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DYNAMIC SIMULATION TESTS OF SEVERAL TRAFFIC CONTROL SYSTEMS FOR THE LOS ANGELES AREA

FOR LIMITED DISTRIBUTION

by

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SUMMARY

This report describes the evaluation of several proposed methods for increasing the air traffic capacity of the Los Angeles area under instrument flight rule conditions. This program was conducted at the CAA Technical Development Center through the use of the dynamic air traffic control simulator. Tests were directed toward the following major objectives:

1. Reassignment or relocation of arrival routes and departure routes to make them as independent of each other as possible.

2. Establishment of preferential routings to reduce the center/tower and center/sector coordination and to expedite the traffic on the most heavily traveled routes.

3. To establish operating procedures for use with the new route structure.

Based on the results of this test program, recommendations are made for:

1. Some procedures which, if implemented, will improve the present system.

2. An improved airway system to be used in the interim period before the long-range plan can be readied.

3. A long-range plan which involves the installation of several new navigation facilities.

INTRODUCTION

Early in 1957, the CAA Office of Air Traffic Control requested the Technical Development Center (TDC) to conduct a simulation study of the Los Angeles area air traffic. In September, four TDC air traffic controllers spent several days in the Los Angeles area observing traffic operations, gathering background material for the study, and discussing the proposed test program with representatives of CAA Region 4. The Region 4 office arranged to detail

13 air traffic controllers to TDC for the simulation runs. Franklin Institute Laboratories (FIL) were requested to assist in the program by preparing traffic samples, drawing up criteria for system evaluation, and analyzing the test results. The actual simulation runs were conducted throughout the month of February. During that period, many hours were spent by the controllers in conferences, discussing various ideas for changes in airway routing and control procedures, and in detailed planning of the required tests. The conclusions and recommendations in this report are based on numerous ideas obtained from a large number of the personnel who participated in the program. The various methods of airway arrangement and control procedures tested are referred to as "systems" in this report.

TEST ASSUMPTIONS

In order to simulate properly route systems which are not in existence, it is necessary to make assumptions in regard to equipment available and in some cases, in regard to changes in regulations governing traffic control operations. The following assumptions were made for the simulation tests of the Los Angeles area:

1. The Los Angeles Air Route Traffic Control (ARTC) Center had a dependable primary radar with coverage within a radius of 70 nautical miles of the Los Angeles International Airport.

2. The Los Angeles ARTC Center had dependable and adequate peripheral communications throughout the area within 100 miles of the airport in order that all instrument flight rule (IFR) aircraft could be in direct contact with the radar sectors.

3. All towers simulated, namely, Los Angeles, Long Beach, and Burbank, were utilizing both arrival and departure radar in the approach control area.

4. The Los Angeles International Airport had sufficient runways so that departures could be handled without any coordination with arrival controllers.

5. Civil jet aircraft would be controlled in the same manner as conventional aircraft; that is, cleared to clearance-limit points at the lowest open altitude and would hold if required.

6. Civil jet aircraft would make 1 1/2°-per-second turns above 5,000 feet, and 3°-per-second turns when below 5,000 feet.

7. The navigation aids used in this simulation would be operating by the time the Los Angeles ARTC Center is equipped with a commissioned radar.

8. A joint-use agreement could be effected between Air Traffic Control (ATC) and the Naval Air Missiles Test Center for the use of warning area No. 289.

9. Warning areas Nos. 290 and 291 would be altered to provide room for flight operations by ATC.

10. The IFR traffic operating presently from El Toro Marine Air Station, Los Alamitos Naval Air Station (NAS), Point Mugu NAS, and Oxnard Air Force Base (AFB) could continue to operate in the same airspace as at the present time. It is realized that the Los Alamitos NAS air traffic hardly can be dissociated from the air traffic at the Long Beach civil terminal, but due to a limited number of aircraft targets available with the present ATC simulator, it was not possible to conduct operations at this airport or the others which are listed. However, care was taken not to encroach upon the airspace presently used at these airports.

11. During the Los Angeles terminal area tests, a controlled rate of flow of 60 aircraft per hour was maintained. To land aircraft at this rate, it was assumed that, from a safety point of view, simultaneous and independent approaches could be made to two parallel runways.

EVALUATION METHODS

Traffic Samples.

Peak-day flight progress strips were obtained from the Los Angeles ARTC Center and the Los Angeles Airport Traffic Control Tower. FTL analyzed the strips to determine traffic flow characteristics, and to provide the basic information used in building Traffic Samples I and II.

Los Angeles terminal area Sample I consisted of 62 aircraft, and by varying the entry time flow rates, from 20 to 60 operations per hour were generated. This sample also was altered in 4 tests so that 60 per cent of the aircraft would be civil jet transports. Table I shows the distribution of aircraft.

Traffic from the 4 busiest hours was compressed into a 2-hour test to form air route Sample II. From this sample, air route strips were constructed for the Los Angeles arrival and departure sectors, and for the peripheral nonradar sectors. IFR traffic, which did not appear in the 2-hour sample because the routes were more than 60 miles from Los Angeles, was posted at the nonradar sectors to block usable altitudes and thus create a more realistic traffic picture for the controllers.

The simulation of both arrivals and departures at Los Angeles, Burbank, and Long Beach precluded the possibility of saturating any one airport or route with the 23 target projectors available during these tests. However, it was desirable to run the tests at less than the maximum airport acceptance rate in order to evaluate the over-all radar control and route system.

The most important index of a system's efficiency is the acceptance rate of the airport. Because Los Angeles International Airport is the primary terminal in the metropolitan area, initial simulation was used to determine the best arrangement for a radar vectoring area at this terminal. Tests were conducted using 2, 3, and 4 clearance-limit points, with both single and dual instrument landing systems (ILS).

Controller Workload.

Controller workload is an important element governing the capacity and safety of a traffic control system. At the present time, the communication measurements are the only portion of the entire load that can be determined accurately. A high-density traffic sample must be programmed, however, before the communication measurements begin to reflect the relative workload of a system. During the terminal area tests, a traffic sample of high density was used, but during the air route tests, the limited simulator target capacity precluded any chance of securing meaningful results. A useful method to supplement quantitative measurements of the controller workload has been to employ subjective analysis by the working controllers. This was done by questionnaires filled out by the controller teams at the termination of the simulation tests.

Controller Questionnaire.

The present and recommended route systems were rated by the Center controllers with respect to the difficulty or ease of control on the major routes to and from Los Angeles, Burbank, and Long Beach. A four-point rating system was used: very difficult, difficult, moderate, and easy. Explanatory comments were made with each rating, and the ratings and comments were discussed in a conference at the end of the simulation program. In order to evaluate the two systems, the following numerical values were assigned arbitrarily to the degrees of difficulty: very difficult - 3; difficult - 2; moderate - 1; and easy - 0.

Climb and Descent.

One of the principal improvements in the route structure tested in the simulation was the provision for one-way descent and climb routes to and from the Los Angeles metropolitan area. One-way airways eliminate the problem of planning altitude changes with respect to fast-closing, opposite-direction traffic. In addition, in nonradar areas, separation minima are much smaller for same-direction traffic than they are for opposite-direction traffic. It has been found through actual operational experience that one-way climb and descent routes are a major factor in increasing the capacity of a terminal area. At Los Angeles, the area in which altitude change can be made is limited by high terrain so that free climb and descent are a necessity. Besides setting up one-way airways, every effort was made to keep major climb and descent routes from crossing each other and en route traffic.

A quantitative comparison was made between the present route structure and the recommended route structure by rating each major arrival and departure route from Los Angeles according to the number of miles of unobstructed descent or climb within 100 miles of Los Angeles. There are 5 major arrival routes and 5 major departure routes so that the maximum score obtainable by this rating is 1,000. A breakdown of the ratings is shown in Table III.

It should be pointed out that, in order to provide independent climb and descent routes, some of the proposed routes are longer than at present; for example, to the north and east. However, in the present system, aircraft often have to gain or lose altitude in holding patterns, and the resultant time en route may equal or exceed the time consumed in the circuitous routing.

TERMINAL AREA TEST PROCEDURES

General.

An analysis of Los Angeles area traffic indicated that the greatest percentage of IFR traffic utilized International Airport. Terminal area tests were conducted to determine the optimum location and number of clearance-limit fixes.

Planning.

The entire Los Angeles area was considered when clearance limits and vector areas were planned. Routes, both arrival and departure, were not restricted needlessly. The proximity of airports and mountainous terrain precluded the possibility of a completely ideal approach configuration for each airport.

Assumptions.

The ILS was used as the final approach aid. Dual ILS approaches also were simulated. It was assumed that separation was sufficient to provide dual independent approaches. Altitude separation provided at glide slope interception would diminish gradually to touchdown. See Fig. 1. Military jet penetrations were started at 20,000 feet, as shown in Figs. 2 and 3. Civil jets and propeller aircraft utilized common altitudes and clearance limits. All aircraft entered the airway system 10 to 15 miles from the clearance limit. All clearance limits were assumed to be VOR ranges.

Traffic Analysis.

Density rates were 30 and 60 aircraft per hour, as shown in Table I. Arrival aircraft only were simulated. By analysis of actual Los Angeles flight progress strips, the percentage of aircraft from all directions was established. The same percentage was used in all tests. In final terminal area tests, 60 per cent of the propeller aircraft were changed to civil jets. Civil jet turn rate was 1 1/2° per second. Other rates for jet aircraft are shown in Table IV.

Approach Controller Positions.

The four approach controllers from the Los Angeles area interchanged positions during these tests. Two approach controllers vectored traffic to 1 ILS runway with the present 3-fix feeder system, as shown in Fig. 4. With a 2-fix feeder system, 2 approach controllers also vectored to 1 ILS runway, Fig. 5. A 4-fix feeder system employed 2 approach controllers vectoring to 2 independent ILS runways shown in Fig. 6. A revised 4-fix approach system, shown in Fig. 7, utilized 4 approach controllers, working as 2 teams, vectoring to 2 independent ILS runways.

Radar Presentation.

The approach control area was presented on two radar scopes shown in Fig. 8. Curved spacing reference lines at 3, 5, and 7 miles from the outer marker were etched on the radar maps. Spacing charts, as shown in Table V, were used as an additional aid to establish optimum separation between arrivals.

AIR ROUTE TEST PROCEDURES

Figure 2 shows the primary ARTC area simulated. This area was divided further into arrival and departure radar sectors. In order to provide a more realistic workload for the radar sector controllers, another sector was simulated encompassing all route fixes on the periphery of the radar sectors. It was the periphery sector controller's responsibility to descend aircraft, where practical, to a realistic altitude before entry into the radar sector of the Los Angeles ARTC Center, and to coordinate with the departure controllers concerning a satisfactory altitude for departing aircraft.

The 4 radar sectors of the Los Angeles ARTC Center were simulated, using 2 superimposed panoramic radar displays (SPANRAD). SPANRAD is a radar tracking device which uses TV techniques to superimpose the picture of a manually generated target marker, with that of the radar target, on a bright tube display. Figure 9 shows the SPANRAD's in use during the simulation tests.

Two radar arrival sectors operated from 1 SPANRAD, and 2 radar departure sectors operated from the second SPANRAD. Each air route sector used an associated flight progress board for its tabular display. The arrival controller identified and tracked all IFR over-flights in addition to his terminating traffic. Target markers at the arrival SPANRAD, 1 inch by 2 1/4 inches, were superimposed on the departure SPANRAD scope which used smaller markers (3/4-inch by 1 1/4 inches), permitting one to differentiate between each control sector. The markers also were color coded, with a different color for the two operations. Figure 10 shows a close-up of the SPANRAD console. Target markers for the arrivals and over-flights carried flight identity, route, altitude, and clearance limit. The departure target markers carried flight identity, altitude, and one fix to determine route of flight.

Nine experienced controllers from the Los Angeles ARTC Center, 2 from the Los Angeles Tower, and 1 each from the Burbank and Long Beach Towers, were detailed to TDC for the tests. Since the Tower personnel were experienced radar operators and the Center controllers were not experienced in radar techniques, the first five air route tests were run primarily to train the Center personnel in the use of radar. Each ARTC controller used direct communications with the aircraft, and was aided by an assistant controller who handled data-collection and tabular-display duties. Also, the assistant controller prepared target markers for the radar controller, and used the interphone system to exchange information with the three towers and the periphery sector.

The Los Angeles ARTC Center radar arrival control area was split into two geographical sectors. One sector handled Burbank arrivals and a portion of Los Angeles International traffic. The other arrival sector handled the remaining Los Angeles traffic, in addition to the Long Beach arrivals. The sectors varied slightly from one test to another, depending on route structures and procedures being tested. The departure radar sectors were similarly divided. The division of control for the recommended system is shown in Fig. 11.

Military jets were issued their long-range clearances prior to departure; all other departures from Los Angeles, Burbank, and Long Beach were issued short-range clearances to an altitude and fix sufficient to allow an uninterrupted climb while being handed off from tower to center radar. Los Angeles ARTC radar was utilized for only 40 to 45 miles on arrivals and departures in order to obtain maximum utilization of the available simulator targets. However, ANC posting was performed at perimeter fixes to evaluate the adequacy of the various route structures. Clearances to fly visual flight rules (VFR) on top were not issued. All aircraft had positive IFR separation, as would be the case in the Los Angeles area when storm conditions exist.

Blocked altitudes were used at several fixes to minimize coordination and simplify the radar departure procedures. In all systems tested, departure tunneling was held to a minimum. Every effort was directed toward providing, wherever possible, an uninterrupted climb to cruising altitude.

To generate departures and control the arrivals effectively, three terminal area IFR rooms were simulated during the air route tests. See Figs. 8, 12, and 13. Los Angeles Tower used two approach controllers, one handling all arrivals, the other handling the departures. Due to lack of equipment, one approach controller handled all operations from Burbank Airport and another approach controller handled all operations from Long Beach Airport.

In the latter portions of the air route tests, "Tower En Route Control" was simulated between the Los Angeles and Burbank Airports, and between the Los Angeles and Long Beach Airports. No attempt was made to extend this type of operation between the Burbank and Long Beach Airports, due to the small demand for this service and because of the added workload it would place on Los Angeles Approach Control.

TERMINAL AREA TEST RESULTS

Present Clearance Limits.

The present clearance limits, Baldwin, Hermosa, and Downey, are shown in Fig. 2. Lateral separation is inadequate between en route traffic on Victor Airway 107 and holding traffic at Baldwin. In fact, Baldwin seldom is used because it is difficult for the pilots to navigate to the intersection and equally difficult for the controllers to vector aircraft from the holding pattern to the ILS course. With few exceptions, pilots will accept an exigent, high rate of descent, and a straight-in approach, rather than take a circuitous route over Baldwin. This is one of the factors contributing to a high-density traffic flow at Downey.

Two-Clearance Limits.

A two-fix system is shown in Fig. 5. A more acceptable trombone-type vector pattern resulted from this arrangement. Traffic was more evenly divided, because better routes were established into both fixes.

Four-Clearance Limits.

Figure 6 shows the traffic divided between four clearance limits. The fixes accommodated a greater volume of traffic. The location of the clearance limits and the alignment of the holding patterns did not prove optimum for expeditious movement. A revised system was suggested.

Four-Clearance Limits (Revised).

The relocated clearance limits are shown in Fig. 7. A high volume of traffic was moved with little difficulty. The Los Angeles Tower controllers preferred this to the other systems tested.

AIR ROUTE TEST RESULTS

Present Route System.

The present route system, shown in Fig. 2, was utilized to provide radar equipment and procedural training for the Los Angeles ARTC personnel. These tests also were conducted to provide a basis for comparative measurements of succeeding systems, to confirm inadequacies previously pointed out by Region 4 personnel, and to note further traffic bottlenecks caused by increased traffic densities.

During the simulation tests, the following problems were considered to be of major importance:

1. Aircraft at Baldwin blocked Victor Airway 23, and forced over-traffic to climb to an altitude above the holding pattern or to stop short and wait for an altitude through the holding pattern airspace.

2. Los Angeles arrivals via Victor 8N, because of high terrain, reached Downey Marker at altitudes prohibiting straight-in approaches.

3. Meshing of traffic from Victor 8 and Victor 16 at Ontario. This combined flow meshing with Victor 8N at La Habra is very difficult to control because of the high minimum en route altitudes.

4. Los Angeles arrivals from the north, via Fillmore and Victor 107, are restricted to 8,000 feet or above until 5 miles south of the Burbank localizer due to Burbank arrivals and departures.

5. All Los Angeles departures en route to the ocean intersections, which include Eel, Dolphin, Carp, Bonita, San Pedro, and Albacore, must tunnel under the arrivals from the northwest en route to the Hermosa pattern.

6. Los Angeles departures, proceeding northeast via Victor 210 and Victor 8, presently are required to climb to high altitudes in holding patterns at the ocean intersections to clear Victor 23 en route traffic and Los Angeles or Long Beach arrivals.

7. West and northwest-bound departures from Burbank cannot operate independently of Burbank arrivals because of terrain restrictions. Burbank departures via El Monte intersection are required to climb to high altitudes before proceeding on course. This procedure forces Los Angeles departures using Victor 210 to climb to very high altitudes before leaving the Los Angeles VOR.

8. Long Beach departures and missed approaches are confined to a small area at low altitudes, due to the location of the Hermosa pattern and the airspace used for radar vectoring by Los Angeles Approach Control.

9. Heavy over-traffic and high terrain on Victor 23 make it very difficult to descend arrivals or climb departures in and out of the metropolitan airports.

During the initial tests, departures from Los Angeles and Long Beach were cleared at random to six fish intersections in the same manner presently employed. This method was discarded for use with radar due to the numerous crossing courses that were created when the aircraft departed the fish intersections en route to Camarillo, Los Angeles, Long Beach, or Oceanside. To remedy this problem, a regimented traffic flow was implemented, as shown in Fig. 2A. This system reduced coordination between the departure controllers, and simplified the radar tracking problems.

The next major problem encountered, following the initial tests on the present system, was caused by excessive coordination between the radar departure controllers and the arrival controllers who were tracking the over-traffic. This occurred when the departure controllers wanted to clear eastbounds across Victor 23. To alleviate this problem, altitudes of 11,000, 12,000, 13,000, and 14,000 feet were reserved on Victor 23 for the use of departure aircraft only. This solution was adequate, but en route flights were forced to altitudes higher than desirable. A list of location identifiers used on route maps is presented in Table VI.

Interim Route System.

The interim route system utilized navigation aids presently programmed for installation. The number and location of these aids were sufficient to provide a dual route structure for the major flow of traffic. Tests of this system consisted of two basic plans, Nos. 2 and 3. Because the terminal area system, as originally planned, did not coincide with previous tests, plan No. 1 was never simulated.

Plan No. 2 incorporated twin trombone-type feeder fixes for Los Angeles International Airport. Northbound en route over-traffic was routed via the relocated Victor 23, and southbound traffic from the north was routed via Victor 501. Arrivals from northwest were routed to Baldwin via Fillmore, and the departures were routed via Oxnard. Details of the traffic routings are shown in Figs. 14 and 14A.

Plan No. 3 evolved when it was learned that Region 4 had programmed omniranges for the Las Cruces and Avalon sites. Plans for obtaining portions of warning areas 289, 290, and 291 had been formulated, making it possible to implement an off-shore airway, yielding a dual flow of traffic along the north coastal route. This structure reduced the congestion at Fillmore, and eliminated two-directional traffic over Santa Barbara. The Los Angeles International terminal area was altered to include four feeder fixes, and traffic flow from the northwest (coastal route) was reversed by clearing the arrivals to Hermosa instead of Baldwin. Details of plan No. 3 routing system are shown in Figs. 15 and 15A.

Recommended System.

The recommended system, shown in Figs. 3 and 3A, included the better features of all maps submitted, and it is believed that it either solves or materially reduces the nine problems of major importance listed under the present route system.

Prior to simulation tests of the recommended system, the following changes were made:

1. Thirty per cent of Los Angeles International Airport traffic was changed to civil jet transports. Speeds and descent and turn rates are shown in Table IV.

2. Three primary clearance limits, Baldwin, Maywood, and Artesia, were provided for Los Angeles Approach Control.

3. Clearance-limit fixes at Los Angeles were restricted to altitudes of 8,000 feet and below.

4. Los Angeles arrival traffic from Palmdale was rerouted to the east via Victor 8, or to the west via Lake Hughes and Fillmore. It was not practical to use V165 between Palmdale and Baldwin because of high terrain, departures crossing Victor 23 at 9,000 and 10,000 feet, and the heavy flow of north coastal traffic into Baldwin.

5. Burbank departures, climbing to the southeast, then back to Burbank range, were restricted to cross the Burbank range at or below 7,000 feet unless coordination was effected with the arrival controller.

6. Long Beach arrivals from the north, via Victor 501, were handled by the ARTC departure controller after crossing the Los Angeles VOR.

7. The Long Beach VOR was relocated approximately 20 miles southeast of its present location. However, subsequent to the simulation runs, a map study indicated that the VOR could serve a dual purpose if it was located on the Long Beach ILS course, approximately five miles from touchdown. It then could serve as an en route navigation aid for Victor 23 and as an outer marker, so located as to provide TSO separation from the Artesia holding-pattern airspace.

The three clearance-limit fixes, as shown in Figs. 3 and 3A, were considered adequate for the traffic densities simulated. By eliminating the Hermosa pattern, Long Beach was provided a more equitable departure and missed-approach area. However, if at some future date the traffic densities at Los Angeles grow in greater proportions than those at Long Beach, it may warrant reestablishing Hermosa as a clearance limit.

The arrival flow from the northwest again was rerouted, so as to terminate at Baldwin. This eliminated all tunneling by Los Angeles departures and reduced the number of aircraft crossing Fillmore and the Burbank ILS course. The traffic flow required that arrivals and departures cross paths somewhere between Los Angeles and San Francisco. However, it was felt that this would resolve itself north of Santa Barbara and Las Cruces, since the northbounds would be at an odd altitude and the southbounds at an even altitude.

Departures from the Los Angeles area utilized blocked altitudes of 9,000 and 10,000 feet when crossing Victor 501 and Victor 23. En route traffic had reserved altitudes of 11,000, 12,000, and 13,000 feet between Val Verde and Avalon on Victor 501, and between Long Beach and Saugus on Victor 23. The blocked altitudes were used by the appropriate controller without coordination. This was an effective method of reducing intrasector workload in the ARTC radar area.

The dual-airway configuration to the east and northeast was a flexible routing system for clearing aircraft to the Maywood and Artesia patterns. The sector supervisor could divide the arrival flow evenly between the patterns by specifying the routing from as far out as Daggett and Palm Springs. Last-minute changes could take place in the Ontario-Arlington area, as shown in Fig. 3. These routes also traverse terrain low enough to provide arrivals with a straight-in approach to the airport when permissible.

Several problems were alleviated by the addition of a second route for en route flights to supplement Victor 23. Traffic was split up with northbounds on Victor 23, and southbounds on Victor 501, thus doubling the number of usable altitudes. This arrangement permitted an easier integration of departures with over-flights, due to the absence of opposite-direction traffic on these airways. This type of routing helped in expediting the descent of arrivals into the Los Angeles area from the north and from the southeast. The one-way flow of traffic also provided Burbank with a system, permitting a continuous flow of arrivals and departures.

Tests of Recommended System Without ARTC Radar.

After the optimum route structure had been determined and found to work well under radar control, it was decided that comparative runs should be made with and without radar in the center. Delay measurements showed that there were 452 minutes of delay when no radar was used and only 61 minutes of delay in the full radar system. In addition, it was necessary to eliminate completely seven flights in the no-radar runs because the target consoles were not available, having been delayed on their preceding flights. If these seven targets had flown, it is reasonable to assume that the delays in the no-radar runs would have been even greater.

Workload in the no-radar runs was much greater than in the radar runs. The air/ground communications times were approximately 32 per cent higher in the air route center and 28 per cent higher in the terminal area. Although the advantages of radar are well known, the contrast between the high workload no-radar control and the relaxed radar control was impressive.

CONCLUSIONS

1. Tests showed that there is excessive coordination required between the arrival and departure air route sectors in the present system.

2. Air traffic at Burbank, even though of moderate density, experiences excessive delay due to lack of a system which will permit a continuous arrival and departure flow.

3. Long Beach Tower controllers are very restricted in authorizing aircraft movements northwest of the airport due to the use of Hermosa as a clearance limit and the proximity of the Los Angeles Tower radar vector area. No solution to this problem is apparent with the present system.

4. The straight-in approaches from Downey Marker to the Los Angeles airport for civil aircraft are undesirable with heavy traffic densities, because little path-stretching can be accomplished to provide fine-grain spacing. Until a newer route structure can be devised, there appears to be no solution to this problem.

5. The military jet penetration utilizing the area west of the Los Angeles omnirange severely restricts the departure routes from Los Angeles Airport.

6. The routes provided for en route over-flights in the interim system as well as the recommended system are much better than those provided in the present system. However, the routes continue to restrict departure traffic and terminal-area arrival traffic because of their proximity to the terminal areas. Because of terrain restrictions to the east of this area, no better solution to this problem was reached during this simulation.

7. Tests indicated that the recommended system could be used without ARTC radar. However, the total traffic movements were reduced considerably when compared to tests using ARTC radar.

8. The westbound radar-only departure route from Burbank, as shown in Fig. 3A of the recommended system, appeared to be very questionable from a safety point of view, and it created a high controller workload.

RECOMMENDATIONS

1. A system of blocked altitudes, similar to that used in these tests, should be implemented as soon as possible to minimize coordination between air route sectors.

2. Procedures should be implemented to provide the Burbank controllers with a system which will permit a continuous arrival and departure flow of traffic in their area.

3. When the necessary navigation aids become available, the recommended air route system described in this report should be installed as rapidly as possible. The procedures used in these tests, or similar procedures, should be adopted.

4. As soon as the route structure permits, the military jet aircraft destined for Los Angeles International Airport should make a straight-in approach from 20,000 feet, starting at the Ontario VOR.

5. Long-range radar should be installed at the Los Angeles ARTC Center as rapidly as possible.

6. The terminal-area arrangement for Los Angeles International Airport, as described in the recommended system, should be installed as soon as practicable. It is believed that three clearance-limit points will suffice for this airport at the present time. When traffic densities warrant, a fourth clearance-limit fix can be added to the area.

7. In the recommended system, the Long Beach ILS clearance limit should be moved far enough southeast to provide TSO separation from Victor Airway 64.

TABLE I

TERMINAL AREA ARRIVAL SUMMARY

100 Per Cent Civil Propeller Aircraft

			Propeller			Military Jet
Origin	Per Cent of Total	No. of Aircraft	Slow	Medium	Fast	
North	18	11	2	6	2	1
Northeast	13	8		1	6	1
East	32	20		4	14	2
South	18	11	1	1	8	1
Northwest	19	12		2	10	

60 Per Cent Civil Jet Aircraft

			Propeller			Jet	
Origin	Per Cent of Total	No. of Aircraft	Slow	Medium	Fast	Civil	Military
North	18	11	2	2	1	5	1
Northeast	13	8		1	3	3	1
East	32	20		2	4	12	2
South	18	11	1	1	3	5	1
Northwest	19	12		1	2	9	

TABLE II

CONTROLLER RATINGS OF TWO SYSTEMS

Route	Present System			Recommended System		
	Airport			Airport		
Arrival	Los Angeles	Long Beach	Burbank	Los Angeles	Long Beach	Burbank
North Coastal	M	M	M	E	D	E
North Valley	D	D	D	E	D	E
Northeast	M	M	M	M	M	M
East	M	M	M	M	M	M
South	M	M	-	E	E	-
Departure						
North Coastal	M	D	M	E	E	M
North Valley	D	D	V	M	M	M
Northeast	D	D	D	M	M	M
East	V	V	D	E	E	D
South	M	M	-	E	E	-
Total	3V, 10D, 15M, 0E			0V, 3D, 13M, 12E		

When V = 3 and Los Angeles = 2
D = 2 Long Beach = 1
M = 1 Burbank = 1
E = 0

Present System Rating -59
Recommended System Rating -23

Legend:

V - Very Difficult

D - Difficult

M - Moderate

E - Easy

TABLE III

MILES OF FREE CLIMB AND DESCENT ON MAJOR ROUTES WITHIN 100 MILES OF LOS ANGELES INTERNATIONAL AIRPORT

Route	Present System (miles)	Proposed System (miles)
Arrival		
North Coastal	0	100
North Valley	0	40
Northeast	25	70
East	0	100
South	50	50
Departure		
North Coastal	60	100
North Valley	0	70
Northeast	20	80
East	0	100
South	75	100
Total	230	810

TABLE IV

CIVIL JET TRANSPORT SPEED PROGRAM

Altitude MSL (feet)	Cruise (TAS-Knots)	Holding (TAS-Knots)
20,000 or above	450	315
18,000	340	
15,000	330	290
10,000	305	270
6,000		245
5,000	260	220
4,000		200
3,000		190
2,000		160

Descent Rate: 3,000 feet per minute, reduced slowly to 500 fpm below altitude of 6,000 feet.

TABLE V

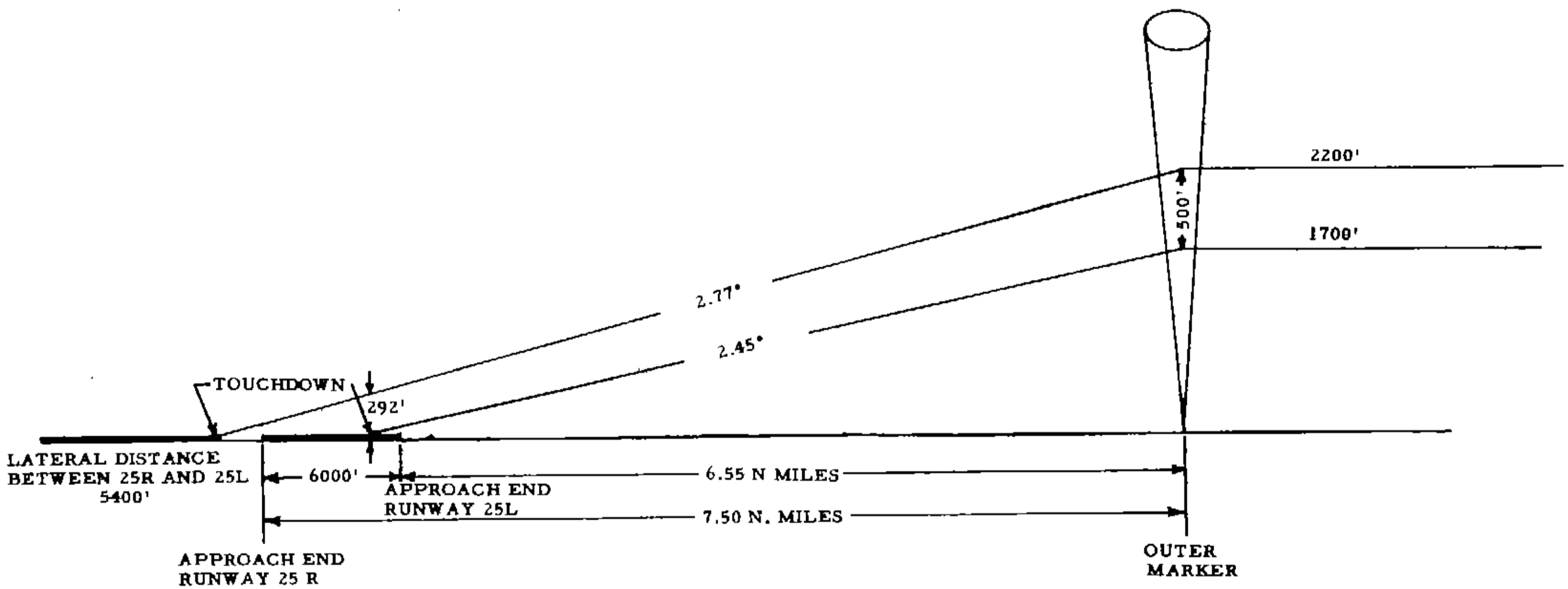
OPTIMUM AIRCRAFT SPACING LOS ANGELES INTERNATIONAL ILS

5 Miles from Outer Marker	Aircraft Sequence		Outer Marker Separation (miles)
	No. 1	No. 2	
6.6	S	M	5.1
7.5	S	F	5.5
10.0	S	J	6.6
3.6	M	S	3.1
5.7	M	E	4.5
7.8	M	J	5.8
3.0	F	S	3.0
3.4	F	M	3.5
7.0	F	J	5.2
1.7 S - 2.9 M - 3.0 F	J	SMF	3.0
5.0	Same Type		4

Aircraft Category		Approximate Approach Speed (mph)	(knots)
S	Slow	120	104
M	Medium	140	122
F	Fast	150	130
J	Jet	180	156

TABLE VI
LOCATION IDENTIFIERS USED ON SIMULATION MAPS

AB	Albacore	DOW	Downey	NX	Hines
AL	Alhambra	DX	Henderson	OAF	Oxnard
AP	Apple	EDW	Edwards A.F.B.	OCN	Oceanside
ARL	Arlington	EL	Eel	ONT	Ontario
ART	Artesia	EX	El Monte	OX	Bullion
AT	Atwood	FL	Fellows	PER	Perch
AVL	Avalon	FIM	Fillmore	PH	Phelan
AX	Arrowhead	FL	Flounder	PK	Pacific
BAL	Baldwin	FO	Fontana	PMD	Palmdale
BE	Bellflower	PX	Pacoima	RY	Reyes
BO	Bonita	GL	Gulf	SBA	Santa Barbara
BR	Broome	GOR	Gorman	SO	Soledad
BS	Barstow	GX	Helendale	SP	San Pedro
BUR	Burbank	HA	Hawkins	SR	Seares
CA	Catalina	HEC	Hector	UX	Point Dume
CAV	Camarillo	HMS	Hermosa	VT	Ventura
CC	Cucamonga	HX	Harvey	VV	Val Verde
CG	Canoga Park	KI	Kingfish	VY	Victory
CI	Newberry	LAX	Los Angeles	WF	White Fish
CO	Carp	LCR	Las Cruces	WHL	Woodland Hills
CM	Costa Mesa	LGB	Long Beach	WL	Woolston
CS	Corona	LHU	Lake Hughes	WR	Wright
CV	Covina	LI	Ling	WX	White Oaks
CY	Cuyama	LU	Lucerne	XX	Pinos
DAG	Daggett	LX	Shoreline	YX	Berry
DI	Diablo	MAY	Maywood	ZX	Saugus
DO	Dolphin	MO	Morrow		



NOTE:

GLIDE SLOPE ANGLE NOT DRAWN TO SCALE
FIELD ELEVATION 126'

FIG. 1 LOS ANGELES PROPOSAL FOR A DUAL INSTRUMENT LANDING SYSTEM

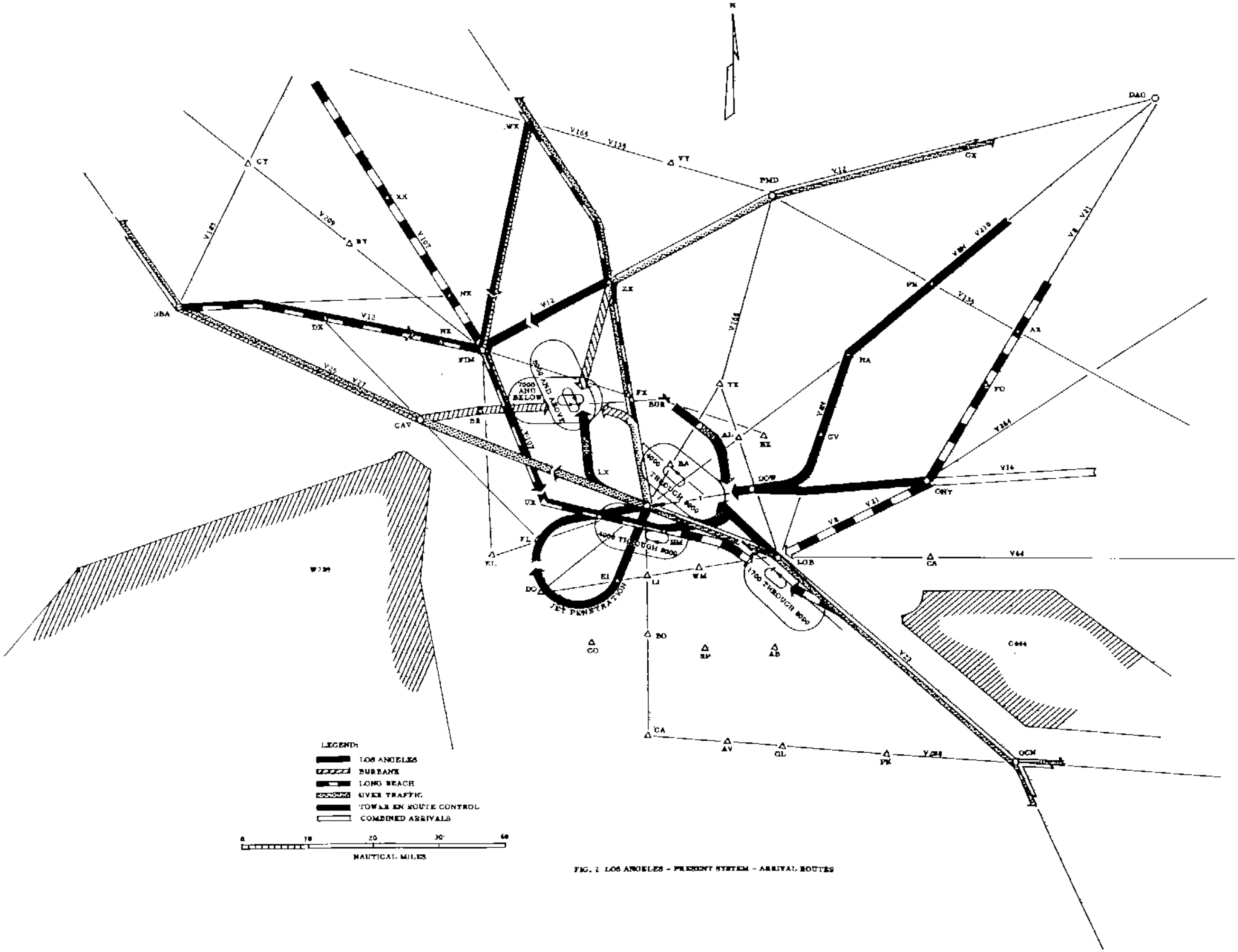


FIG. 2 LOS ANGELES - PRESENT SYSTEM - ARRIVAL ROUTES

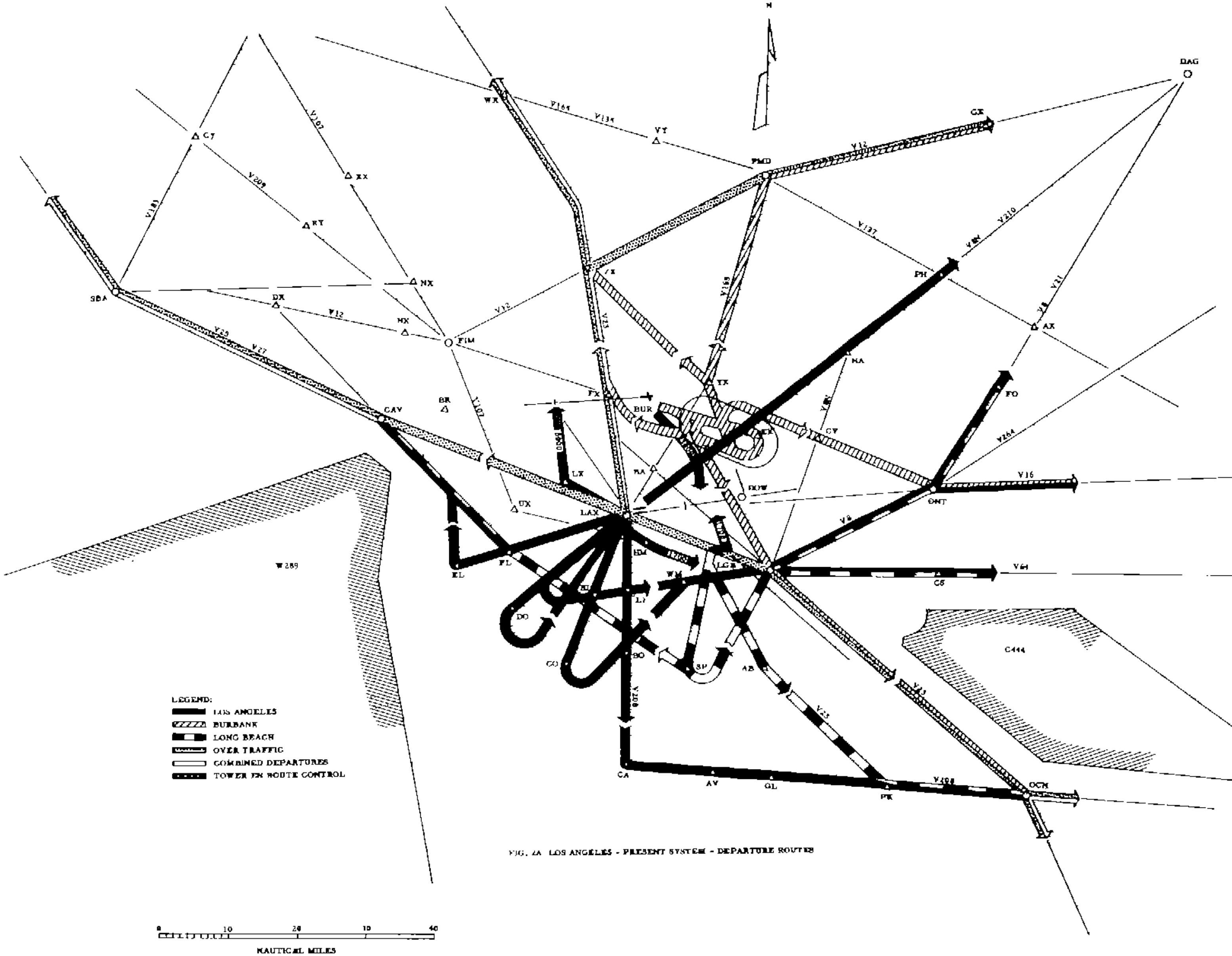


FIG. 2A LOS ANGELES - PRESENT SYSTEM - DEPARTURE ROUTES

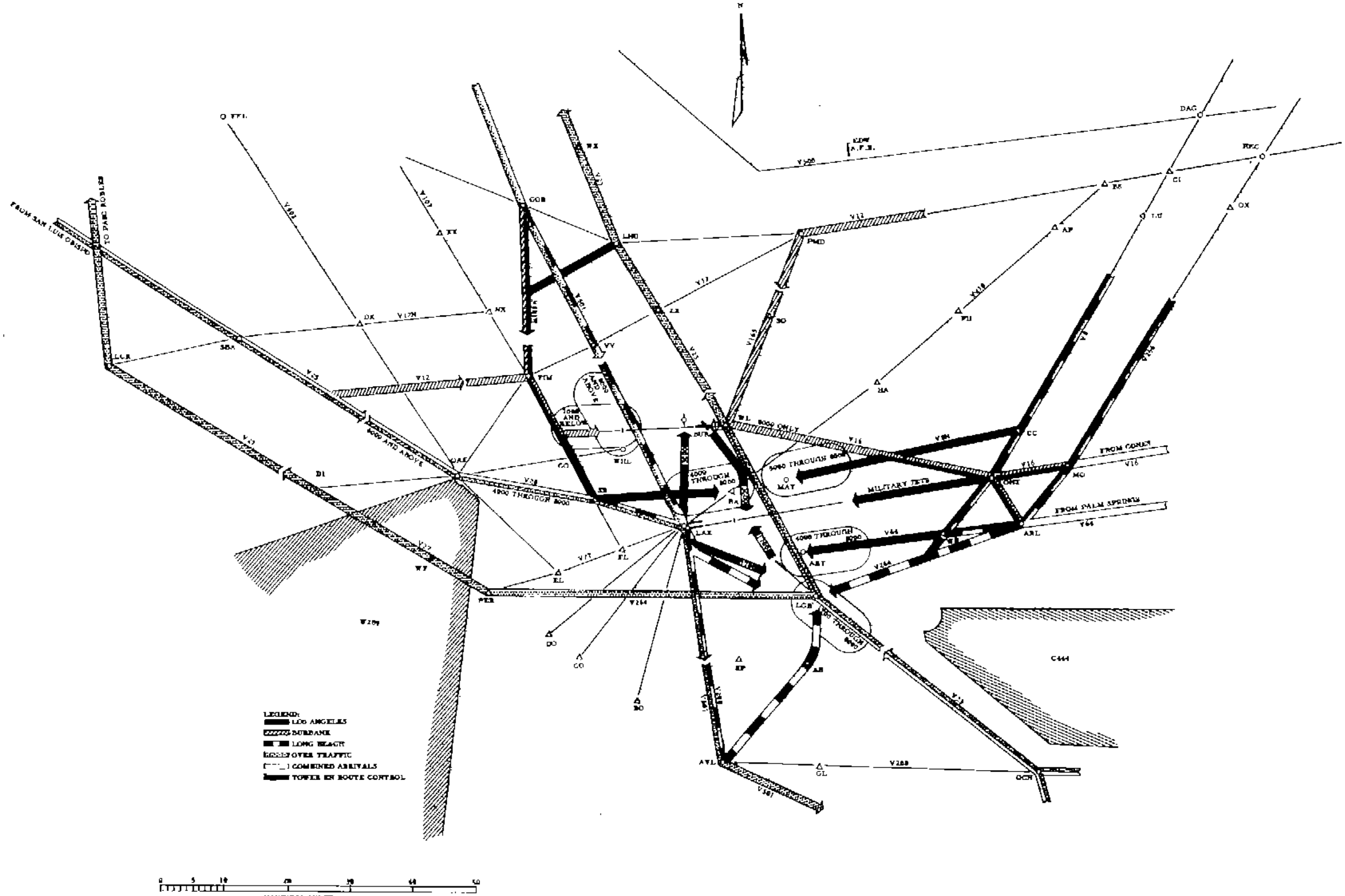


FIG. 1 LOS ANGELES - RECOMMENDED SYSTEM - ARRIVAL ROUTES

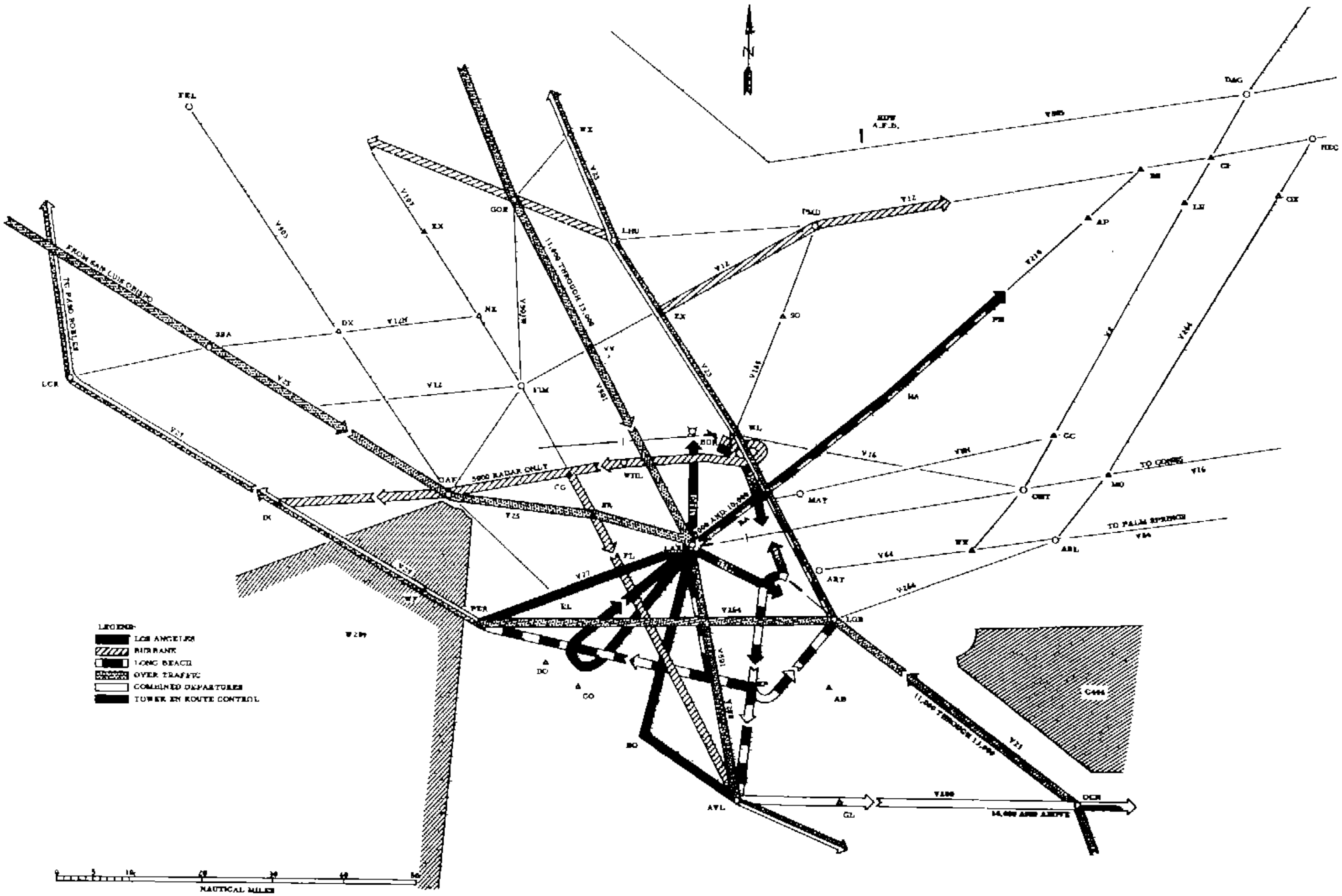


FIG. 3A LOS ANGELES - RECOMMENDED SYSTEM - DEPARTURE ROUTES

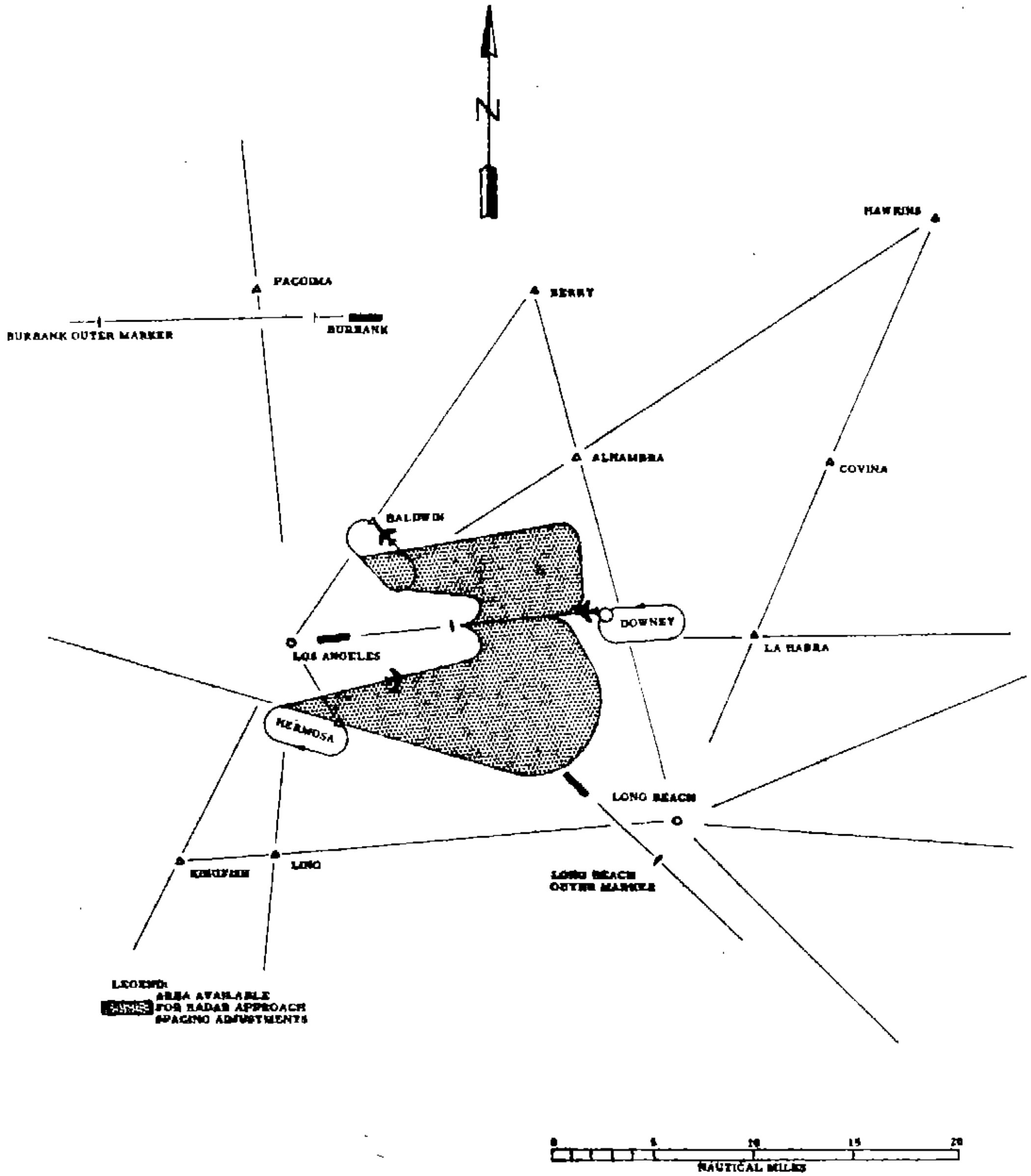


FIG. 4 LOS ANGELES TERMINAL AREA - PRESENT SYSTEM

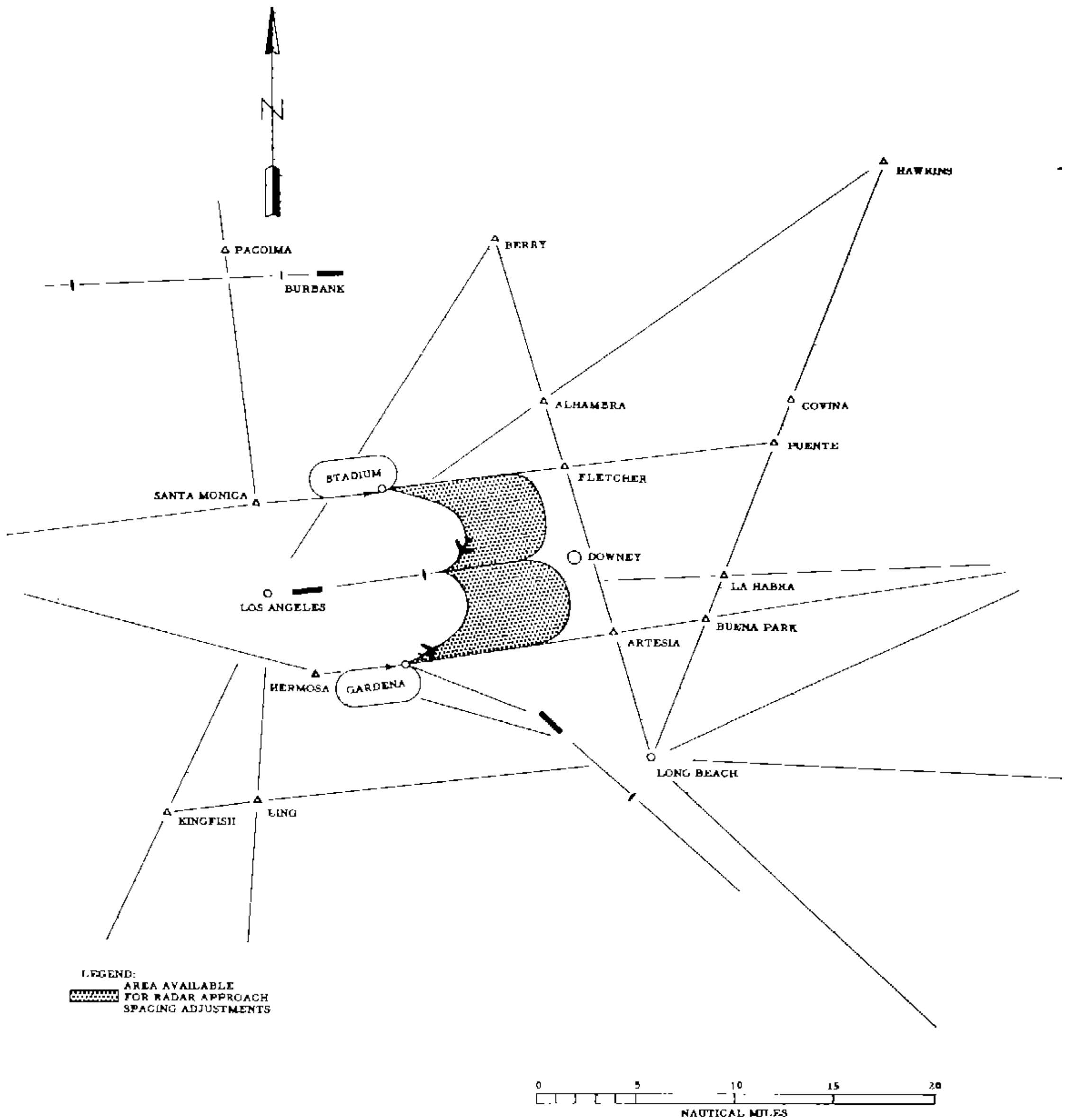


FIG. 5 LOS ANGELES TERMINAL AREA- PROPOSED TWO FIX FEEDER SYSTEM

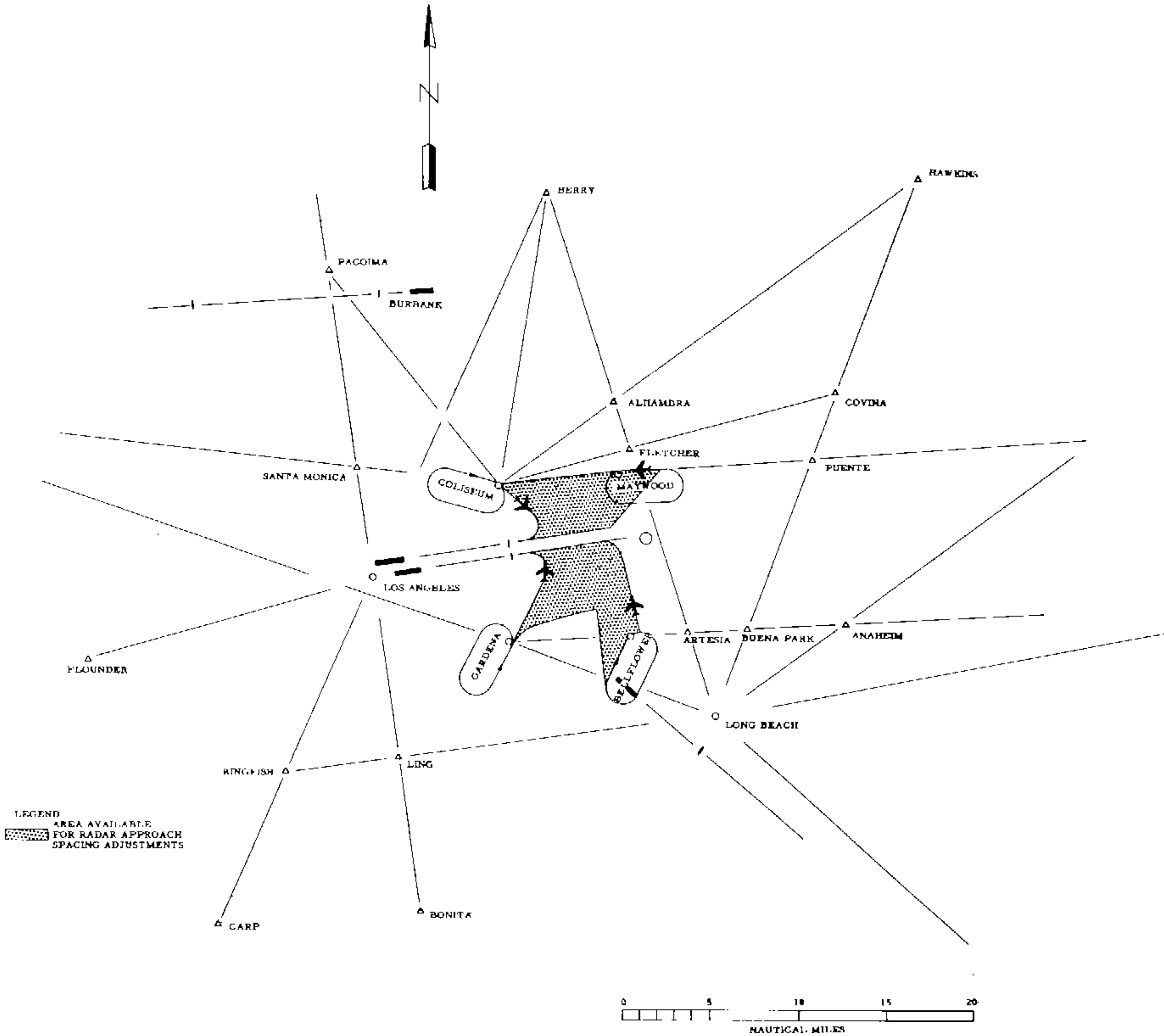


FIG. 6 LOS ANGELES TERMINAL AREA - FOUR-FIX FEEDER SYSTEM

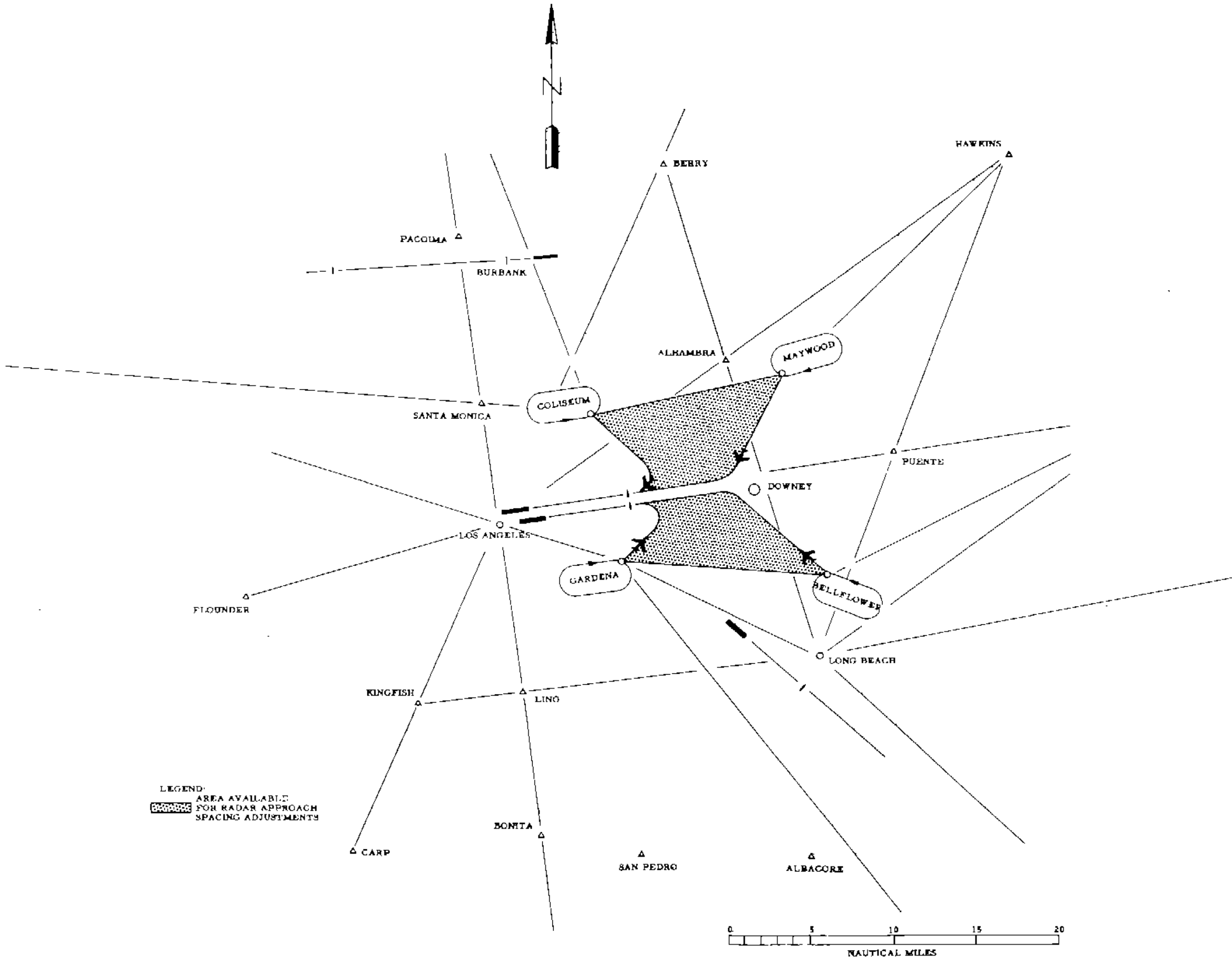


FIG. 7 LOS ANGELES TERMINAL AREA - REVISED FOUR-FIX FEEDER SYSTEM

FIG. 8 SIMULATION ARRANGEMENT OF LOS ANGELES APPROACH CONTROL

FIG. 9 SIMULATION ARRANGEMENT OF LOS ANGELES AIR ROUTE CENTER

FIG. 10 CLOSE VIEW OF LOS ANGELES CENTER SPANRAD DISPLAY

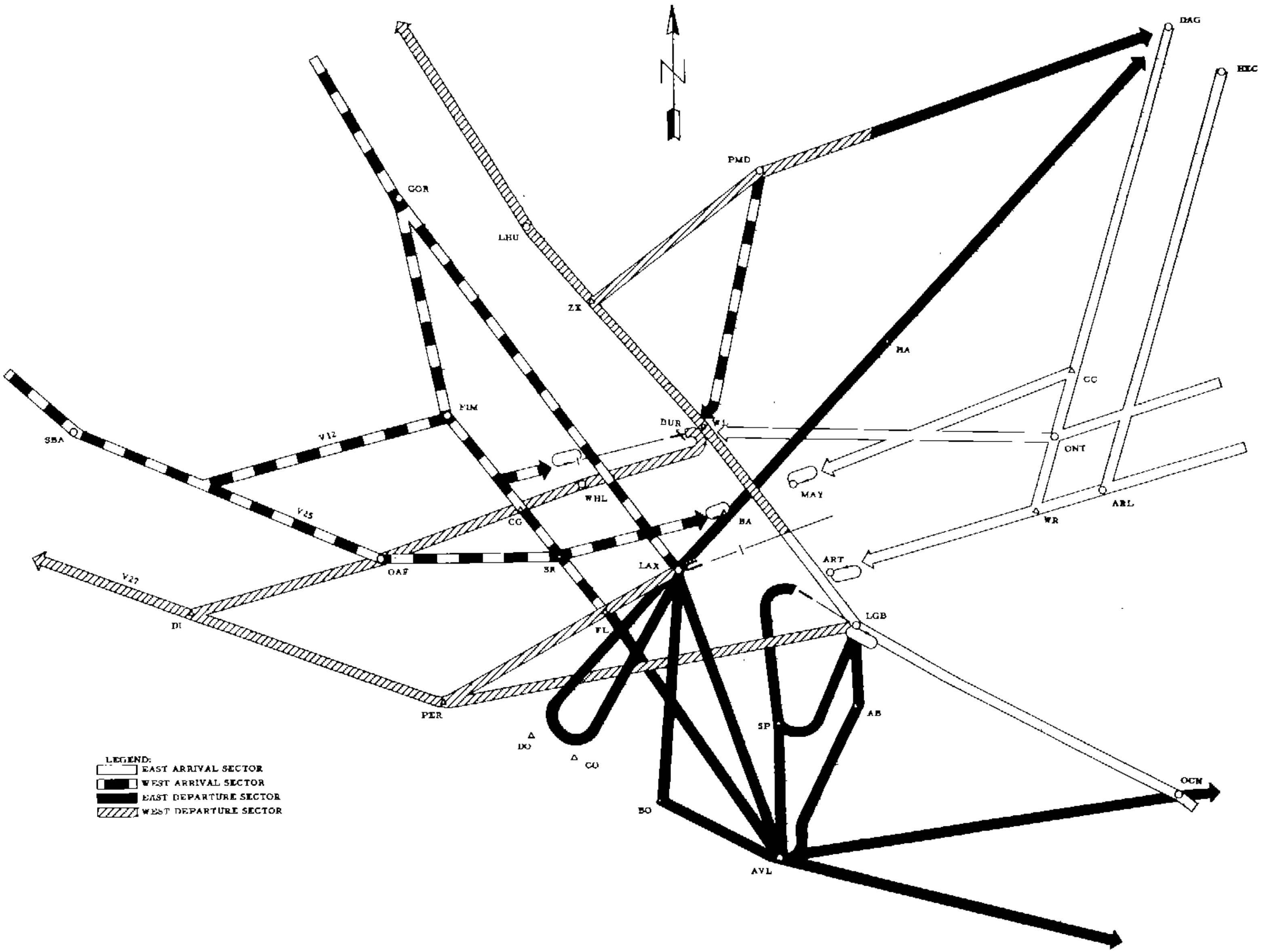


FIG. 11 LOS ANGELES - DIVISION OF CONTROL

FIG. 12 SIMULATION ARRANGEMENT OF BURBANK APPROACH CONTROL

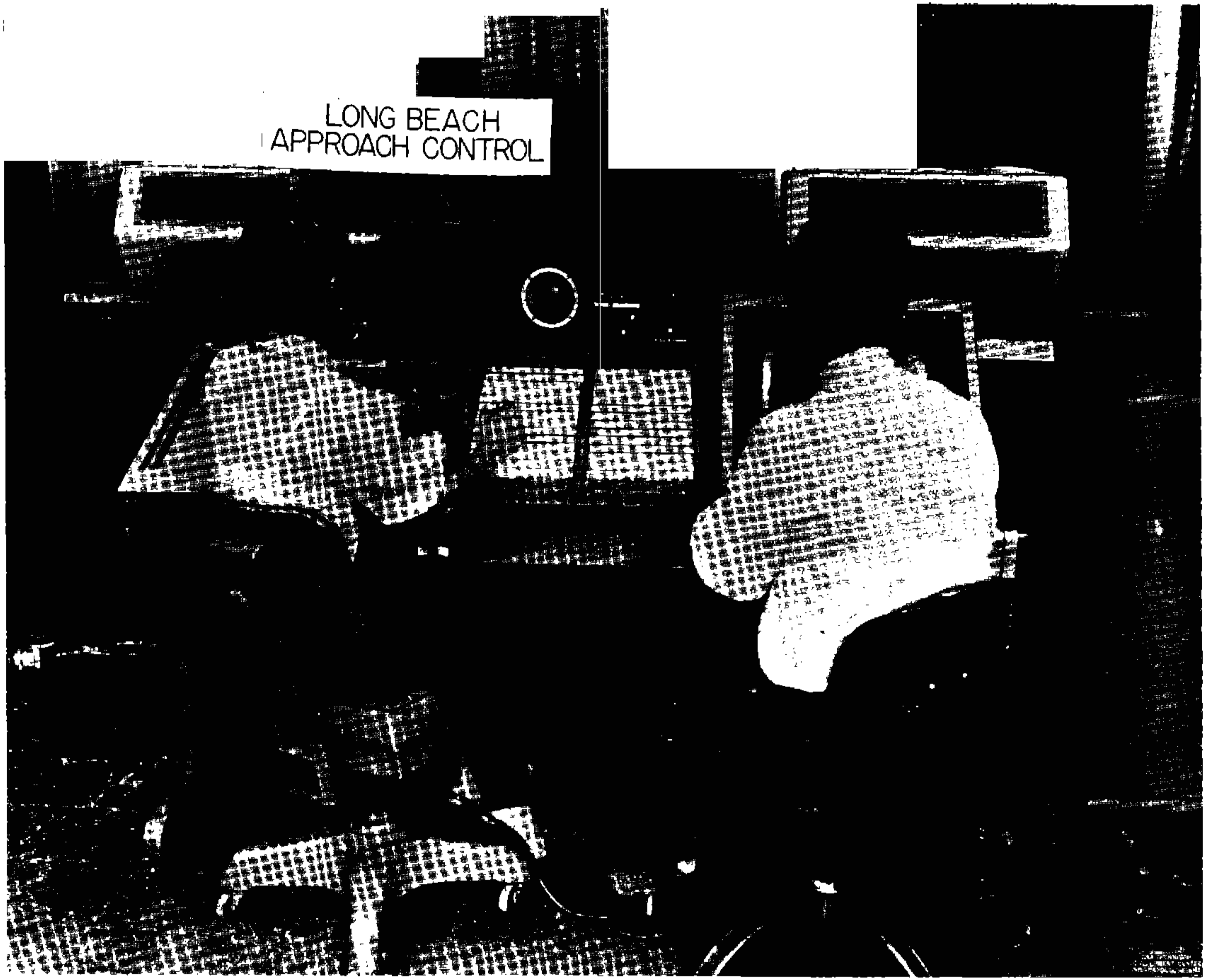


FIG. 13 SIMULATION ARRANGEMENT OF LONG BEACH APPROACH CONTROL

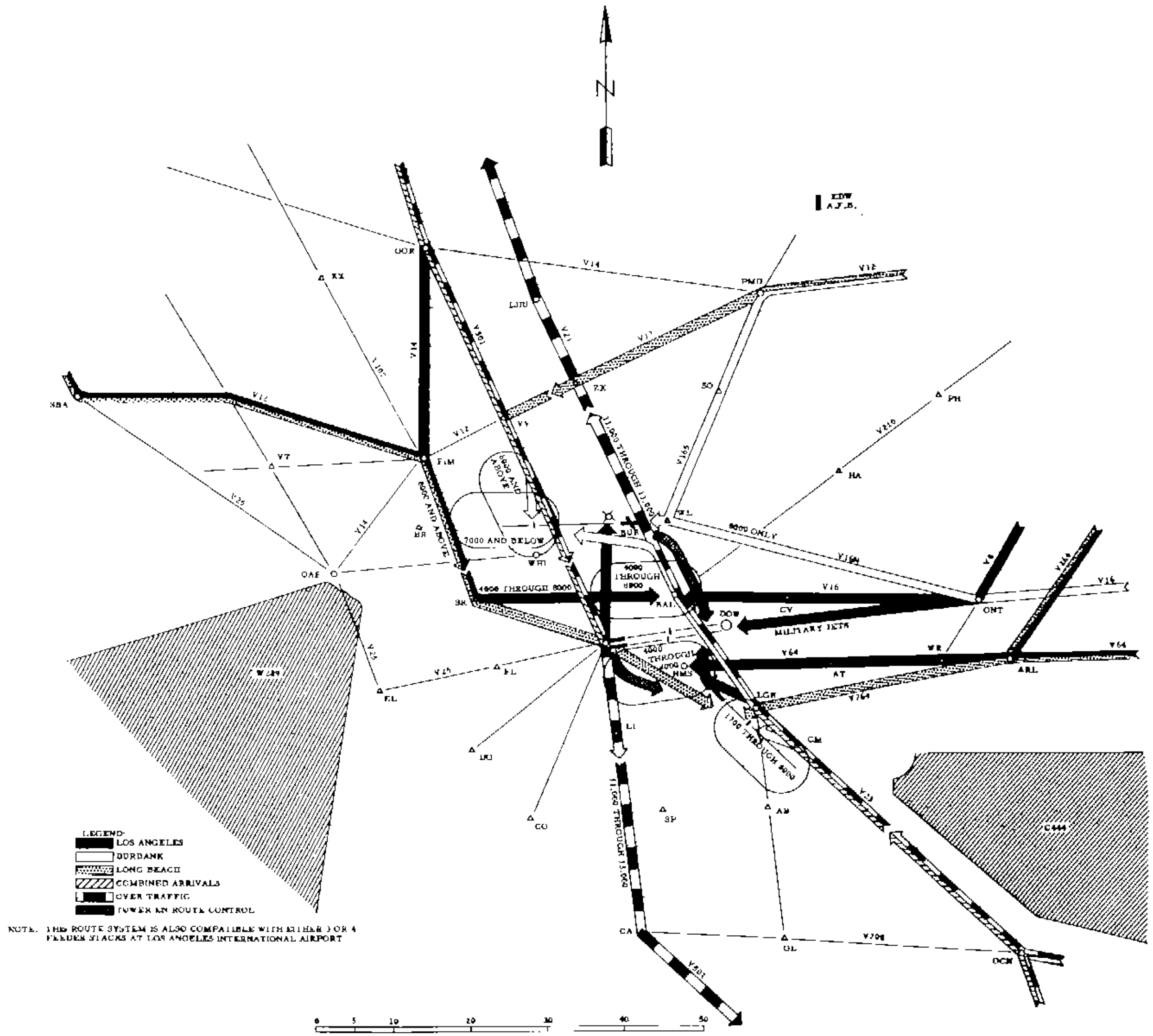


FIG. 14 LOS ANGELES - INTERIM SYSTEM - 2
ARRIVAL ROUTES

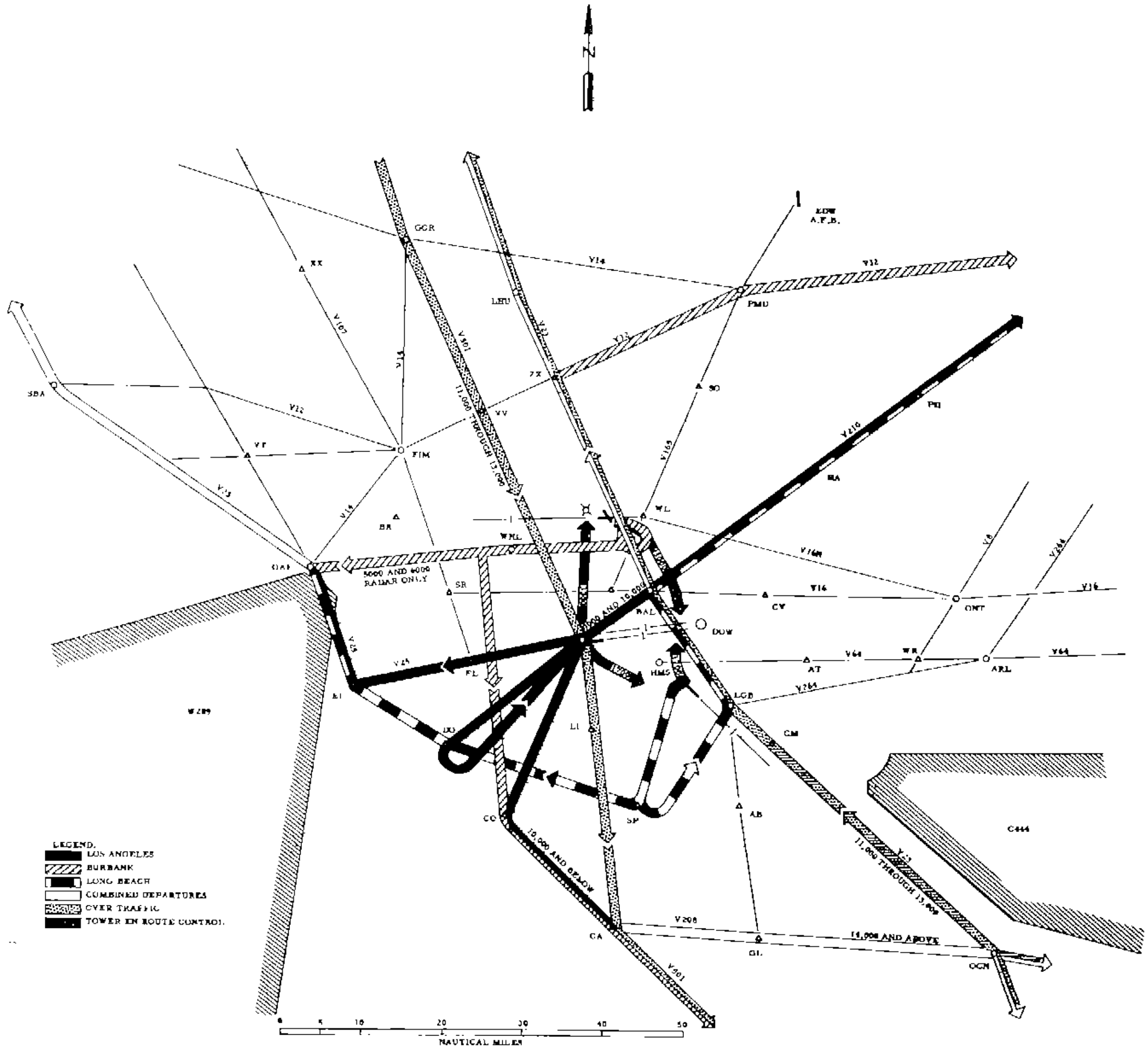


FIG. 14A LOS ANGELES - INTERIM SYSTEM - 2
DEPARTURE ROUTES

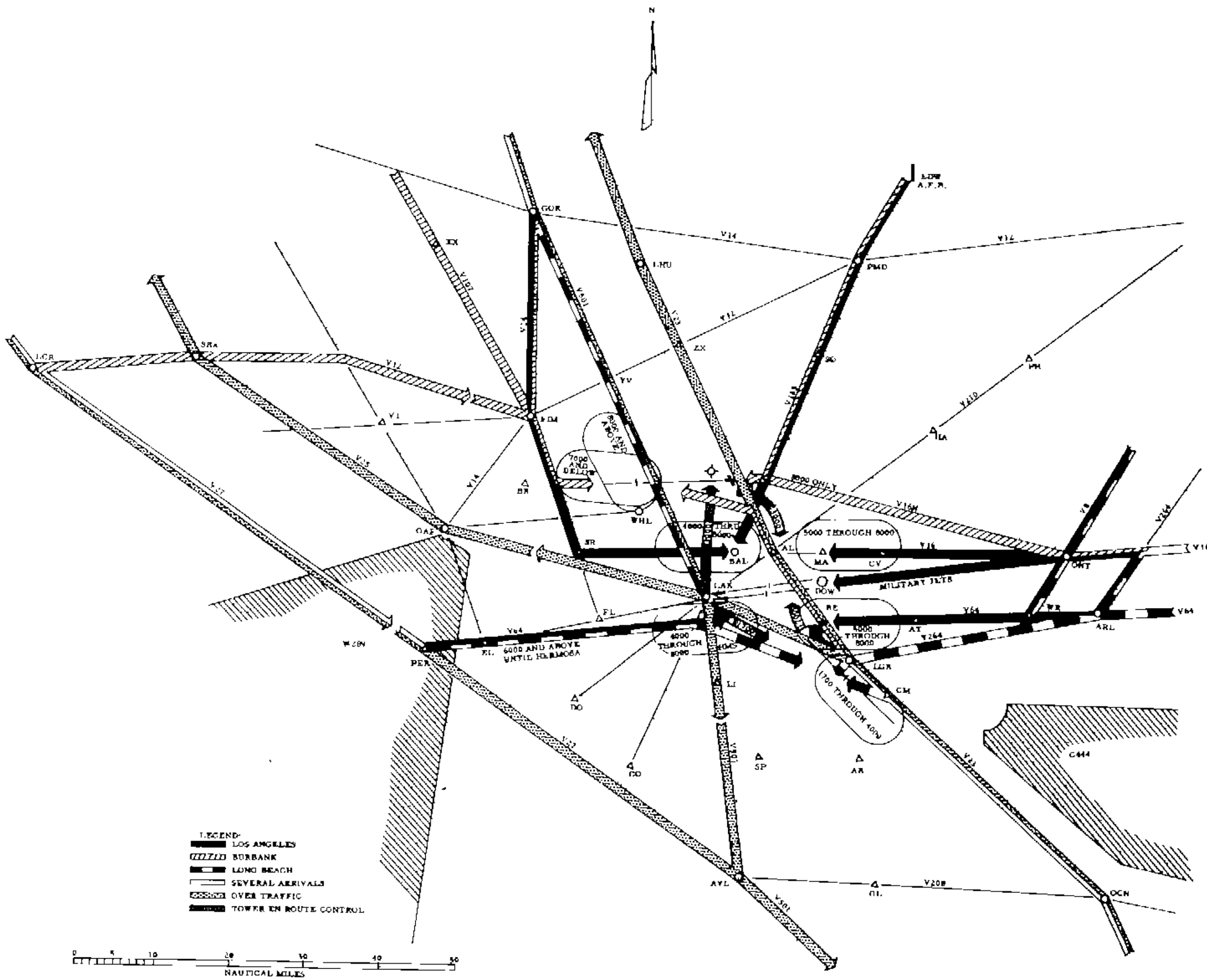


FIG. 15 LOS ANGELES - INTERIM SYSTEM - 3
ARRIVAL ROUTES

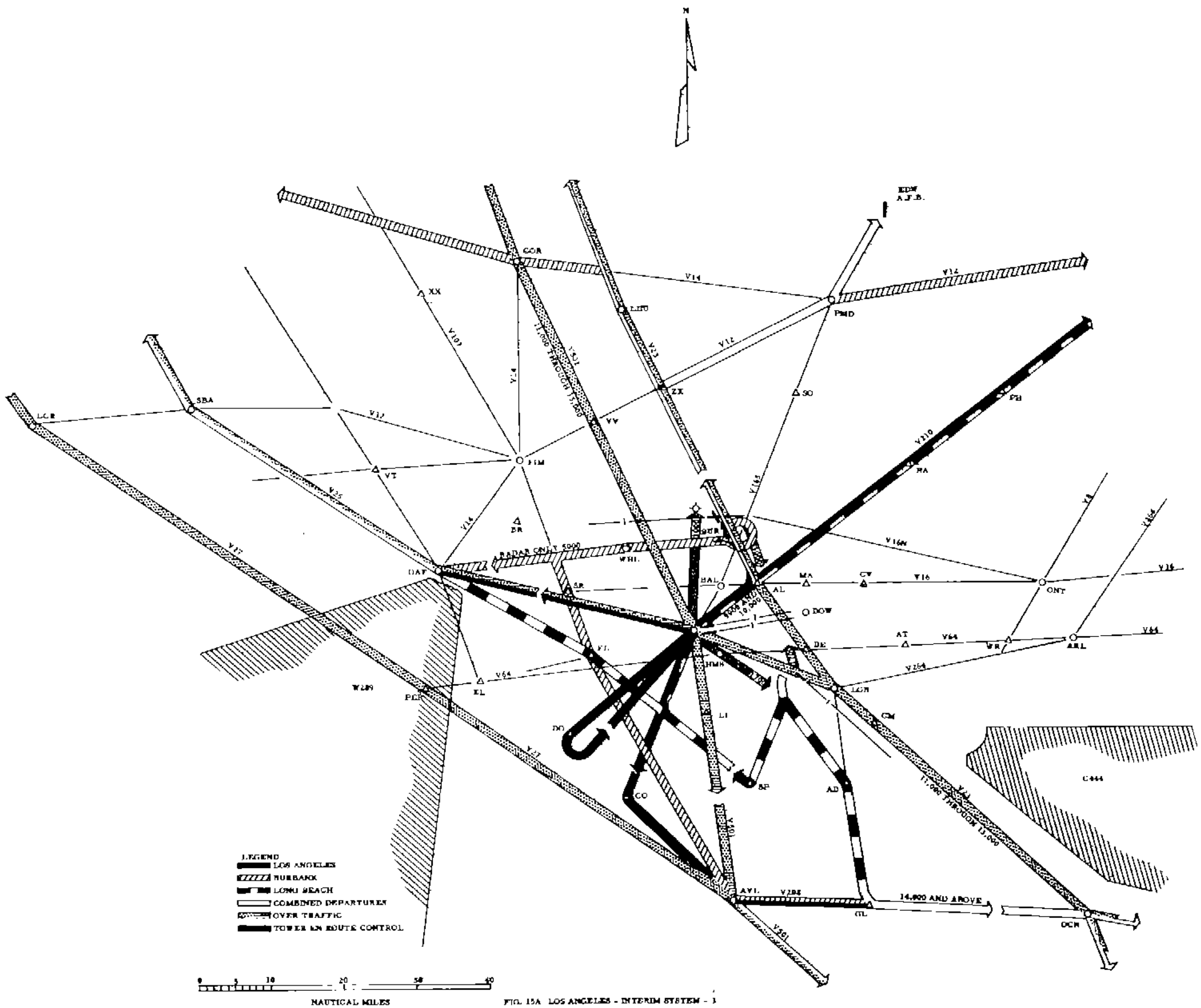


FIG. 15A LOS ANGELES - INTERIM SYSTEM - 1
DEPARTURE ROUTES