study, departure delay was assumed to be the interval between the scheduled takeoff time as determined from the traffic sample, and the actual takeoff time which was recorded on an Esterline-Angus recorder.[1]

2. Arrival Delay

From the basic traffic input data tabulated in the traffic samples, a theoretical approach gate or outer marker time was computed for each arriving aircraft. This theoretical time was based on the normal time required for the aircraft to proceed from the entry fix to the approach gate, assuming that no other aircraft was involved. The actual arrival time of each aircraft over the appropriate approach gate was recorded on the Esterline-Angus recorder. The theoretical gate time was then subtracted from the actual gate time, to determine the delay to each arriving aircraft. This figure, then, included all delays, whether caused by holding, descent, path stretching, or velocity control.

3. Shuttle Delay

From the scheduled departure time tabulated on the traffic sample, a theoretical gate time was computed for each shuttle flight. This figure represented the time the shuttle would be over the approach gate inbound, assuming that it had departed on schedule and had been the only aircraft in the approach system. The actual arrival time of the aircraft over the approach gate was recorded on the Esterline-Angus recorder. The theoretical gate time was then subtracted from the actual gate time to determine shuttle delay. This figure then included the effects of all factors, including delayed takeoff, which might have delayed the actual arrival.

The chief reason for tabulating shuttle delays separately from the delays to other arriving aircraft was to see whether delays in the system were distributed equitably between arrivals from inside and outside the terminal area.

4. A & S Delay

Arrival delays and shuttle delays were averaged together in the tabulations, under the title of A & S (arrival and shuttle) delay. This figure represented the average delay to all landing aircraft in the system.

5. Shuttle Flying Time

In view of the excessive flight time often required by shuttles between Amon Carter and Love Field under the present system, this item was recorded as another index of system performance. Shuttle flying time was the difference between takeoff time and arrival time inbound over the approach gate (outer marker), as recorded for Carter-toLove and Love-to-Carter shuttle flights. Actual flight time from takeoff to landing would

[1] TD Report #191, "Development of a Dynamic Air Traffic Control Simulator by Richard E. Baker, Arthur L. Grant, and Tircy K. Vickers, Oct. 1953, P. 7.

be about two minutes longer than the figures tabulated in this column.

Control Agencies.

The Fort Worth-Dallas simulation program marked the first use of the air route section of the dynamic simulator. This section, manned by air route traffic controllers, simulated the operation of the Fort Worth and Dallas sectors of the Fort Worth ARTC Center. It was assumed that each sector was equipped with a separate air/ground radio channel, as well as interphone connections to all control towers, air carrier, military, and CAA communications agencies within the area bounded by Waco, Mineral Wells, Ardmore, and Tyler.

To speed up the simulation program, as well as to economize on the use of personnel for these tests, the air route section of the simulator was not used during all test runs. Instead, it was employed only for the first run of each new phase and sample of the program. During this run, controllers recorded the altitude of each arriving aircraft at the time of its entry into the terminal area. During repeat runs of each phase and sample, each aircraft was carefully programmed to enter the terminal area at the same altitude at which it had entered during the initial run of that phase and sample. As far as the terminal area was concerned, use of this procedure kept the input to the traffic problem realistic and consistent, even when the air route section was not being operated.

Carter Tower operations were simulated by one controller and one assistant controller, using a single 12-inch surveillance radar display and associated flight progress boards. The Love Field Tower was simulated in the same manner. Each tower had an exclusive air/ground communications channel, and a direct interphone to the associated ARTC sector.

As previously noted, one of the most critical problems of the present system is the need for coordination between the four IFR traffic control agencies. Because the actual traffic count of Sample 1 showed that the number of aircraft operations at each of the four western airports (Carswell, Meacham, Carter, and Hensley) was relatively small, it was decided to combine Meacham and Carter approach control and handle the combined operation from the Carter Tower. This merger, which reduced the number of coordinating IFR agencies from four to three, worked successfully in the initial tests and appeared to be a practical arrangement even in working the higher densities of the later traffic samples.

TESTS AND RESULTS

Tests without Radar

1. Purpose.

Because of the limitations of present S-band radar equipment in heavy precipitation, as well as the necessity for developing fail-safe procedures, a considerable portion of the simulation program was devoted to the establishment of control systems which could continue in operation without benefit of a radar display. Therefore, many simulation tests were conducted completely without radar. On some radar tests, sudden failure of radar equipment was simulated, to determine whether safe operations could still be maintained.

2. Initial Tests.

In the initial tests, the existing layout of navigation facilities was simulated. Present operating procedures were utilized, with two exceptions:

a. To reduce the number of coordinating agencies, Carter and Meacham approach control were combined. Carter approach control had jurisdiction over IFR operations at Carswell, Meacham, Hensley and Carter Fields.

b. In line with previous simulation studies,[2] which had established the desirability for keeping final approach paths as short as practicable, ILS outer markers were utilized as the primary holding fixes for Meacham and Love Fields, in place of Haslet and Coppell, respectively. For the same reason, the Dallas fan marker was used instead of Duncanville, for north approaches to Love Field.

Arrival routes used in these tests are shown in Fig. 1. Departure routes are shown in Fig. 2. Even at the low level of traffic in tests of Sample 1, it was apparent that the coordination necessary in clearing westbound traffic from Love Field, or eastbound traffic from either of the other airports, could get quite involved at times.

3. Sector Altitude Boundaries.

At the present time, the approach control sectors in the Fort Worth-Dallas terminal area include all airspace up to and including 5,000 feet MSL. Altitudes above this level are controlled by the Fort Worth ARTC Center. This arrangement was followed in the initial simulation tests. However, it soon became apparent that a revision to the approach control sector boundary would be desirable.

---

[2] Application of Simulation Techniques in the Study of Terminal Area Air Traffic Control Problems, TD Report No. 192, by C. M. Anderson and T. K. Vickers, November 1953, see P. 7.

It will be noted from Sample 1 that shuttle flights between airports in the Fort Worth-Dallas terminal area make up almost half of the total takeoffs and landings. Initial simulation tests indicated that the handling of such operations formed the most critical phase of the entire traffic problem, since each shuttle flight required coordination between two approach control towers, and in many cases, the ARTC center as well.

To eliminate the necessity for coordination with the ARTC center in handling shuttle flights, it is necessary for the approach control sectors to extend high enough to contain all routine shuttle operations. However, any extension of the approach control sector above this altitude level places an unnecessary restriction on ARTC operations by requiring abnormally high entry altitudes for over-flying or arriving aircraft. The time required to descend from such levels often leads to increased arrival delays.

A graphical analysis[3] was made to determine the optimum altitude for shuttle operations under the most critical traffic conditions. These conditions were assumed to be as follows:

1. Shuttles would have to operate simultaneously in both directions, from Love to Carter and from Carter to Love.

2. Approach systems of both airports would be loaded with other traffic.

3. No radar would be available.

The graphical analysis showed that 4,000 feet was the optimum shuttle altitude for these conditions. Lower altitude limits lowered airport capacities by causing a large gap in the approach sequence preceding the arrival of a shuttle flight. Higher shuttle altitudes increased the flight times and in-flight delays of shuttle flights, and also increased the air/ground communications workload in getting the flights up and down through more altitude levels.

Use of the 4000-foot altitude level enabled each shuttle to descend again en route to the approach fix, with no delay in starting approach from that point, and with a normal approach interval behind the preceding aircraft.

Subsequent simulation runs indicated that the graphical analysis was correct; that there was no advantage in ever clearing a shuttle flight above the 4000-foot level. Therefore, the upper boundary of the approach control sectors was lowered to 4000 feet MSL in order to take advantage of lower entry altitudes for arriving aircraft. This change worked satisfactorily in all subsequent tests.

3 Ibid.

4. Shuttle Procedures.

The initial simulation tests indicated the desirability of establishing simple standardized procedures for the handling of Love-to-Carter and Carter-to-Love shuttle flights. Such procedures should have the following characteristics:

a. They should provide independent routes in each flight direction, with positive altitude separation at crossing points.

b. They should require a minimum amount of coordination between control agencies.

c. To entail a minimum amount of interference with other arrival and departure operations, procedures should permit each shuttle flight to vacate the minimum altitude as soon as possible after takeoff.

d. To avoid producing large gaps in the approach sequence at the destination airport, shuttle routes used for no-radar operations should provide a secondary clearance limit as well as a primary clearance limit for each direction of flight.

e. To reduce controller work load and aircraft flight time, procedures normally should enable shuttles to be integrated with other arrivals with no in-flight delay to the shuttle aircraft.

The lack of such procedures in the past has resulted in the extremely high flight times, flight altitudes, and work loads associated with shuttle operations. Fig. 3 shows the initial shuttle procedures used in the simulation tests. Although this procedure was an improvement, tests showed that it did not always provide positive altitude separation between opposite-direction shuttles at crossing points.

In an effort to provide greater safety for simultaneous shuttles in both directions of flight, the system shown in Fig. 4 was tried. In this system, shuttles from Carter climbed to 3000 feet in the Grand Prairie holding pattern before proceeding toward Dallas, while shuttles from Dallas climbed to 4000 feet at the Dallas range before proceeding toward Carter. Results of this test are shown in Fig. 5.

Although this system provided positive ANC separation between all shuttle flights, it greatly restricted the flow of shuttle traffic. Eastbounds could not leave Grand Prairie until the 3000-foot level was vacated at the Dallas range, and westbounds could not leave Dallas range until reaching the 4000-foot level. This restricted the number of simultaneous shuttle flights to a maximum of two. Ground delays to subsequent shuttle flights were increased drastically and controller work load went up. This ultimately affected other operations as well;

arrival and departure delays were increased to a high level. Therefore, this system was abandoned.

The original system shown in Fig. 3 was then modified to provide a greater degree of safety for simultaneous operations. The modified system, which is shown in Fig. 6, included the following changes:

a. Shuttles from Love Field took off southeast instead of south to provide a longer distance in which to climb before crossing the Dallas range westbound. All these flights were able to cross the Dallas range at 2000 feet or above and to reach 3000 feet well before reaching the Hensley intersection.

b. Shuttles from Love Field were restricted so as not to be on the left side of the course between the Dallas range and the Hensley intersection.

c. Shuttles from Carter were restricted to maintain 2000 feet until one minute southeast of the Hensley intersection.

Results of the first test with this system are shown in Fig. 5. As this modified system met all requirements for successful shuttle operations without radar, it was adopted as standard for subsequent tests under conditions when airport operations were southeast and no radar was used. With these procedures it was possible to have as many as four shuttle flights in progress at the same time (two in each direction of flight). It was found that rigid adherence to these standard procedures eliminated tower-to-center coordination regarding shuttle operations.

Several times during the early tests, controllers made the mistake of clearing Carswell-to-Dallas or Meacham-to-Dallas shuttle flights to the Carter outer marker at 3000 or 4000 feet, planning on being able to re-clear the aircraft immediately to the Dallas outer marker. In many cases, arriving traffic at Dallas forced these aircraft to hold at the Carter outer marker. This in turn delayed other Carter arrival traffic. To correct this situation, it was found that the easiest way to handle the Carswell-to-Dallas or Meacham-to-Dallas shuttle flights was to clear them via Hensley intersection at 4000 feet, where they entered the normal shuttle stream en route to Dallas.

Using the modified southeast shuttle system shown in Fig. 6 as a model, work was started to establish a similar system for use when north operations were in progress. One possible solution would be to have the shuttles climb to different altitudes (3000 and 4000 feet) at their respective outer markers before proceeding toward the other field. However, this system would be the equivalent of the system shown in Fig. 4, and would be subject to all the restrictions of that very inefficient system. Therefore, no time was given to this procedure. Instead, a new facility was provided to perform the same function as Duncanville in the southeast shuttle system, to set up an independent climbing route which would enable opposite-direction shuttle flights to switch altitudes between the points where their routes crossed. Since the Haslet H facility was no longer needed for Meacham Field traffic, it was assumed that this facility was moved to a point on the Dallas localizer course about 11-1/2 miles northwest of the Dallas outer marker. This new radio fix was known as Reservoir. It could also be defined as the intersection of the Dallas localizer course and an ADF bearing of 14 degrees from the Carter outer locator.

The initial shuttle procedure tested with this facility is shown in Fig. 7. It soon became apparent that this system had two disadvantages:

a. Positive altitude separation did not always exist between westbound and northbound shuttles in the vicinity of Grapevine.

b. The WFAA-WBAP radio towers at Grapevine intersection required a crossing altitude of 2200 feet, which forced the westbound shuttle route to 3200 feet. In order to accommodate four shuttles simultaneously, the 4200-foot level had to be used. This, in turn, restricted the use of the 5000-foot level by the ARTC Center through the area.

Because of these complications, the initial system was abandoned. The procedure was then changed to the one shown in Fig. 8. This procedure worked out quite satisfactorily in subsequent tests. Patterns used for northwest landings are shown in Fig. 9.

5. Freeze Control.

In addition to the tests which were conducted specifically to devise more efficient shuttle flight routes, other tests were made to evaluate the adequacy of the freeze control system which has been used in the past. The object of this system was to distribute arrival delays equitably between arrivals from inside and outside the terminal area. It also tended to allow shuttle flights to take most of their proposed delay on the ground, before departure, rather than in the air.

To operate this system, flight plans for all proposed IFR shuttle flights were filed with the ARTC Center. Integrating these proposed arrivals with other arrivals, the Center then issued an expected approach time (or "freeze time") for each flight at the appropriate approach fix. Based on this time, the shuttle pilot would attempt to be ready for takeoff at a time sufficiently early to enable his aircraft to arrive at the approach fix at the expected approach time.

Tests showed that this procedure was very inefficient. It caused a large increase in controller work load, because of the additional coordination activity required between airline office and ARTC, between ARTC and the towers, between towers and pilots, and between towers. The bookkeeping work load was similarly increased. Even in simulation, shuttles could not always take off on time, because of other airport traffic, and because of the extra coordination required. Shuttles were not always in position to start approach at the planned approach times. When they arrived late, they often had to hold at the approach fix to wait for other traffic which had arrived in the meantime. There were other times, while shuttles were being held on the ground awaiting their expected takeoff time, that unexpected gaps developed in the approach sequences. These gaps, long enough to accommodate one or more approaches, could not be utilized because no shuttle was in position to take advantage of this contingency. Delays piled up, not only for shuttle flights, but for other traffic as well. It was concluded that if the "freeze" control procedure would not work satisfactorily in simulation tests, it would have even less chance of working satisfactorily when dealing with the additional variables encountered in actual operations. No further tests were made on the freeze control ppocedure. Although it might have been an improvement over no system at all, it became only a bottleneck after the simple standard shuttle procedures were developed.

Tests showed that the standard shuttle procedures performed the same purpose as the freeze control procedures, with much less work load for control personnel and considerably less delay for the aircraft concerned. The standard shuttle procedure performed a flow control function because its use automatically limited the number of shuttle flights to two in each direction at any one time. Each shuttle could be cleared for takeoff with no delay expected at the destination. After two flights were on their way from one airport, there was no point in clearing any more for awhile, as any extra flights would be faced with a higher cruising altitude (which would have required prior coordination from the Center), plus additional holding time in flight. This procedure allowed a smooth flow of traffic without bunching shuttles at the other end of the line. As a result, no shuttle flight ever needed to be coordinated with the ARTC Center. Meanwhile the Center issued, to other arrivals, expected approach times eight to ten minutes apart. This was actually conservative enough to permit approach control to sandwich occasional shuttles into the approach sequence without setting back the expected approach time of the other arrivals. Approach control would advise the Center regarding any appreciable change in the last expected approach time issued, so that subsequent expected approach times could be approximated more closely. Results of this system are compared with results of the freeze control system in Fig. 10.

Tests with Radar.

1. Extent.

A considerable portion of the simulation program was devoted to the investigation of the most practical methods for the application of radar procedures to the control of traffic on the Fort Worth-Dallas terminal area. This portion of the program was conducted in two phases:

a. Simulation of ASR-2 or ASR-3 type surveillance radar at Carter and Love Fields.

b. Simulation of high-power terminal area surveillance radar for combined Center-Approach Control operations.

The radar coverage simulated in the tests is shown in Fig. 11.

2. Shuttle Procedures.

During the initial radar tests, no particular routes were specified for shuttle flights between Carter and Love Fields. After takeoff, such flights were turned on downwind leg for approach to the other airport, as shown in Fig. 12. Although this procedure worked satisfactorily under light traffic conditions, the crossover of flight paths in the area between the two airports could produce a hazardous condition if the controller's attention was temporarily diverted to other areas. In addition, these paths tended to interfere with Hensley Field operations. To provide greater safety and to simplify coordination between towers, shuttle routes were changed to eliminate this crossover. The modified routes, which worked satisfactorily in subsequent tests, are shown in Figs. 13, 14, and 15.

3. Offset Holding Fixes.

Previous simulation studies had shown the advantage of establishing holding fixes offset from the final approach course, as an aid in handling heavy traffic demand rates with radar.[4] Application of this feature to the Fort Worth-Dallas area was investigated. There was not enough room to establish a twin-fix feeder arrangement for either Carter or Love Fields; neither was there enough space to establish a holding fix between the two parallel ILS courses. Therefore, only single-fix systems could be used; and any offset holding fixes would have to be west of Carter or east of Love. As the Dallas VOR was too far away from the field for ideal vectoring arrangements, it was moved to Highland Park. An additional VOR or TVOR facility was established at Pulley. This configuration of facilities, with the resulting flight routes, is shown in Fig. 16.

As indicated in Fig. 17, subsequent tests of this arrangement showed that use of the offset holding fixes had very little effect on average delays. Even at the increased traffic rates of Sample 3, traffic

[4] Ibid. p. 9.

moved so fast under radar control that arrivals seldom reached these offset clearance limits before they could be cleared for approach. The layout was not very practical for shuttle traffic, as such aircraft would have to make long detours, in many cases, to proceed via the offset fixes. This would have complicated traffic paths considerably, and added to controller work load. Therefore, the outer markers were retained as the primary clearance limits for Carter and Love Field arrivals; and the establishment of the Highland Park and Pulley VOR facilities is not recommended at this time.

4. Control Room Layout.

Figure 18 shows the layout of control equipment which was used to simulate operation of the IFR room at Carter Tower. A similar arrangement was used to simulate operations at Love Field. It will be noted that the radar controller is provided with small flight progress boards adjacent to his radar scope. Previous tests[5] have shown the necessity of keeping the pictorial display (radar scope) and the symbolic display (flight progress board) together, so that the approach controller has simultaneous access to all information regarding aircraft under his control.

The standard layout for IFR rooms places the radar scope several feet away from the flight progress boards. Such an arrangement leads to increased coordination between personnel, increased work load, and a much higher exposure to misunderstanding and confusion. This situation can be corrected through the use of small (even portable) flight progress boards on the ledge in front of the radar scope. These boards are used to post only the flights under actual control. Flight progress strips are prepared by the data transfer man, who handles most of the interphone communications. Strips are passed to the radar controller who handles his own strip marking procedures to keep flight data current. The radar controller is primarily concerned with air/ground communications.

For such a system to function properly, lighting arrangements must be adequate for the flight progress boards, but must not debase the radar display. Many different lighting systems have been tried on the simulator.[6] Most successful so far is a tri-chromatic system which uses a ceiling fixture containing red, blue, and green lamps. These lamps produce a mixture of light which is apparently white but is actually deficient in the amber portion of the spectrum. An amber filter is used on the face of the radar scope, and a small semicircular hood is placed around the top portion of the scope to shield it from the light source. The trichromatic light mixture produces adequate ambient lighting in the radar room, but does not interfere with the use of the radar scope.

[5] Ibid. P. 17

[6] Ibid. P. 17

5. Horizontal Display Equipment.

The radar tests previously described simulated operations with ASR-type radar installations at Love and Carter Fields. Shortly after the original program was completed, the simulator was equipped with a new 30-inch horizontal bright tube display, as shown in Fig. 19. Because the new display opened up possibilities for an entirely new concept of combined Center-Approach Control terminal area operations, the program was extended to include tests using this equipment.

The new scope was large enough to permit several controllers to function as a team while handling traffic in a comparatively large radar area. Therefore, it was possible to simulate an installation in which the Air Route Traffic Control and Radar Approach Control functions for the entire Fort Worth-Dallas terminal area were located in a single room, with Center controllers and Approach controllers sharing the same radar display.

The scope covered the large circular area shown in Fig. 11, at a scale of approximately 2-1/2 miles to the inch. Three controllers were used, one for Carter Approach Control, one for Dallas Approach Control, and one to handle the ARTC functions for the Fort Worth and Dallas Sectors. Each controller had at least one exclusive air/ground communications channel.

Identification markers were used to keep track of the various targets on the scope face. These markers were of heavy paper stock, approximately one by two inches in size, bluntly pointed at one end to indicate flight direction. Different colored markers were used to indicate different types of operations. Ordinary lead pencils were used to post flight data, which included the following items on each marker:

Aircraft identification
Aircraft type or speed class
Route, if pertinent
Destination
Clearance limit and altitude.

Tests showed that this concept of combined Center-Approach Control terminal area operations resulted in an extremely flexible system which practically eliminated coordination problems between the Center Sector controller and the approach controllers. As all controllers had complete and current information on all IFR traffic in the terminal area, they were able to make immediate use of available airspace as soon as such opportunities occurred. They were also able to share the workload equitably during sudden surges of traffic. Having adjacent Center sectors a few feet away made it extremely simple for the Center controller to coordinate terminal area arrivals and departures with the other ARTC sectors.

The result was a considerable reduction in controller work load and a speedup in traffic flow as shown in Fig. 20. Although the tests were based on the use of what is yet highly experimental and expensive radar equipment, they pointed out the tremendous advantages which could be obtained from the Center-Approach Control radar team idea, if suitable equipment of this type ever becomes available for actual operations.

In tests simulating radar failure, it was found that this system continued to function in a highly successful manner, even without radar. Use of the identification markers on the map overlay of the horizontal scope still provided a type of pictorial display which was far superior to the old tabular posting flight progress board system. As aircraft reported passing each fix in the terminal area, the identification marker was moved ahead. The result was a simple and practical block system of traffic control, with a low controller work load. Because radio fixes were close together, block lengths were short, and the pictorial representation of the spatial relationships between the various aircraft was almost as good as if the radar was operating. The scanning work load was very low because each aircraft was represented by only a single simple marker, instead of by the multiple strip postings of a standard flight progress board. This factor contributed to the inherent safety of this type of traffic control system.

Miscellaneous Tests.

1. Use of Short Clearance Limits.

Early simulation tests in this program utilized departure procedures which required that all IFR departures receive ARTC clearance prior to takeoff. In these tests, departure delays ran high, because of the time required for requesting, transcribing, and issuing the complete clearance for each flight. It was believed that a number of factors already present in the local traffic system would make this procedure unnecessary. These factors included:

a. Direct air/ground ARTC communications facilities.

b. An unusually large block of airspace under approach control jurisdiction.

c. A multiplicity of radio fixes within this block, suitable for use as initial clearance limits for departures.

Making use of the factors, a very simple departure procedure was established. Aircraft taxiing out for takeoff were given IFR clearance to one of the clearance limits shown in Fig. 2,. at the top altitude available in the approach control sector. Normally this altitude was 4000 feet. If this altitude was already in use, 3000 feet would be specified if available; 2000 feet was used only in rare occasions to get an aircraft started on its way, when it was certain that a higher level would become available within the next few minutes.

As soon as the aircraft was off the ground, the tower issued the following data to the Center:

Aircraft identification
Estimate at clearance limit
Altitude.

As soon as practicable, the aircraft was changed to ARTC frequency to receive air route clearance direct from the Center. The flight remained posted on the approach control flight progress board until information was received from radar, or from the Center, that the aircraft had vacated the approach control sector.

By eliminating lengthy interphone conversations, as well as the transcription and transmission of long clearances prior to takeoff, this procedure reduced departure delays and approach control work load appreciably. During these tests, the new procedure worked satisfactorily from the ARTC standpoint. It was as easy to integrate a departure with other ARTC traffic on the basis of an estimate at the initial clearance limit, as it would have been on the basis of an estimated departure time. Because of the size of the approach control sector, each pilot had plenty of time in which to secure his ARTC clearance before he reached his initial clearance limit.

2. Elimination of Shuttle Traffic.

A rather obvious, though drastic, method of solving the most critical traffic problem in the Fort Worth-Dallas terminal area would be to eliminate routine shuttle operations altogether. Some idea of the effects of such a policy can be obtained from Fig. 21, which shows the results of comparative tests on Samples 2 and 2A. Although the same number of airline seats to and from the terminal area were still available, theoretically, the elimination of the shuttle flights from Sample 2 to form Sample 2A reduced the number of aircraft operations by one-half, and reduced aircraft delays by two-thirds.

3. Choice of Approach Runways.

a. Southerly Landing Operations: One consideration in this study was to set up a system which would allow instrument approaches to be made in at least two directions at each major airport. For southerly operations, existing facilities dictate approach directions as follows:

Airport	Primary Approach Aid	Landing Direction
Carswell	GCA	South
Meacham	ILS	South
Carter	ILS	Southeast
Love	ILS	Southeast
Hensley	GCA	South
	GCA	Southeast

In all tests, Hensley arrivals were handled in the Carter approach sequence. Both south and southeast approaches to Hensley were simulated. For south approaches, Hensley arrivals proceeded inbound to the Carter outer or middle marker, where they were turned on base leg and vectored into the final approach course, for precision airport radar (PAR) approach by Hensley GCA. For southeast approaches, such aircraft were released to Hensley GCA when over the Carter middle marker, for straight-in approach to Runway 13. These procedures are shown in Fig. 22. All procedures worked satisfactorily. However, from the air traffic control standpoint, the southeast approach was preferable for the following reasons:

1. It required less controller work load.

2. It was completed more quickly.

3. The aircraft remained clear of the area between Carter and Love Fields. This was especially desirable when shuttle flights were in progress.

The disadvantage to the southeast approach is that Runway 13 is only 5200 feet long, while Runway 17 (the south runway) is 7500 feet long. For this reason, a south approach would be preferable sometimes from the flight safety standpoint.

b. Northerly Landing Operations: For northerly operations, existing facilities allow a somewhat wider choice of landing directions, as follows:

Airport	Primary Approach Aid	Landing Direction
Carswell	GCA	North
Meacham	ILS (Back-course)	North
Carter	ILS (Back course)	Northwest
	ADF*	North
Love	ILS (Back course)	Northwest
	ADF	North
Hensley	GCA	North
	GCA	Northwest

* Or VOR, if proposed facility installed at Webb.

Various combinations of these approach directions were tested. It was found that north, rather than northwest, approaches were preferable at

Carter and Hensley, for the following reasons:

1. Aircraft were not holding over Hensley Field; this simplified the radar picture when approaches to Hensley were in progress and facilitated simultaneous approaches to Carter and Hensley.

2. Hensley arrivals landed on the longest runway available.

In using this procedure, Carter arrivals used Grand Prairie as the approach fix, Hensley arrivals used either Grand Prairie or Webb, and were vectored to the final approach course for PAR approach to Runway 35.

North approaches worked satisfactorily for Love Field, using the Dallas fan as the approach fix. However, northwest approaches appeared slightly more preferable for the following reasons:

1. Back-course ILS navigational guidance should be somewhat more precise than back-bearing ADF guidance from the Dallas LF range station.

2. Love Field arrivals remained well clear of Hensley traffic.

The Ross Avenue intersection has been unsatisfactory as an approach fix for northwest approaches in the past because of its proximity to Love Field. Therefore, it is recommended that a fan marker and/or (preferably) a compass locator be installed on the Dallas localizer course, in the vicinity of Fair Park, for this purpose. This facility is shown in Fig. 9.

4. Configuration of VOR Facilities.

One objective of the simulation program was to determine the best location for:

a. The Fort Worth VOR, which had unsatisfactory operational characteristics at its present site, and was slated for relocation.

b. One proposed new VOR facility for the terminal area.

In determining the optimum locations for these radio aids, it was desired to set up an arrangement of VHF navigational aids which would:

a. Provide dual airways to permit two-way traffic on all important routes.

b. Provide a means of by-passing "over" traffic around the immediate approach and holding areas.

c. Provide an expeditious penetration and approach pattern for jet aircraft.

In setting up various possible arrangements of facilities, consideration was also given to the possible relocation of the Dallas VOR. Besides the Highland Park site previously described in this report, a site at Forney, and another seven miles northeast of Forney also were tested. It was finally determined that neither of these sites offered enough operational advantages over the present Dallas VOR site to justify moving this facility.

Three different proposed sites were tested for the Fort Worth VOR. They were all in the area north-northwest of Carswell Field. The site which appeared to be most suitable from the air traffic control standpoint was near Boyd, Texas, as shown in Fig. 11. It was far enough north to form an east-west by-pass route clear of the holding airspace reservations at Carter and Dallas outer markers. It was far enough west to permit independent route operations clear of the relocated Amber 4 airway (north course of Fort Worth LF range station). It also formed a convenient clearance limit, in lieu of the Haslet marker, for aircraft inbound to Carswell Field. Jet aircraft inbound to Carswell could cross Boyd at about 10,000 feet MSL for a straight-in GCA approach.

The proposed new VOR facility was simulated at a site near Webb, Texas. This site, which is shown in Fig. 11, is about eight miles south of the Grand Prairie marker, and in line with the north-south runway at Carter Field. The proposed site worked out very satisfactorily in the simulation tests. It provided the terminal area with:

a. A southerly by-pass route for east-west traffic.

b. A VOR approach course for north landings at Carter Field.

c. A convenient route, independent of Carswell and Meacham traffic, for southbound departures from Carter Field.

d. A radio fix for jet penetration and GCA pickup, for approaches to Hensley or Carter. Tests showed that this jet approach path required considerably less time and controller workload than the one presently prescribed.

It should be emphasized that the VOR sites mentioned in this section were chosen from the traffic control standpoint, and not from the electronic standpoint; as the simulator is not equipped to evaluate the electronic characteristics of various VOR locations. Either of the recommended sites could be moved a mile or two without appreciably changing the traffic flow characteristics of the system.

Figure 11 shows the by-pass routes which were possible with the recommended configuration of VOR facilities. Simulation tests showed that these routes were very useful in eliminating conflictions between "over" traffic and holding traffic. The by-pass routes tended to simplify the radar display by keeping through flights clear of the area normally used for radar vectoring. This reduced controller work load appreciably.

As shown in Fig. 23, these routes provided a set of outer clearance limits for the jurisdictional changeover and radar identification of arrivals. Between these points and the airport, arrivals were on a flight path which was clear of all other aircraft except others bound for the same airport. This independent area was large enough to permit the approach controller to get most of his arriving traffic in proper sequence before it reached the holding fix.

VOR departure routes are shown in Fig. 24. The peripheral by-pass routes were sufficiently distant from the airport that a departure could climb to an altitude above the approach control sectors before reaching the airway. This served to reduce coordination between agencies in many cases. For example, an east-bound flight from Meacham formerly required coordination between Carter approach control, Dallas approach control, and the Fort Worth ARTC Center. Using the by-pass route, the departure would require coordination only between Carter approach control and the Fort Worth Center.

5. Operation of Jet Aircraft.

Figure 25 shows the jet approach procedure presently authorized for Hensley Field. This procedure requires the jet aircraft to descend to 2000 feet on an outbound heading and proceed all the way back to the range station at that altitude. Each approach requires coordination between Dallas approach control and Carter approach control, and temporarily ties up traffic at Dallas, Carter, and Hensley Fields.

Figure 25 also shows a proposed jet approach procedure which utilizes Grand Prairie as the penetration and approach fix. This procedure is considerably shorter than the one presently authorized. Normally, it would not require coordination with Dallas approach control, nor would it affect operations in progress at Love Field.

As previously indicated in this report, one reason for choosing the Webb site for the proposed additional VOR facility was to provide convenient VHF navigational guidance for jet approaches to Hensley and Carter Fields. Simulation tests showed that this VOR procedure, which is shown in Fig. 26 worked very satisfactorily.

Figure 27 shows the present jet approach procedure authorized for Carswell Field. This is an ADF procedure based on the use of the Fort Worth LF range and the Haslet H facility. As Haslet serves no other useful purpose in the proposed system, it is recommended that another jet approach procedure be adopted, and that Haslet be decommissioned so that its components can be used elsewhere. Figure 27 shows a recommended jet approach procedure using the proposed Boyd VOR. Aircraft would descend, in the holding pattern if necessary, to cross Boyd at about 10,000 feet for a straight-in GCA approach to Carswell.

CONCLUSIONS

1. Consolidation of Meacham and Carter Approach Control will reduce coordination work load.

2. The most critical IFR traffic problem in the Fort Worth-Dallas area is the operation of shuttle flights between Carter and Love Fields. Use of standard shuttle procedures as developed during this simulation program will reduce shuttle flying time, aircraft delays, and controller work load.

3. No advantage is gained by clearing shuttle flights above 4000 feet MSL in the Fort Worth-Dallas terminal area.

4. Reduction of approach control sector ceilings from 5000 to 4000 feet MSL should reduce descent delays and result in a satisfactory operating arrangement.

5. As shown in Fig. 28, use of adequate radar procedures by Love and Carter Approach Control should reduce aircraft delays by approximately two-thirds for equivalent traffic loads.

6. Use of freeze control for shuttle flights is a potent source of aircraft delays. This procedure will become unnecessary when standard shuttle procedures or radar control is adopted in the Fort Worth-Dallas terminal area.

7. The establishment of offset holding fixes for Love and Carter Fields is not justified at this time. Use of ILS outer locators as primary holding fixes for Love and Carter Fields provides more accurate spacing of approach intervals than can be obtained through use of Coppell and Haslet. Similarly, use of Dallas fan marker (with one-minute right-hand pattern) is far superior to the use of Duncanville as the primary holding fix for north approaches to Love Field; the southbound departure route via White Rock and Trinity Fork works out satisfactorily in this case.

8. Use of short clearance limits for departure flights is particularly well adapted t the Fort Worth Dallas terminal area, due to the large amount of airspace under approach control jurisdiction. This departure procedure tends to reduce approach control workload, as well as delay to departing aircraft. No adverse effects on air route traffic control were noted during extensive simulation tests of this procedure.

9. Comparative tests of north and northwest landing operations at Love and Carter Fields produced relatively little difference in traffic delays. However, other factors in the configuration of terminal area facilities may make it preferable to land Carter and

Hensley approaches north rather than northwest, and Love approaches northwest rather than north. Installation of a fan marker and/or compass locator at Fair Park would facilitate northwest approaches to Love Field.

10. Relocation of the Fort Worth VOR to a site near Boyd, and installation of a proposed new VOR at a site near Webb would, in conjunction with the present Dallas VOR, set up a very useful arrangement of dual VHF airways which would by-pass the terminal area and simplify both terminal area and en route control operations. The resulting route layout would still be compatible with the present LF system as long as the latter remains in use.

11. Use of the Grand Prairie H facility as the radio fix for jet approaches to Hensley or Carter Fields appears preferable to the use of the Dallas LF range for this purpose.

12. Tests indicate that the proposed Webb VOR would make a satisfactory VHF radio aid for jet approaches to Hensley or Carter Fields.

13. A policy restricting routine IFR shuttle operations could be expected to double the capacity of the Fort Worth-Dallas terminal area for handling long-range traffic operations.

14. Tests indicate that coordination work load could be greatly reduced if traffic could be handled by a team of approach controllers and en route controllers working from a common radar display. Implementation of such a system will depend on the development of improved radar equipment, including a suitable horizontal plotting s cope which would permit pertinent control data to coincide with the position of the various aircraft targets. The simplification of control work load possible with such a display tends to reduce aircraft d elays and to provide a large increase in terminal area traffic capacity.

RECOMMENDATIONS

The recommendations in this section are arranged to form a suggested step-by-step plan for increasing the traffic capacity of the Fort Worth-Dallas terminal area.

Group A--Procedural Changes.

1. Combine Meacham and Carter approach control functions at Carter.

2. Change primary holding fixes from Haslet to Fort Worth outer marker, and from Coppell to Dallas outer marker. Establish a one-minute holding pattern at each fix.

3. For north approaches to Love Field, change primary holding fix from Duncanville to Dallas fan marker. Use one-minute right-hand pattern at Dallas fan, routing southbound Dallas departures via White Rock or Wilmer.

4. Adopt standard shuttle procedures as described in Section III-A-4 and III-B-2 of this report. Discontinue use of freeze control for shuttle flights.

5. Lower approach control sector ceilings from 5000 to 4000 feet MSL.

6. Adopt short clearance limit procedure for departures, as described in Section III-C-1 of this report.

7. Change jet letdown from Dallas range to Grand Prairie marker, as shown in Fig. 25.

Group B--Facility Changes.

1. Proceed with the installation of airport surveillance radar at Love and Carter Fields. Change standard IFR room layout slightly to provide the approach controller with small flight progress boards adjacent to the radar scopes. Install tri-chromatic light fixtures with amber scope filters, to provide adequate ambient room lighting without debasing the radar picture.

2. Move Fort Worth VOR to new site near Boyd, as shown in Fig. 27. Establish this fix as primary clearance limit for Carswell arrivals, in place of Haslet.

3. Move Fort Worth middle locator to outer marker site.

4. Decommission Haslet; move H facility to Reservoir as shown in Fig. 7, move fan marker to Fair Park as shown in Fig. 9.

5. Install proposed new VOR at site near Webb, to establish dual VOR routes as shown in Fig. 11 and a new VOR jet approach procedure as shown in Fig. 26.

Group C--Miscellaneous Changes

1. Because this project has uncovered many other methods of boosting terminal area traffic capacity, a policy of restricting or eliminating IFR shuttle flights may not be necessary at this time. However, if traffic demand continues to rise to the point where the improved system cannot handle it adequately, the elimination of routine shuttle operations by fixed-wing aircraft would be an important means of increasing the ability of the system to accommodate traffic from outside the terminal area.

2. Because of the very extensive simplification of controller work load provided by the en route-approach control team concept for handling traffic operations in terminal areas as complicated as Fort Worth-Dallas, it is recommended that immediate steps be taken for the development and procurement of suitable horizontal radar displays for this purpose. Future planning for such areas should be directed toward the combination of all en route and approach control functions in a single room, with controllers working as a team around a common pictorial display.

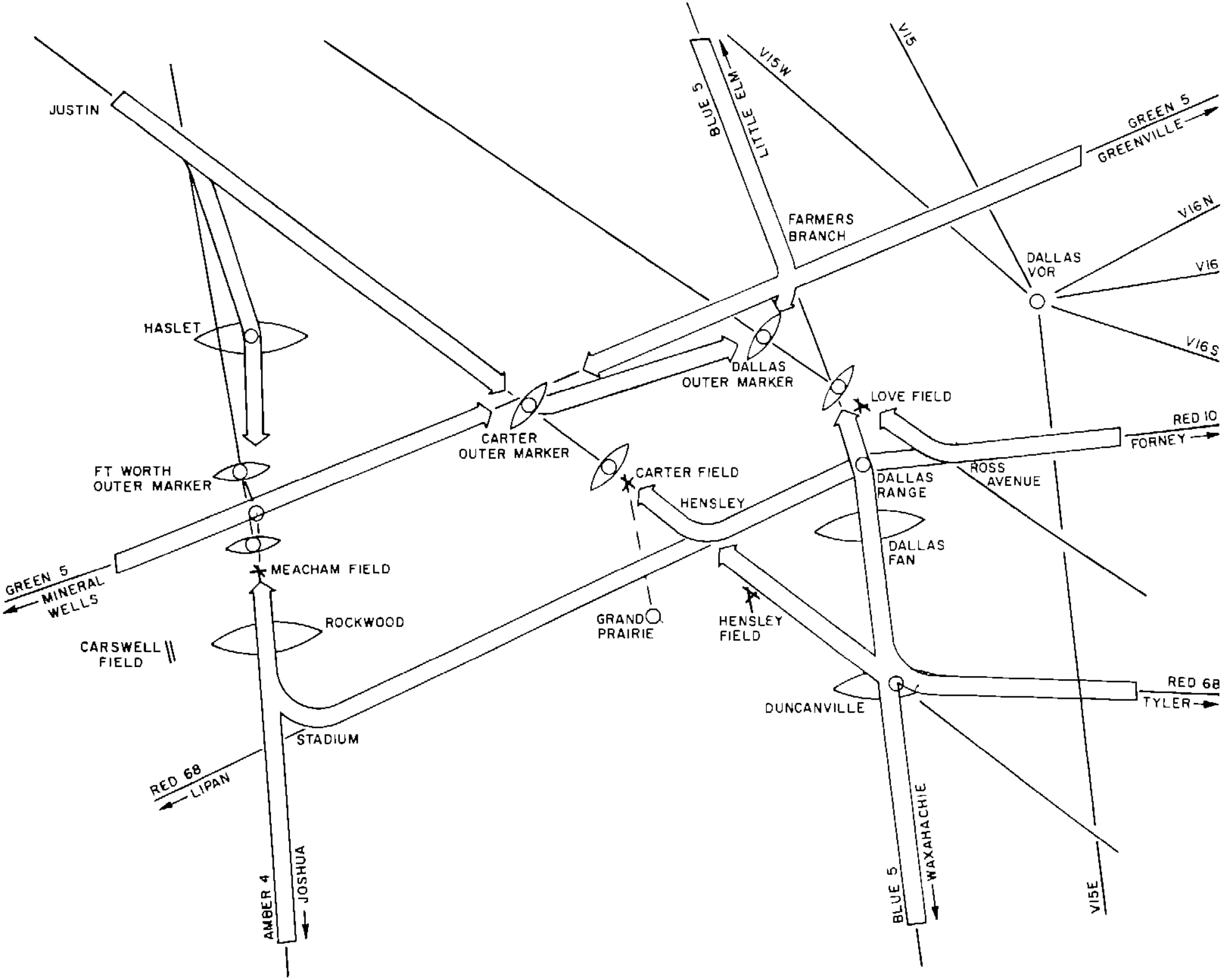


FIG I ARRIVAL ROUTES USING PRESENT FACILITIES

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS INDIANA

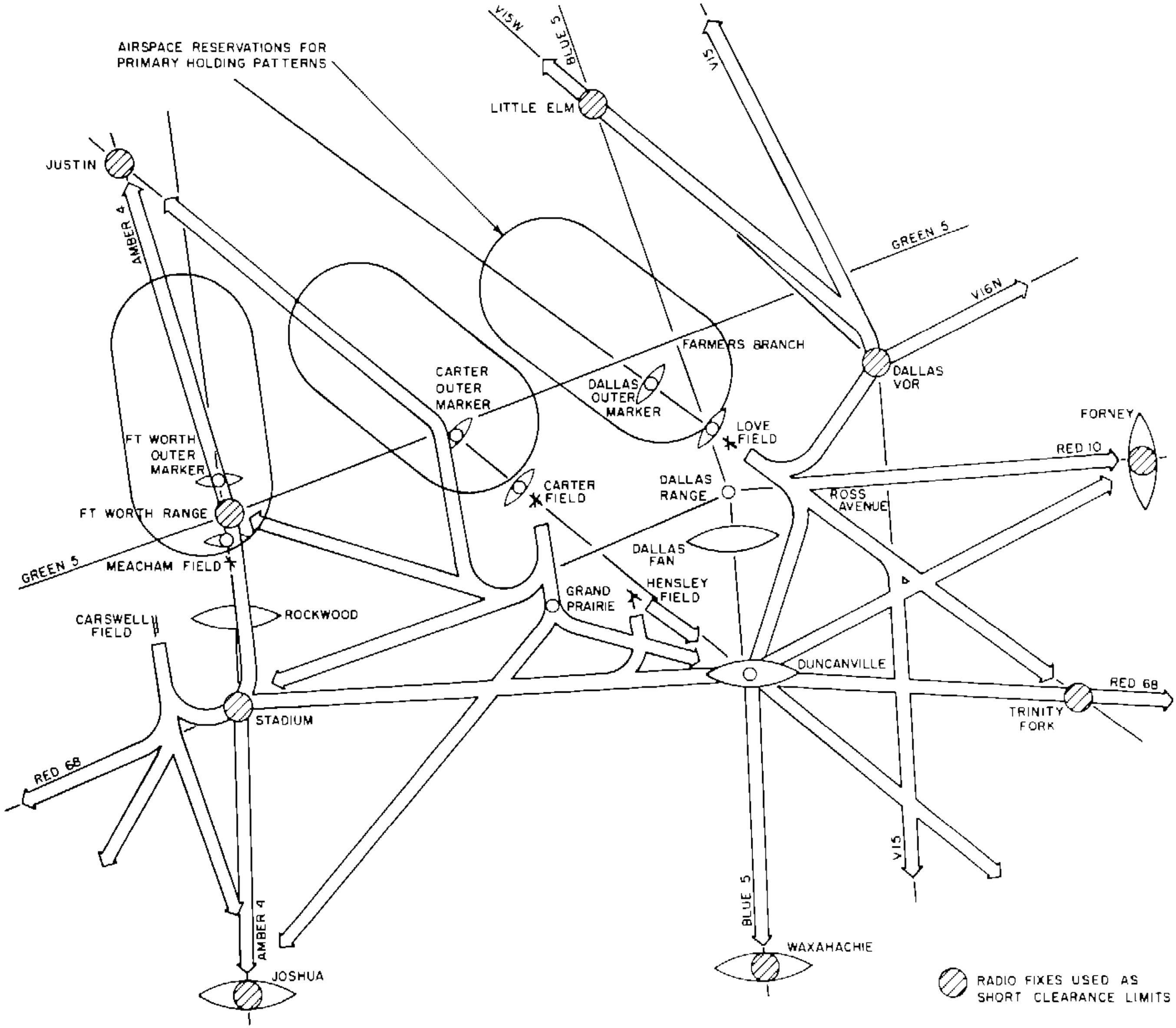


FIG 2 DEPARTURE ROUTES USING PRESENT FACILITIES

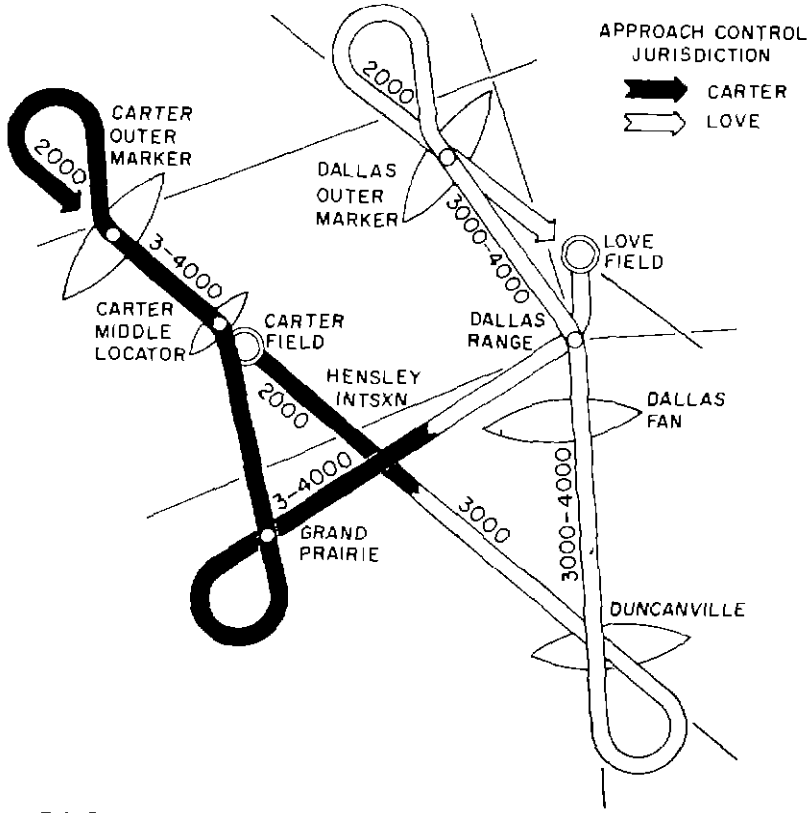


FIG 3 INITIAL SHUTTLE PROCEDURE - SE LANDINGS - NO RADAR

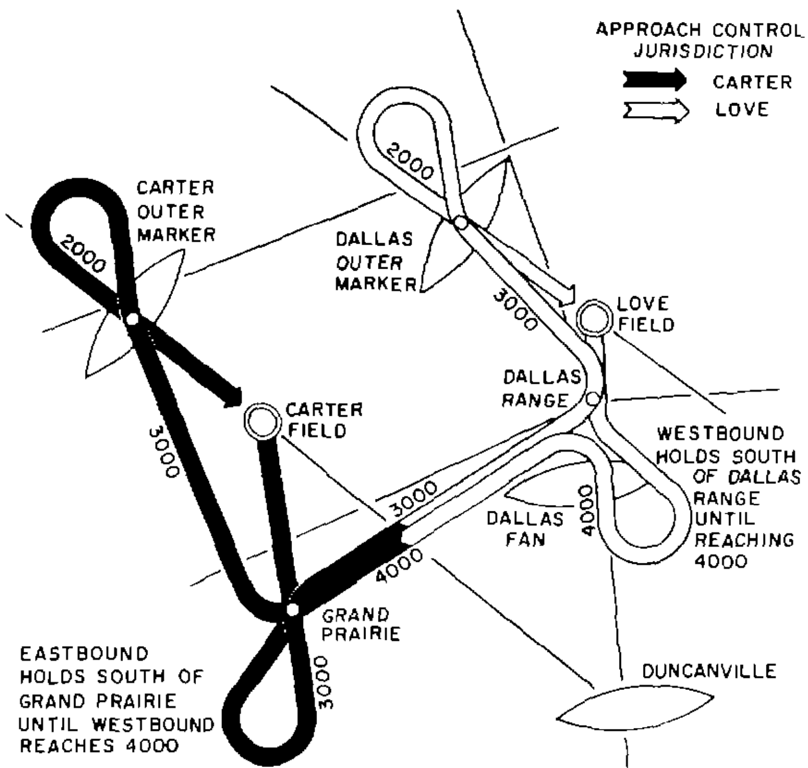


FIG 4 INTERMEDIATE SHUTTLE PROCEDURE - SE LANDINGS - NO RADAR

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS INDIANA

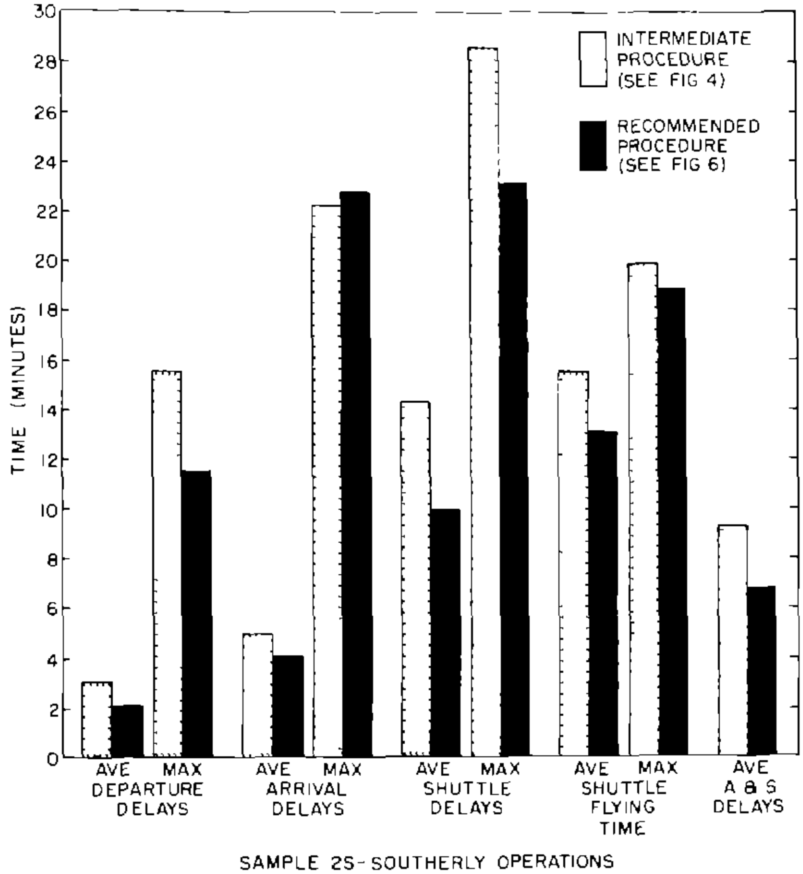


FIG 5 COMPARATIVE RESULTS–INTERMEDIATE AND RECOMMENDED SHUTTLE PROCEDURE – NO RADAR

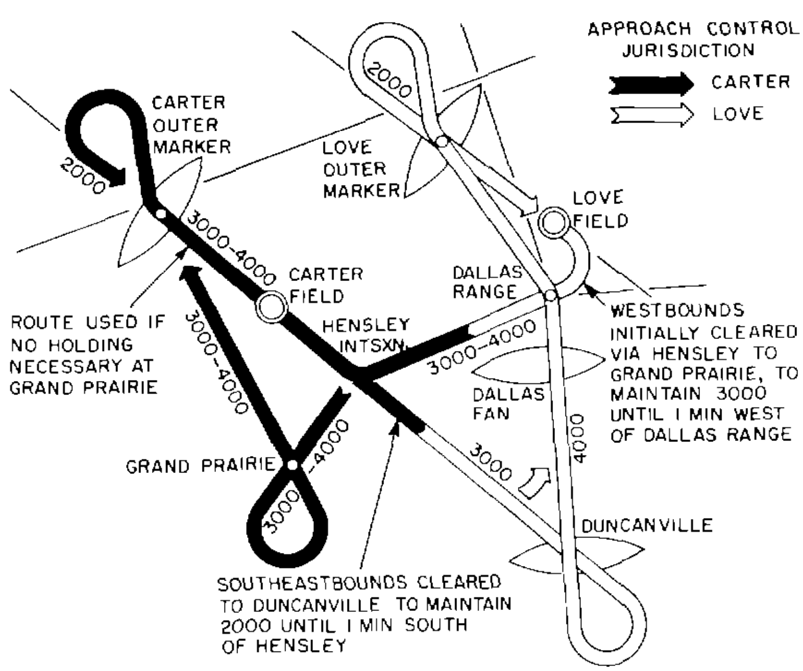


FIG 6 RECOMMENDED SHUTTLE PROCEDURE– SE LANDINGS–NO RADAR

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

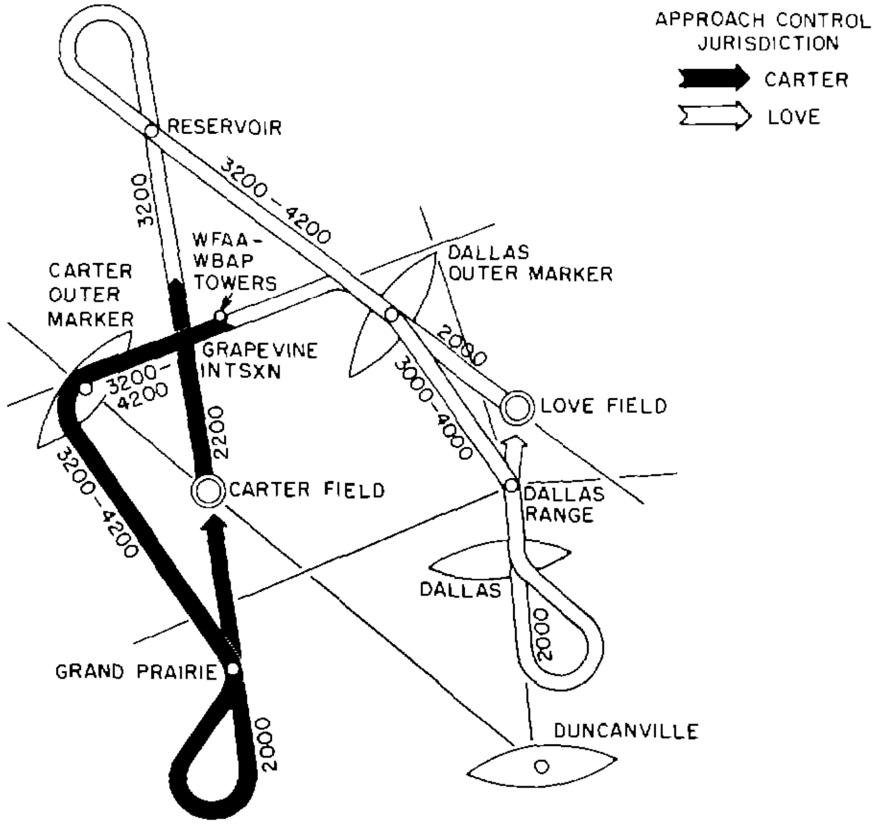


FIG 7 INITIAL SHUTTLE PROCEDURE - NORTH LANDINGS

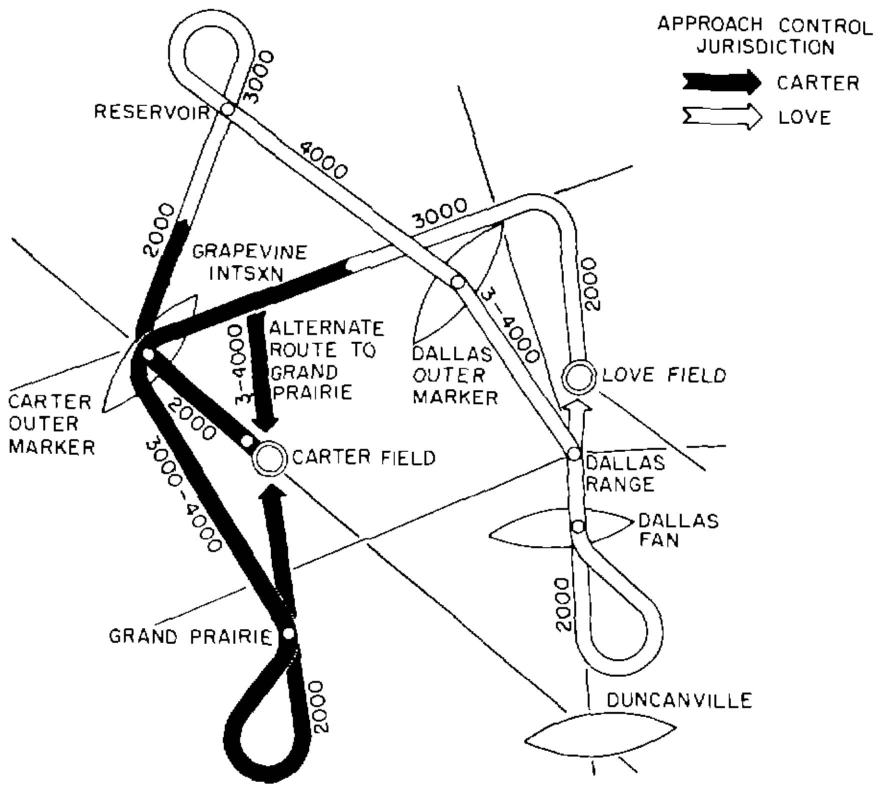


FIG 8 RECOMMENDED SHUTTLE PROCEDURE-
NORTH LANDINGS - NO RADAR

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS INDIANA

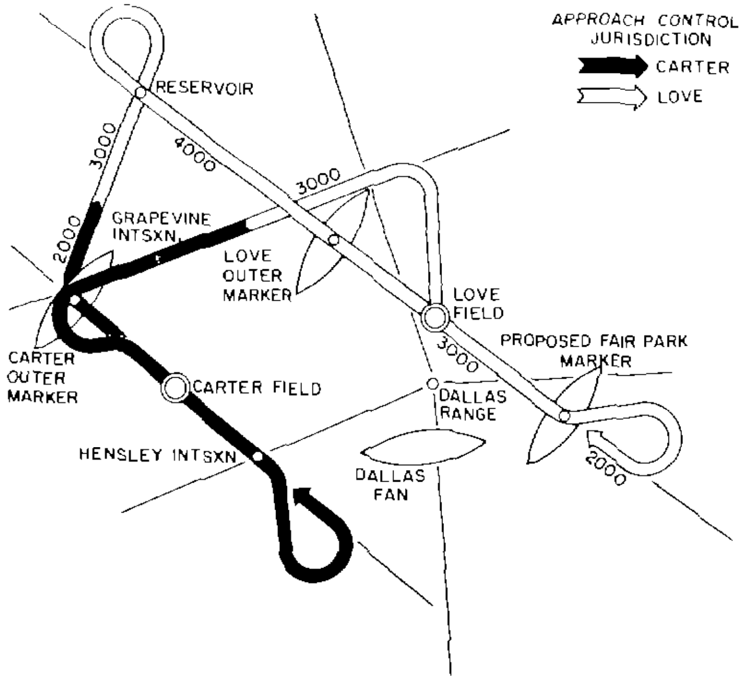


FIG 9 RECOMMENDED SHUTTLE PROCEDURE-
NW LANDINGS-NO RADAR

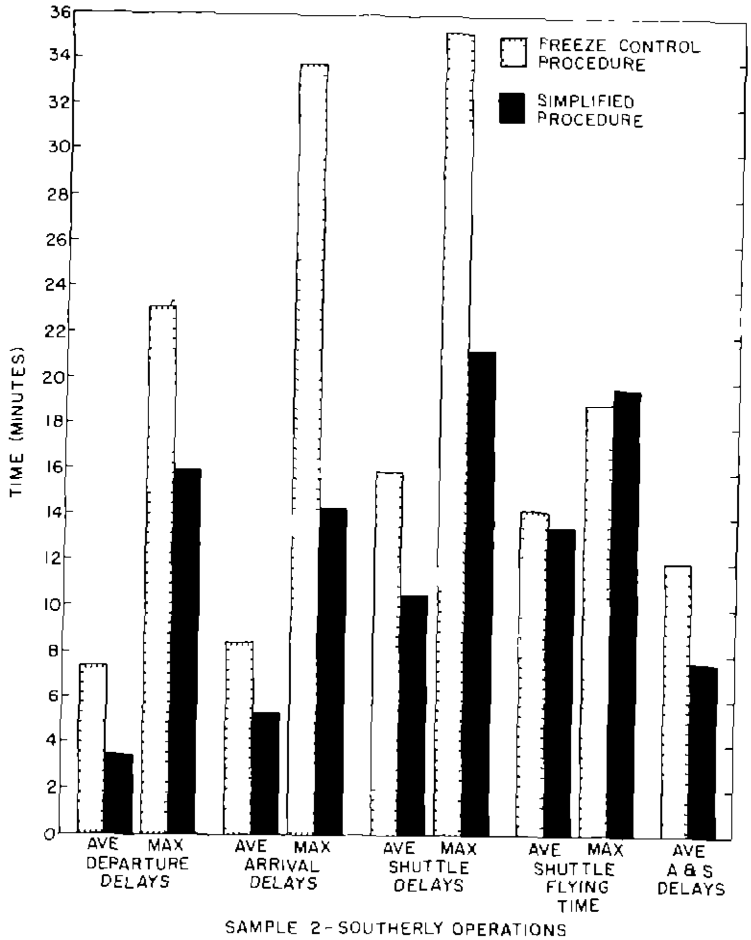


FIG 10 EFFECT OF FREEZE CONTROL-NO RADAR

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS INDIANA

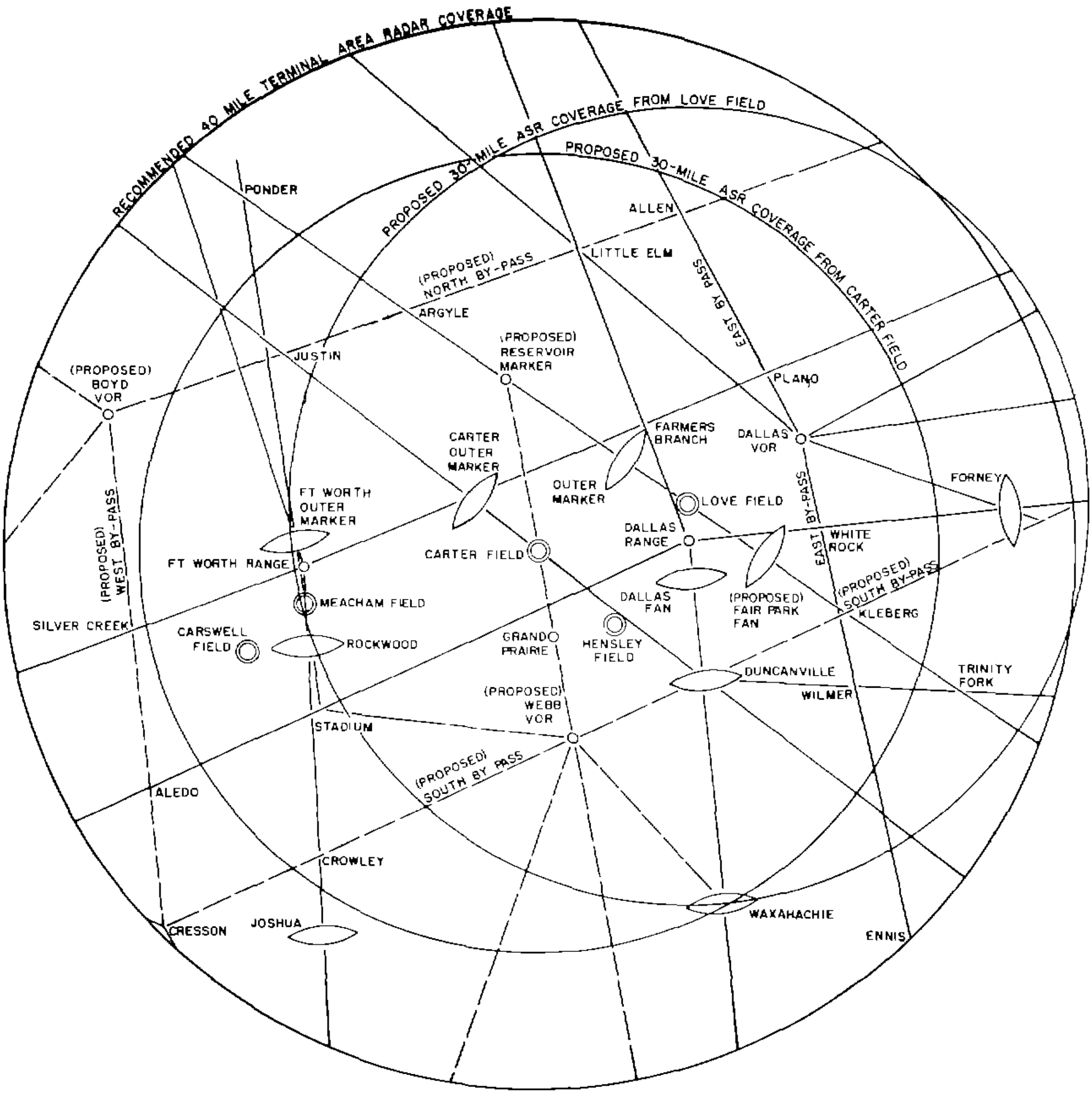


FIG. 11 PROPOSED RADAR COVERAGE AND NAVIGATION AIDS

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS, INDIANA

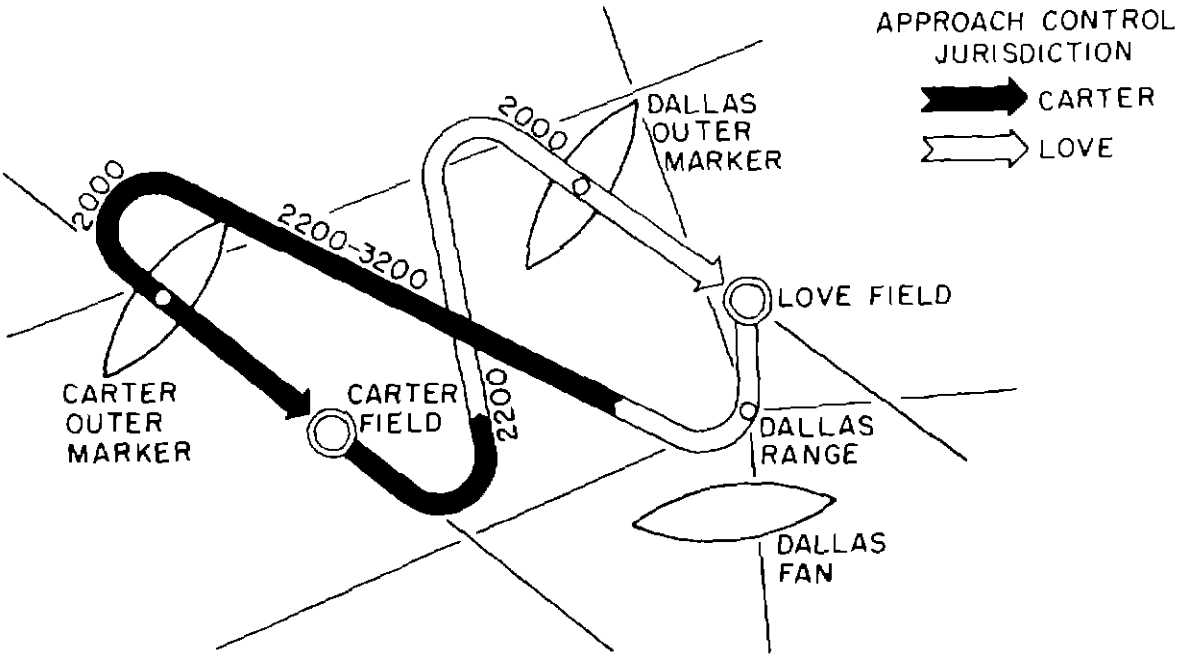


FIG. 12 INITIAL SHUTTLE PROCEDURE-
SE LANDINGS-WITH RADAR

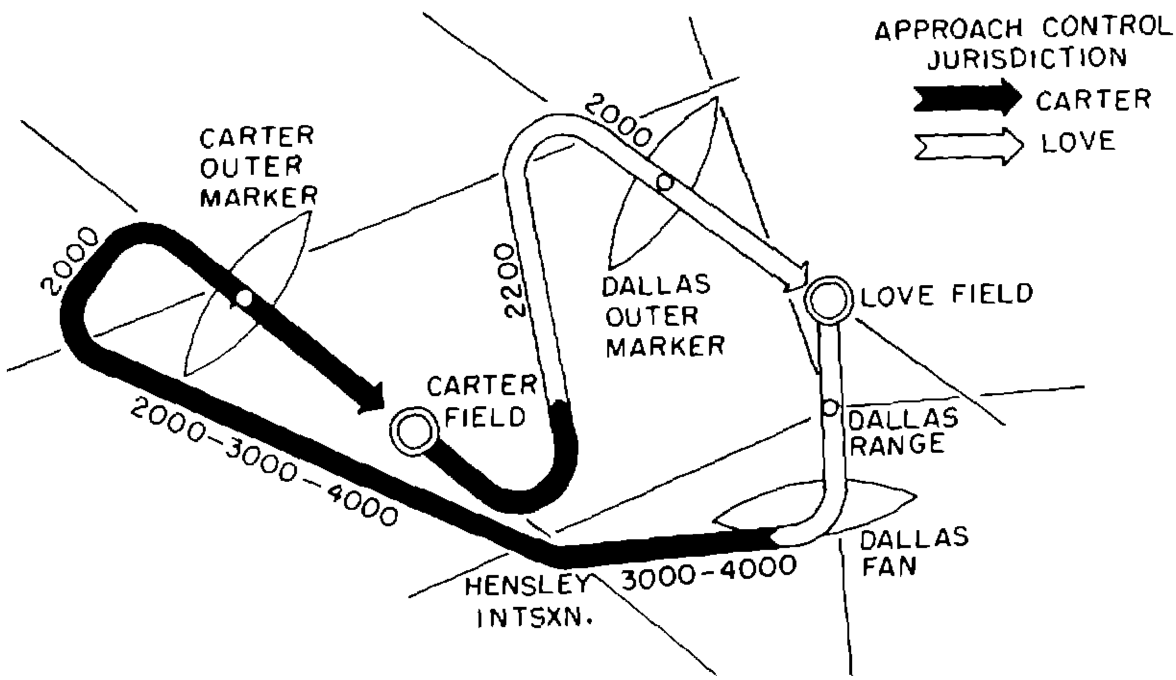


FIG. 13 RECOMMENDED SHUTTLE PROCEDURE-
SE LANDINGS-WITH RADAR

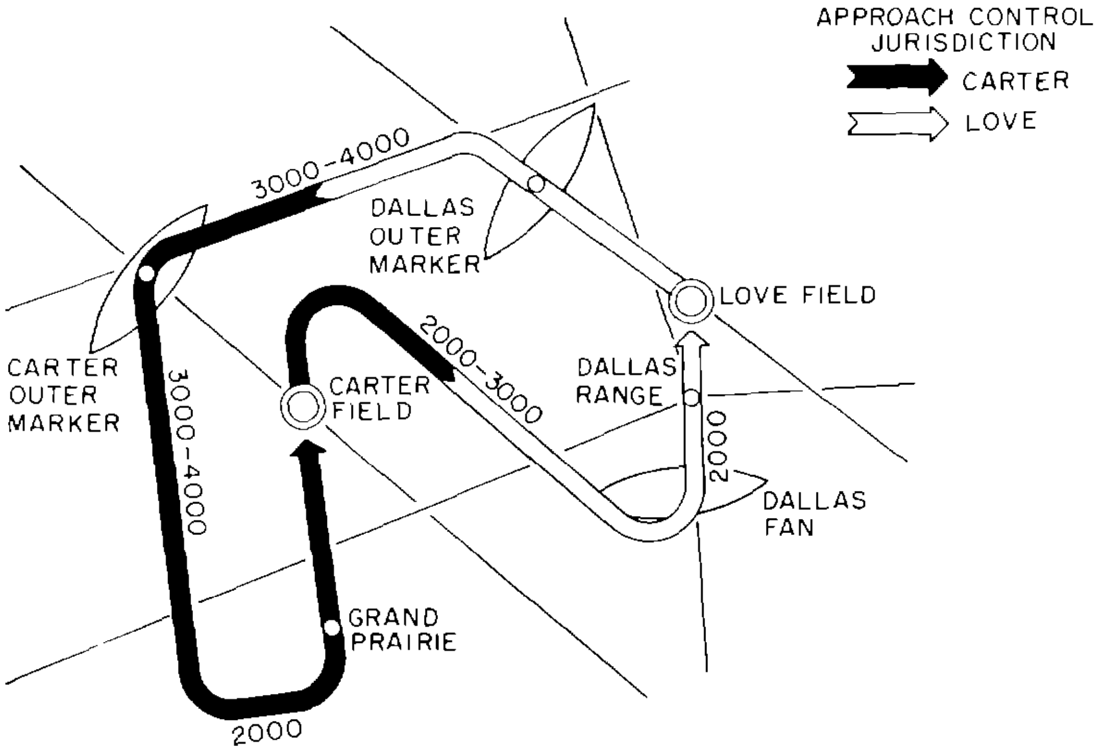


FIG. 14 RECOMMENDED SHUTTLE PROCEDURE-
NORTH LANDINGS-WITH RADAR

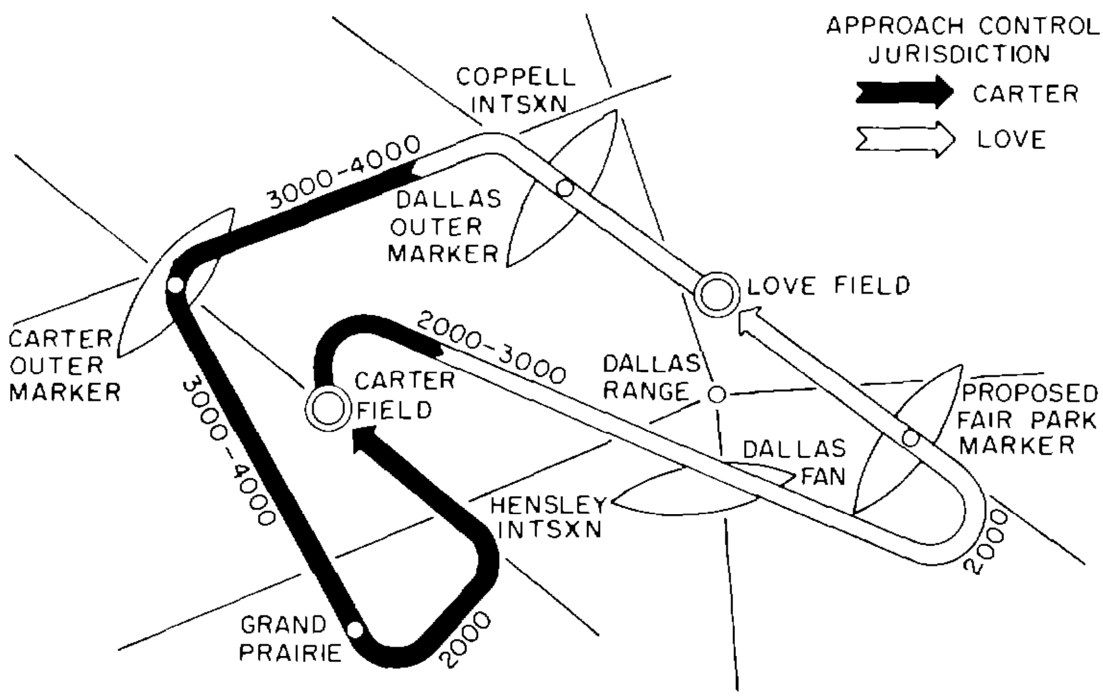


FIG 15 RECOMMENDED SHUTTLE PROCEDURE-
NW LANDINGS-WITH RADAR

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS INDIANA

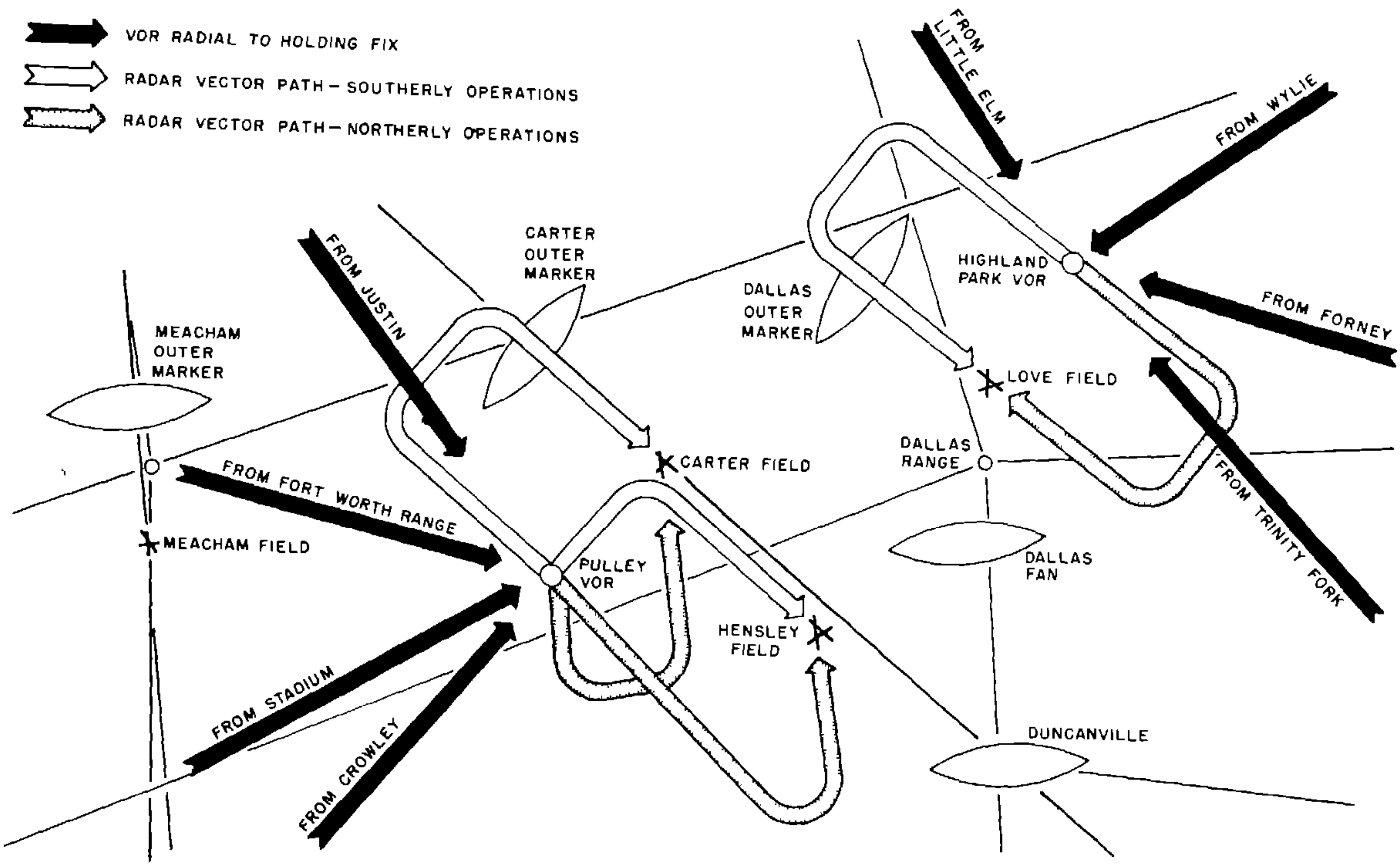


FIG 16 USE OF OFFSET HOLDING FIXES

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

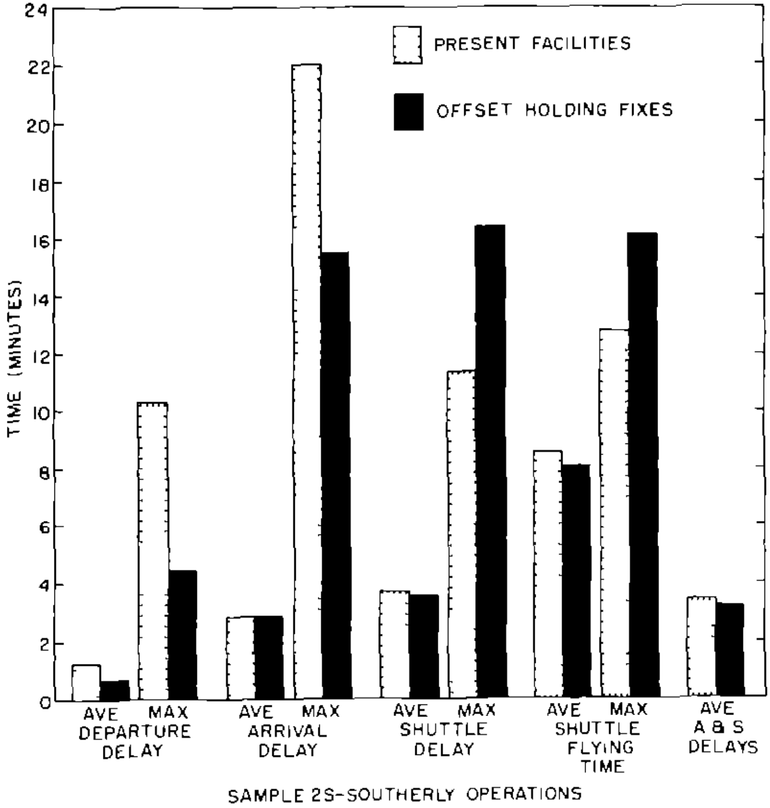


FIG 17 EFFECT OF OFFSET HOLDING FIXES-WITH RADAR

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS INDIANA

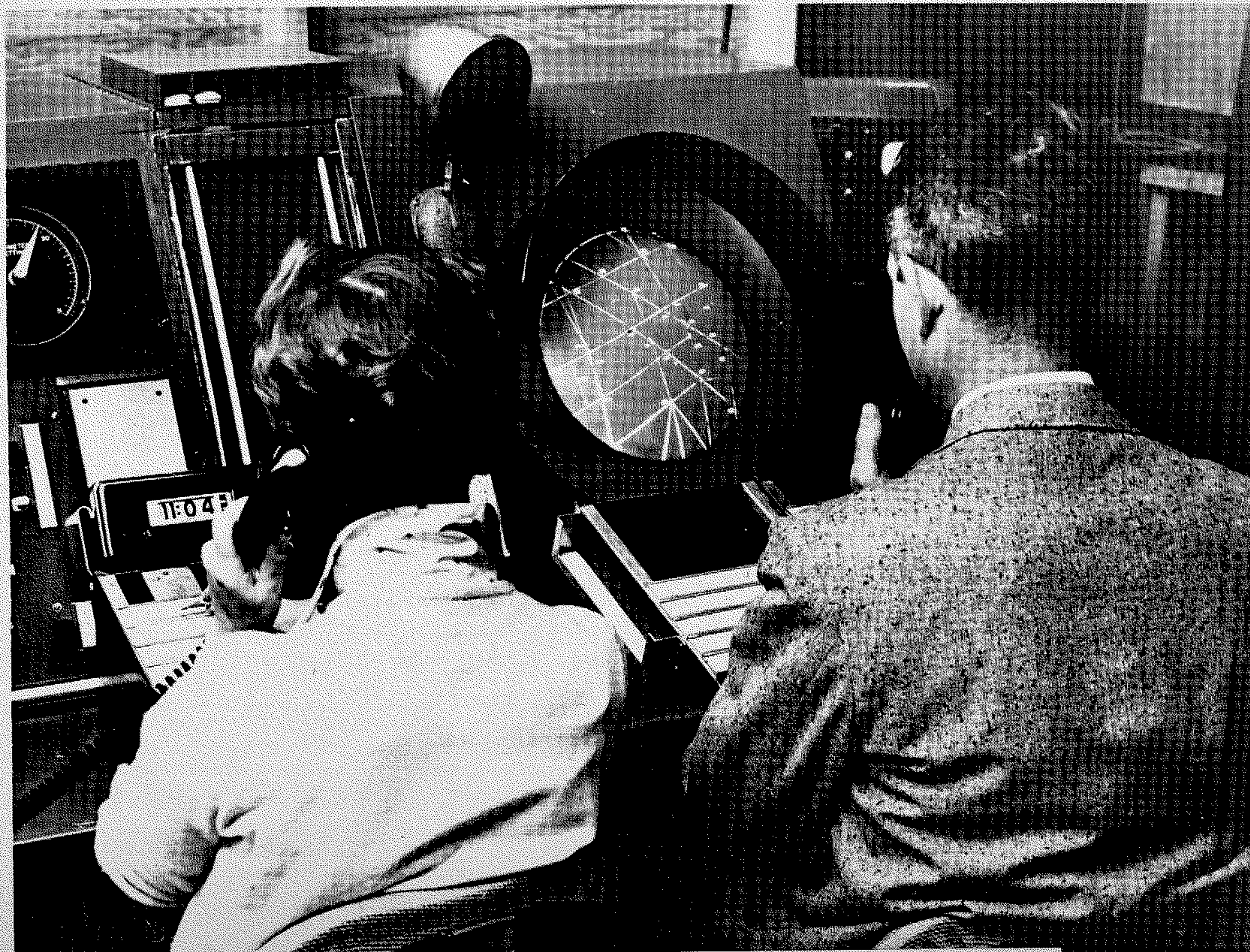


FIG. 18 EQUIPMENT LAYOUT FOR TESTS OF LOVE FIELD IFR ROOM OPERATIONS

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS, INDIANA

FIG. 19 COMBINED CENTER/APPROACH CONTROL OPERATIONS USING HORIZONTAL BRIGHT TUBE DISPLAY

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS, INDIANA

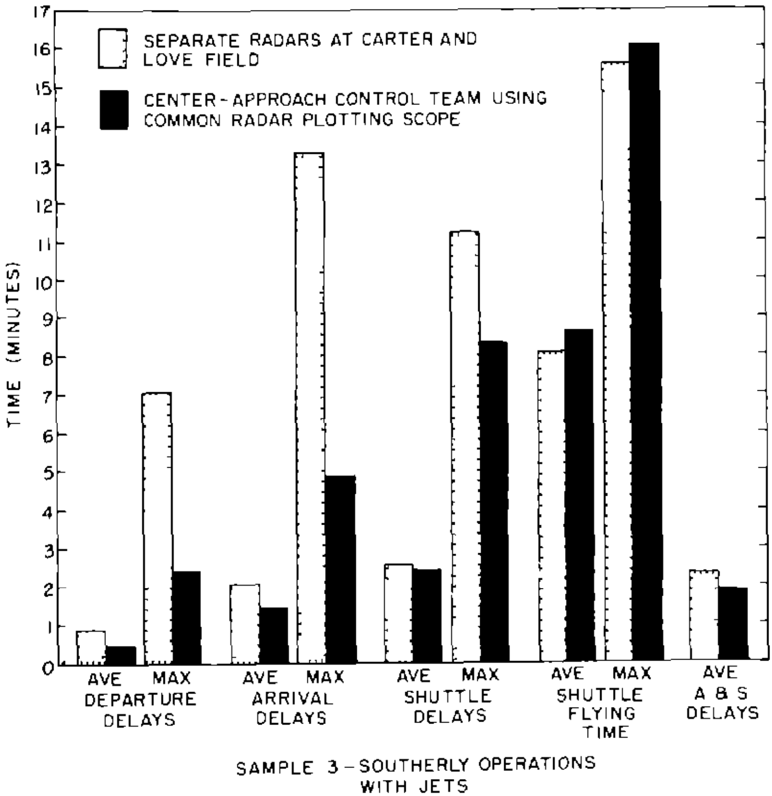
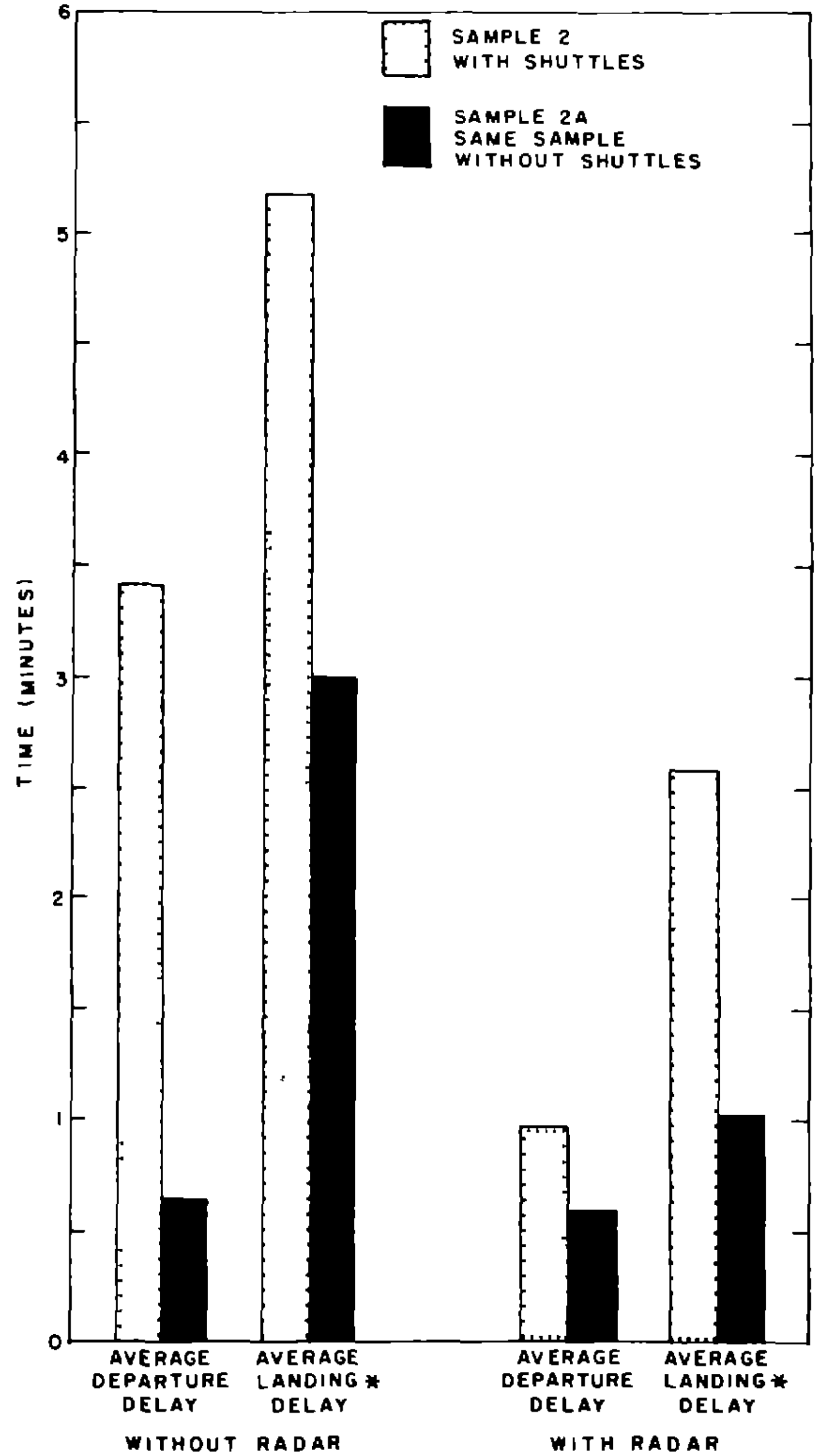


FIG 20 EFFECT OF COMBINED CENTER-APPROACH CONTROL OPERATIONS USING COMMON DISPLAY

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

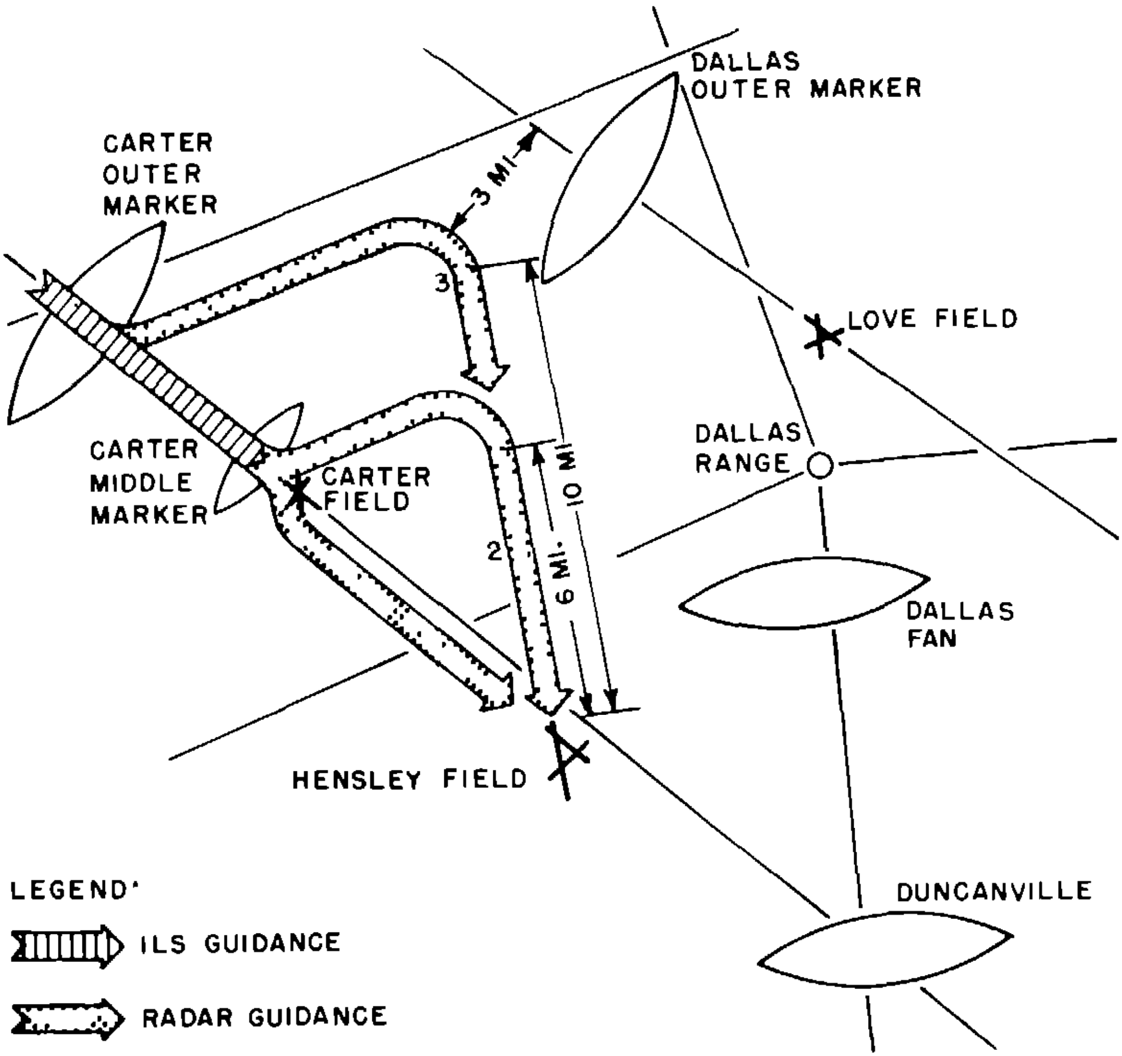


SAMPLE 2 AND 2A—SOUTHERLY OPERATIONS

* A & S DELAY—SAMPLE 2 ARRIVAL DELAY—SAMPLE 2A

FIG 21 EFFECT OF SHUTTLE TRAFFIC

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA



NOTE
NUMBERS INDICATE ORDER OF PREFERENCE
FROM AIR TRAFFIC CONTROL STANDPOINT

FIG. 22 SOUTHERLY APPROACH OPERATIONS — HENSLEY FIELD

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS INDIANA

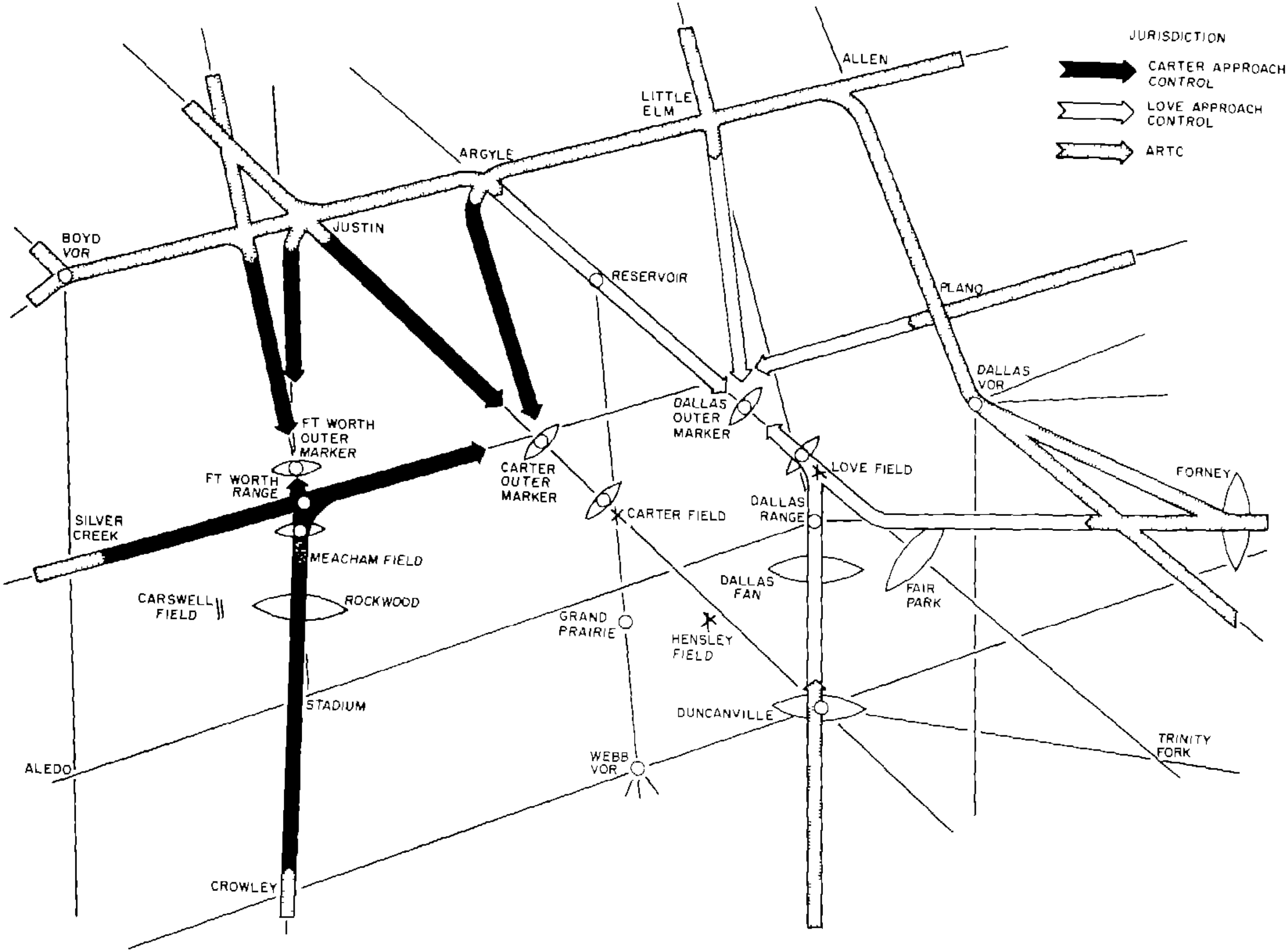


FIG 23 MAIN ARRIVAL ROUTES USING PROPOSED VOR LAYOUT

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

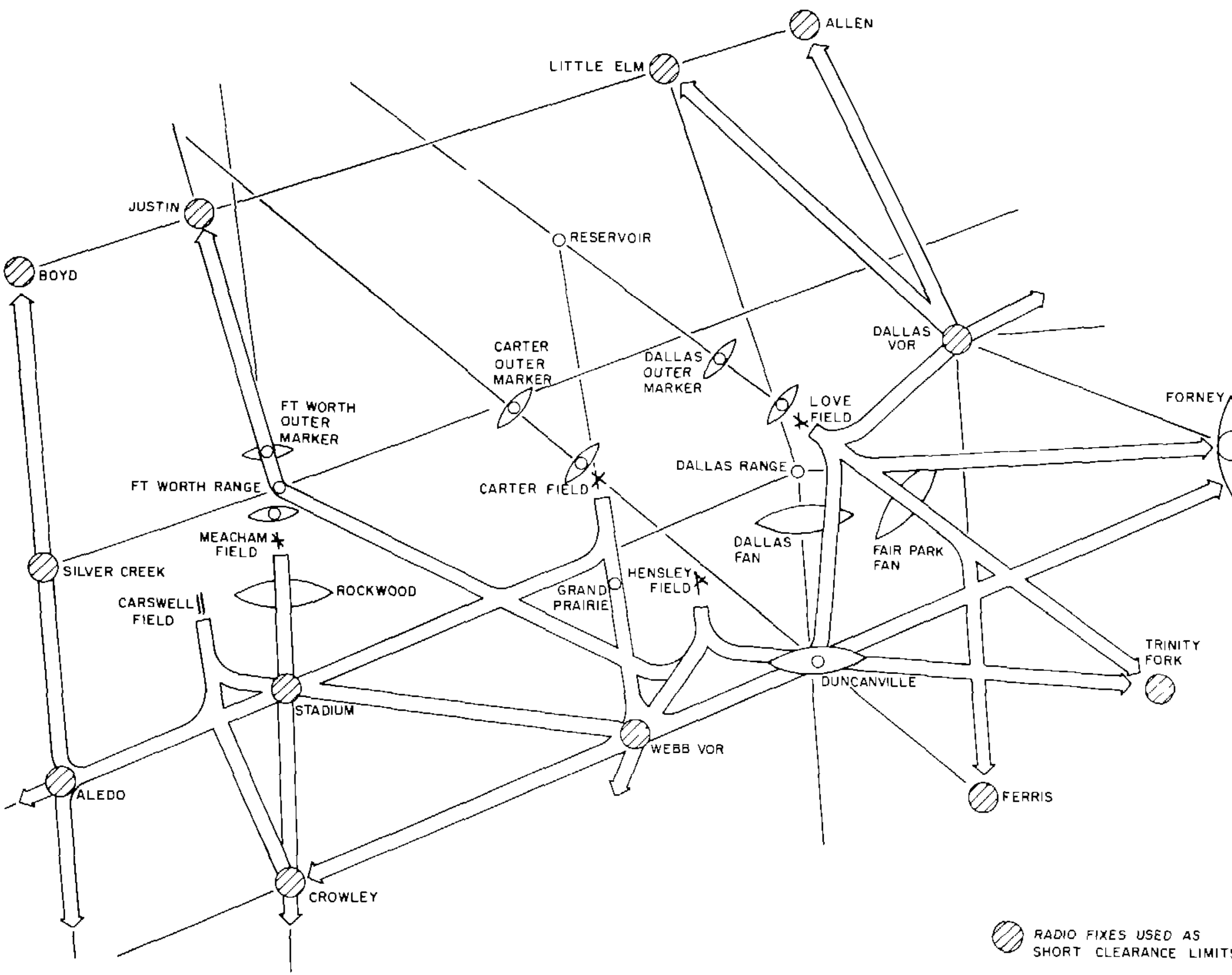


FIG 24 MAIN DEPARTURE ROUTES USING PROPOSED VOR LAYOUT

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

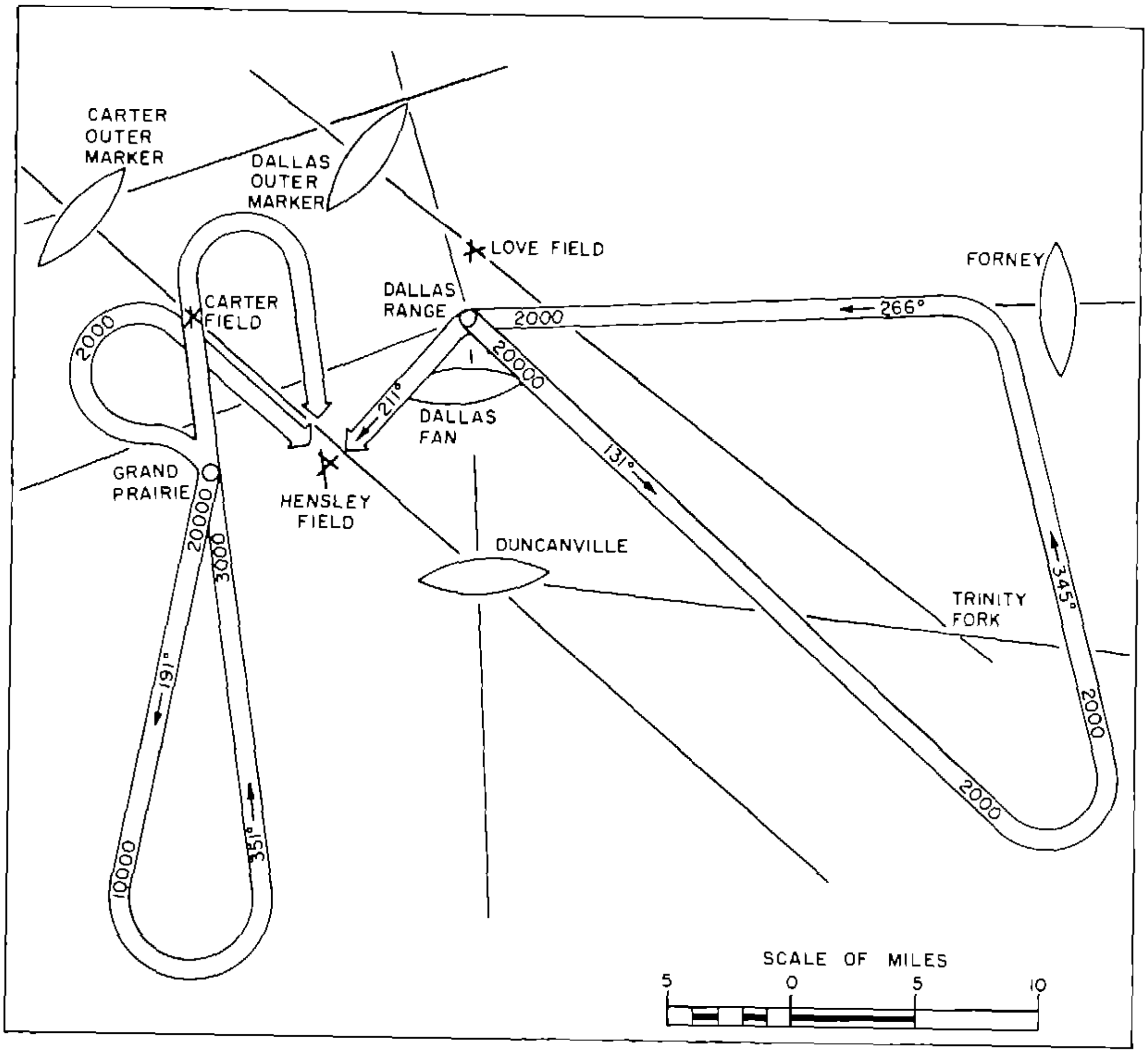


FIG 25 LF JET APPRACHES TO HENSLEY LEFT PROPOSED GRAND PRAIRIE ADF PROCEDURE, RIGHT PRESENT RANGE PROCEDURE

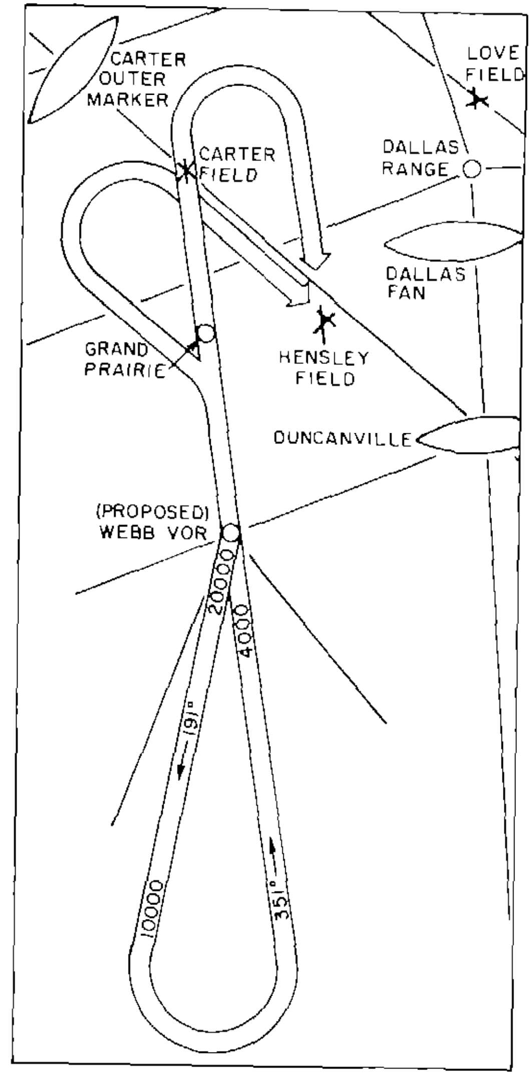
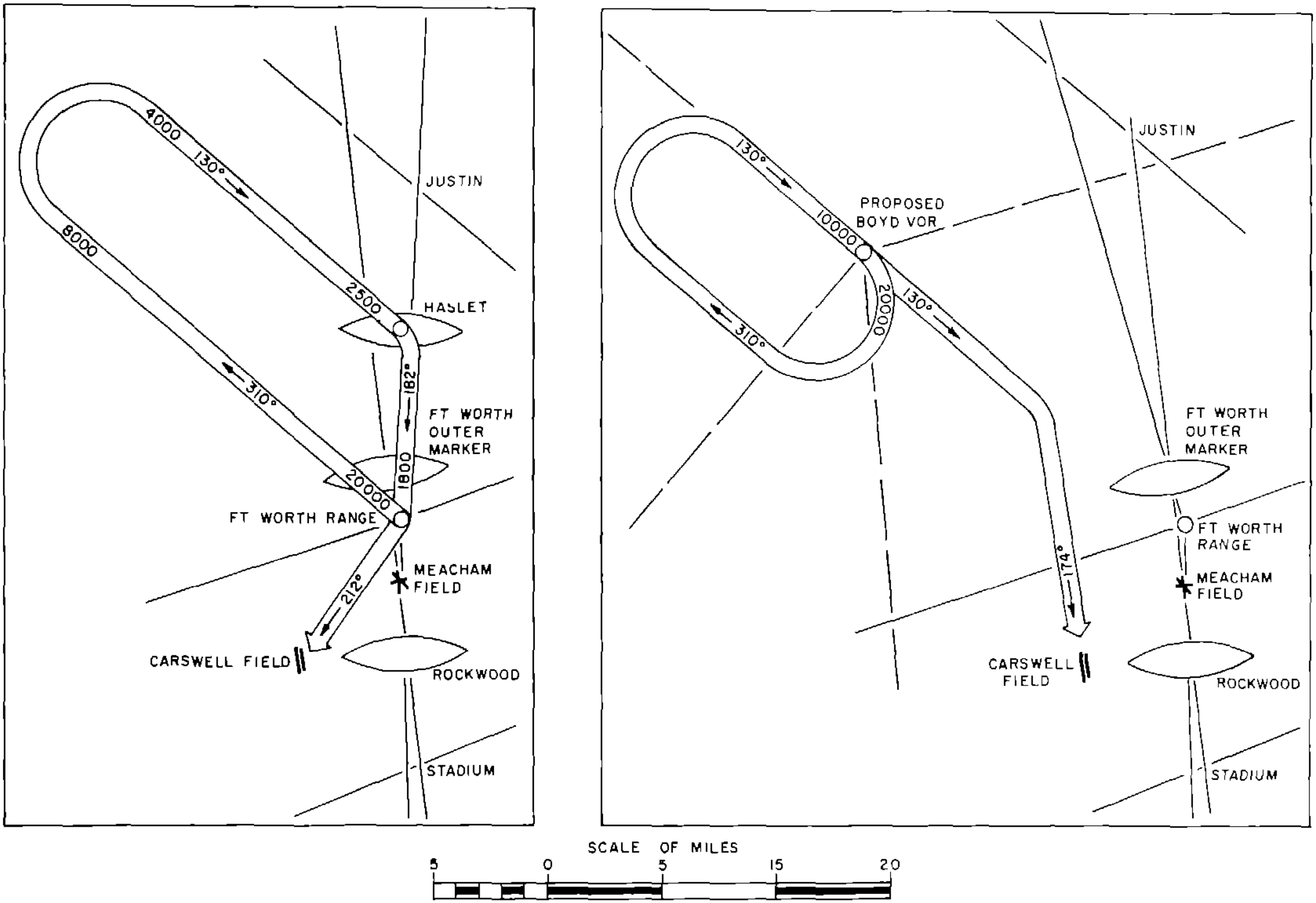


FIG 26 PROPOSED VOR JET APPROACH TO HENSLEY

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS INDIANA



LEFT PRESENT ADF PROCEDURE

RIGHT PROPOSED BOYD VOR PROCEDURE

FIG 27 JET APPROACHES TO CARSWELL

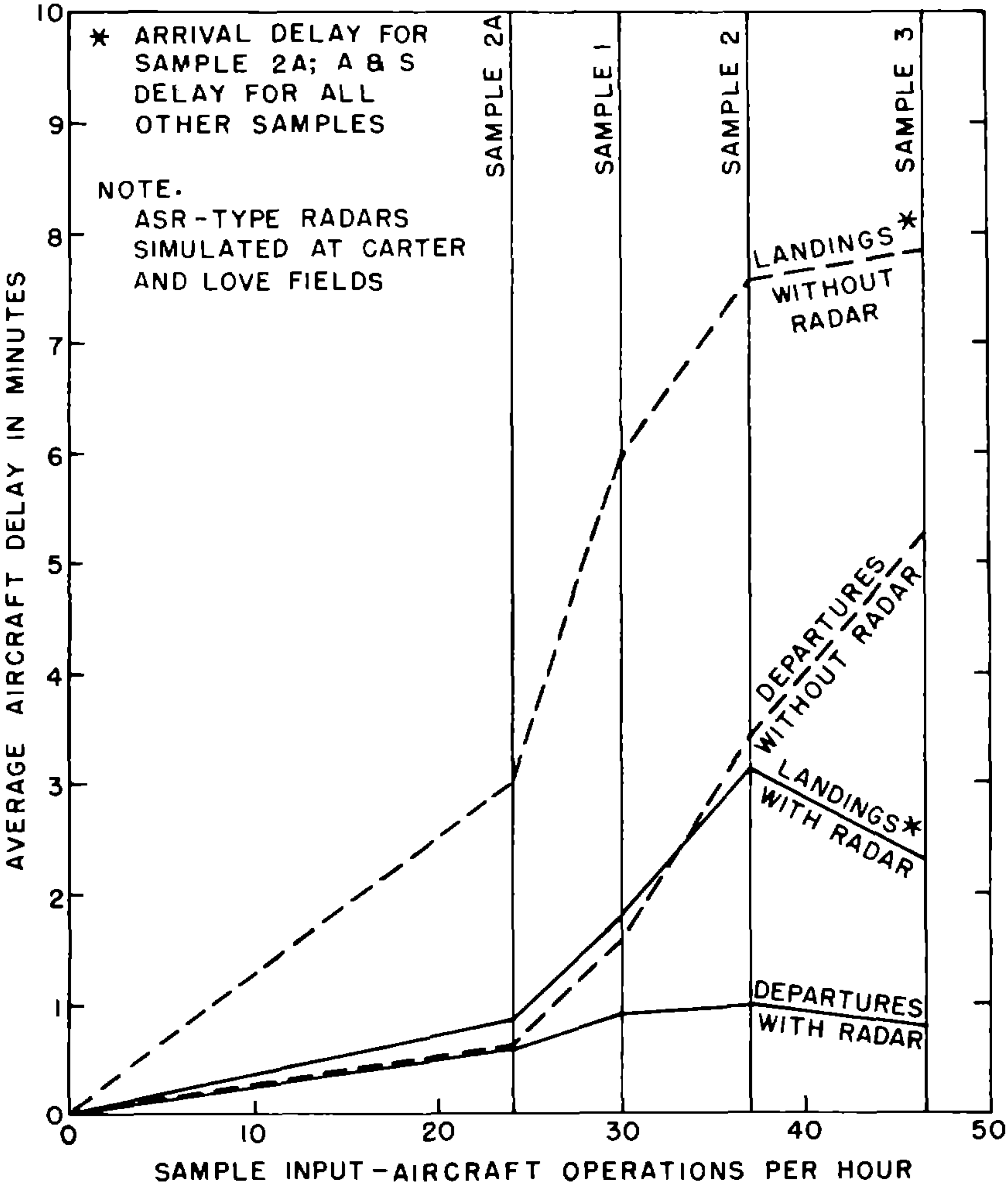


FIG. 28 EFFECT OF RADAR PROCEDURES ON AVERAGE DELAYS

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA