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Simulation Tests of Air Traffic Operations in the Seattle-Tacoma Area

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by

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SIMULATION TESTS OF AIR TRAFFIC OPERATIONS IN THE SEATTLE-TACOMA AREA

SUMMARY

This report describes a study of various methods of controlling IFR air traffic in the Seattle-Tacoma area. This study was conducted through the use of simulation facilities located at the FAA Technical Development Center.

Tests of the present airway system showed that it was poorly adapted to the use of radar procedures and would not be able to accommodate predicted increases in traffic demand. Modifications to the present route layout offered some improvements in traffic flow which can be gained immediately with only minor changes in the present layout of navigation facilities. Additional improvements can be obtained through the installation of new navigation aids to provide a better system of preferential one-way airways for the routes of heaviest traffic flow.

During the last phase of the study, the proposed Tacoma Municipal Airport was introduced. Three proposed runway alignments for this airport were tested to determine which would be most compatible with traffic operations at the adjacent airports. It was found that a runway alignment approximately parallel to the instrument runway at McChord would produce the least amount of interairport interference and, consequently, the least restriction on potential IFR traffic capacity at each of the three airports concerned.

Simulation tests of a common IFR room for the entire area indicated that such a facility would be well adapted to handle IFR operations at Seattle-Tacoma, Boeing, McChord, Tacoma Municipal, and Sand Point Naval Air Station.

INTRODUCTION

In May 1958, the CAA Office of Air Traffic Control requested the Technical Development Center (TDC) to conduct simulation studies of the Seattle-Tacoma area. In gathering background material for this study, three TDC controllers spent a week in the Seattle area. On October 14, 1958, they met with representatives of the Washington office, the Fourth Regional Office, and local ARTC, RAPCON, and tower personnel to discuss the present and future problems of the area and to define the objectives and assumptions of the simulation program.

Present Problems.

One reason for the relatively low volume of IFR traffic presently handled in the Seattle area lies in a combination of factors which restrict traffic flow and greatly increase the average controller workload per aircraft. The most important factors are listed below.

1. High terrain east and west of the area restricts approach and departure routes to a relatively narrow valley area and also tends to confine airway routes into narrow channels.

2. Poor siting characteristics of present navigation aids prevent their use in certain desirable locations. As a result, almost all routes converge over the Seattle Airport, creating mutual interference between arrival, departure, and en route traffic, greatly increasing controller workload. An insufficient number of navigation aids prevents the establishment of one-way airways which are necessary to move a high volume of traffic.

Program Objectives.

The objectives of the simulation program were defined as follows.

1. Determine the ability of the present route structure, aided by Air Route Traffic Control (ARTC) radar, in accommodating at least 30 per cent increase in IFR traffic density.

2. Establish a procedure to enable eastbound departures to clear the high terrain without being intermingled with terminal and en route traffic in the vicinity of the airport.

3. Without employing any additional VOR facilities, modify and test a route structure for the immediate future to provide bypass airways and one-way traffic flow on major routes.

4. Improve the arrangement of feeder fixes to facilitate radar vectoring procedures at Seattle-Tacoma International (SEATAC) and Boeing Airports.

5. Devise and test a route structure, using additional VOR facilities as necessary, to provide the capability of accommodating at least 85 per cent increase in IFR traffic density.

6. Determine whether a possible combination of system improvements would allow the addition of the proposed Tacoma Municipal Airport at the Peninsula site, without seriously affecting the flow of other IFR traffic in the area. Investigate various runway alignments at this airport, within a range of 336° to 003° magnetic, to determine effects on arrival and departure operations at McChord Air Force Base (AFB) and SEATAC.

7. Determine the effects of the following changes in control jurisdiction:

a. Changing McChord RAPCON to a conventional radar approach facility with the Seattle ARTC Center assuming jurisdiction of all airspace above 4,000 feet in the area presently controlled by McChord.

b. Combining, in one common IFR room, the terminal area traffic control functions presently handled by SEATAC approach control, McChord RAPCON, and the Seattle ARTC Center.

Test Assumptions.

The general assumptions governing the simulation tests were defined as follows:

1. It was assumed that the VOR siting problems, which have plagued the Seattle area for years, would be solved by implementation of the new Doppler VOR. This TDC development[1] has demonstrated a considerable improvement in accuracy over the conventional VOR in tests at difficult sites, and initial FAA procurement of Doppler VOR equipment now is under way.

2. The study would embrace the area within a radius of approximately 80 miles of the Seattle-Tacoma International Airport. Adequate ARTC radar coverage, as well as capability for direct air/ground/air communications, would exist throughout this area.

3. Airport traffic flow would be studied at SEATAC, Boeing, Sand Point, and McChord. Paine and Whidbey Island traffic also would be simulated because of its effect on traffic in the Seattle complex.

4. The Olympia jet penetration, proposed by the 25th Air Division, USAF, would be used as the primary penetration for McChord.

5. The ADC jet-climb corridor at McChord would be tested initially with an alignment of 293° magnetic.

6. A new ILS would be commissioned at SEATAC for approaches to Runway 16. The primary approach direction would be south at all airports in the area, except McChord, which would utilize north approaches.

7. The ATC radar beacon system would be commissioned at the Seattle ARTC Center.

8. The ceiling on the Fort Lewis restricted area, south of the Nisqually River, would be 2,500 feet.

9. The dimensions of the standard TSO holding area would be increased, as shown in Fig. 1, to anticipate a regulatory change which now appears imminent.

10. Civil jet aircraft would be controlled in a conventional manner unless holding delays were excessive, in which case holding would be accomplished at altitudes of 20,000 feet or above.

[1]Stirling R. Anderson and Robert R. Flint, "The CAA Doppler Omnirange," unpublished Technical Development Report.

Traffic Samples.

Flight progress strips, recording 3 recent days' of IFR operations, were obtained from the Seattle ARTC Center for analysis to determine the distribution of traffic by route, airport, and aircraft type. The resulting data were used to construct the traffic samples used in the simulation tests. Although the route distribution, by percentage, was maintained, the traffic density, in operations per hour, was increased in order to test the various systems under loads representative of predicted future traffic. The percentage of jet traffic was increased to reflect a predicted future trend. Details of the traffic samples are summarized in Table I.

EVALUATION METHODS

Measurements.

Six controllers from the Seattle ARTC Center, two from McChord RAPCON, and two from SEATAC Tower, were detailed to TDC for the simulation tests. Because some of these controllers had no previous radar experience, it was necessary to devote a considerable portion of the simulation time to training activities. Although only the last runs of each phase were used for comparative measurements of system performance, the wide variation in controller skill made a large difference in the test results. Subsequent examination of aircraft delay data showed that the effects of having a certain controller at a certain position during a specific test run could rule out the differences which normally would be expected between the delays of different systems. The time available for the test program did not permit these overshadowing effects to be eradicated. As a result, much of these data are not considered to be of sufficient value to be included in this report.

Subjective Opinions.

Although the recorded test data were disappointing, for the reasons explained above, the test program did provide a very good opportunity to study the air traffic flow characteristics of the entire area, and to develop and refine a number of improvments in route layouts, feeding systems, and control procedures. The effects of these changes were obvious to controllers and test observers. These modifications were evaluated by the test controllers, who recorded their subjective opinions on questionnaires which were prepared for this purpose. At the conclusion of the program, a critique was held, using a tape recorder to obtain a permanent record of the proceedings. The information thus obtained was used to substantiate the findings, which are summarized in this report.

TEST PROCEDURES

Phase I - Present System.

Control Procedures.

The first week of simulation was devoted to a study of the present route structure and terminal area procedures, to determine what effect the addition of radar at the Seattle ARTC Center would have on the traffic flow, and to determine if any immediate improvements could be made to utilize this radar to the fullest extent.

The route structure, which is shown in Fig. 2, was divided into two Center radar sectors with associated manual sectors to provide ANC backup and data handling. One sector controlled Amber 1 and Victor 23 Airways north of Seattle. The other sector controlled the area south and east of Seattle from Victor 27 to Victor 2 north. A peripheral sector was established encompassing the route fixes to the south and east to provide a more realistic workload for the sectors in the terminal area. It was the duty of the peripheral sector controllers to descend arrivals to suitable altitudes before entry into the radar sectors of the Seattle ARTC Center, and to coordinate departure altitude data with the Seattle sector controllers.

During the first phase of this program, the area presently controlled by McChord RAPCON remained unchanged. However, the facilities and personnel available at TDC permitted the use of only two radar controllers and a coordinator to accomplish a task that in actual practice requires considerably more personnel. This required the elimination of some phases of the operation.

The Seattle ARTC Center operation remained basically unchanged from present procedures, with the exception of eastbound departures from SEATAC. These departures were cleared to a fix in the vicinity of the present Monroe H facility. SEATAC departure control performed a radar hand-off to Seattle ARTC Center northeast of the airport, and the Center radar controllers established the aircraft on a southbound course to intercept Victor 2 or Green 2 after sufficient altitude to clear terrain had been reached. See Fig. 2.

Equipment.

The two radar sectors of the Seattle ARTC Center were simulated using one superimposed panoramic radar display (SPANRAD) as shown in Fig. 3. SPANRAD is a radar tracking device which uses television techniques to superimpose the picture of a manually positioned target marker, with that of the radar target, on a bright tube display.

McChord RAPCON utilized two simulated ASR scopes, one for en route and arrival traffic and one for departure control. A third position of operation coordinated traffic information with the Seattle ARTC Center and SEATAC Tower, using a conventional flight progress board to display traffic.

Two scan-conversion radar monitor scopes were installed in another location to simulate the SEATAC Tower arrival and departure positions which were simulated as a side-by-side operation. The tower personnel who participated in the planning of this simulation agreed that it would be necessary to move their present departure position out of the tower cab and into a location adjacent to the arrival position in order to control the volume of traffic that was to be simulated. The areas used for vectoring are shown in Figs. 4 and 5.

Phase II.

System Modifications.

The second and third weeks of the simulation program were used in a study of the system modified as follows:

1. The Shelton homing facility was increased in power to provide a by-pass route, Blue 86, west of Seattle.

2. A homing facility was installed at Monroe to provide a one-way route for northbound departures out of SEATAC, Boeing, and Sand Point Naval Air Station (NAS).

3. Preferential routes were designated north, south, and east of Seattle to establish independent one-way arrival and departure paths for the major portion of the IFR traffic.

4. A VOR intersection at Harper was established as a feeder fix for radar-vectored approaches to SEATAC and Boeing.

5. The McChord jet-climb corridor was realigned to a heading of 336° magnetic.

6. Approach control was implemented at Paine.

7. An additional arrival scope was implemented at SEATAC.

Comparative tests of this route layout were made, using separate control agencies and a common IFR room. These tests were designated as Phase IIA and IIB, respectively.

Phase IIA - Separate Agencies.

Control Procedures.

The route structure is shown in Fig. 6. This area was divided into four Center radar sectors with associated manual sectors to provide ANC backup and data handling. One sector controlled the traffic on Amber 1 northwest of Seattle, including the Kitsap holding pattern at 4,000 feet and above. Kitsap intersection was used as a clearance limit for all southbound traffic en route to the Seattle-Tacoma complex (Boeing, Seattle-Tacoma, and Sand Point NAS). This sector also controlled the arrivals and departures at Whidbey Island NAS.

The second sector controlled the traffic on Victor 23 and Green 10 north of Seattle, Victor 2 north, Green 2, Victor 2, and Victor 2 southeast of Seattle, and the Seattle LF range holding pattern at 5,000 feet and above. This holding pattern was used as a clearance limit for all westbound traffic en route to the Seattle-Tacoma complex. This sector also controlled the arrivals and departures at Paine AFB and the northbound departures from the Seattle-Tacoma complex.

The third sector controlled the traffic on Victor 23 east, which was primarily south- and eastbound departures from the Seattle-Tacoma complex and McChord AFB. This sector also controlled the westbound arrivals to McChord AFB.

The fourth sector controlled the traffic southwest of Seattle from Victor 23 west to Victor 27, which was primarily northbound traffic with the exception of a few low-altitude westbound flights from SEATAC and Boeing to Olympia or Hoquiam. The Harper intersection was used as the clearance limit for all northbound flights en route to the Seattle-Tacoma complex from 4,000 to 10,000 feet. The use of altitudes above 10,000 feet was restricted because of the McChord jet-climb corridor. Because of the high volume of radio communications required in operating this sector, it was necessary to use two radio controllers to handle this traffic. In actual practice, the extra communications workload for which the second controller was needed would normally have been handled by a high-altitude sector.

In Phase II, the McChord RAPCON functioned as an approach control facility but retained jurisdiction of 4,000 feet and below in the area shown in Fig. 6. The primary landing direction was north. Conventional aircraft departing McChord were cleared to either the Carbonado intersection or the Case intersection. The departure controller established aircraft on course to the fix and handed them off to the Seattle ARTC Center radar controller. Jet departures were cleared to the McChord LF range or TVOR to make a left turn after takeoff, climbing to an altitude previously assigned by the Center, and subsequently were handed off to the Center en route to Carbonado or Swanson intersections. ADC jet recoveries were effected from the Hoquiam VOR via the recovery corridor. Straight-in approaches were made from Toledo and Olympia by all types of aircraft, after the aircraft were clear of the respective airways, as shown in Fig. 6.

SEATAC Tower controlled all arrivals and departures at Seattle-Tacoma Airport, Boeing Field, and Sand Point NAS. The primary landing direction was south. Three clearance limits were used in the terminal area to serve as feeder fixes for the arrival controllers, as shown in Fig. 7. Kitsap intersection and the Seattle LFR were controlled at one arrival position and the Harper intersection was controlled at the other arrival position. Northbound traffic departing Seattle-Tacoma or Boeing was tunneled at 4,000 feet or below by the departure controller, and a radar hand-off to the center was effected when the aircraft was clear of the Seattle LFR holding pattern. A buffer line between Seattle-Tacoma and Paine Tower was established to define their respective areas of jurisdiction as shown in Fig. 6. North landings were simulated at SEATAC utilizing the same clearance limits. All vectoring was accomplished on the west side of the airport as shown in Fig. 8.

Equipment.

Four radar sectors of the Seattle ARTC Center were simulated. The two north sectors shared one SPANRAD and the two south sectors shared another. Each sector utilized an associated flight progress board for ANC backup and data handling. Figure 3 shows a typical sector control layout.

The McChord RAPCON operated as a conventional airport approach control facility, using one arrival scope and one departure scope as shown in Fig. 9.

The SEATAC Tower used two arrival scopes and one departure scope. The single scope used for Paine and Whidbey Island operations is shown in Fig. 10.

Phase IIB - Common IFR Room.

Control Procedures.

In this portion of the test program, the four sectors of the Seattle Center, as well as the arrival and departure positions of McChord, SEATAC, and Paine/Whidbey Island, were located in the same room. Coordination between the Center and the other agencies was handled by a single controller, due to a limitation in the number of personnel available. In actual practice, it would be desirable to add another coordination position to share this workload.

Control jurisdiction and procedures remained the same as those used in Phase IIA.

Equipment.

The Seattle Center utilized two SPANRAD units as in previous runs. McChord and Seattle-Tacoma approach control used four scopes with the two departure positions and the three arrival positions adjacent to each other as shown in Fig. 11. Although it was necessary for the two SEATAC arrival controllers to share a single scope because of space and equipment limitations, the over-all operation was not impaired by this arrangement.

The procedures and routings used in testing the common IFR room concept were identical to those used in the previous runs of the Phase II system.

Phase III.

System Modifications.

The fourth week of simulation was devoted to a study of a future system for controlling traffic in the Seattle-Tacoma area. During this phase of the tests, the proposed Tacoma Municipal Airport was simulated at the Peninsula site.

The route structure, navigational facilities, preferential route system, and procedures, which are shown in Fig. 12, were based on the installation of new VOR facilities at Shelton, Lebam (40 miles west of Toledo), Toledo, Wenatchee, Paine, Dungeness, and Neah Bay. The Seattle VOR was relocated to a site approximately 7 miles east of SEATAC. Feeder fixes were established at Rainier and Puget to serve Tacoma Municipal and McChord.

The route structure was modified further by the addition of new airways and bypass routes to create a more desirable preferential route system. The LF airways were abrogated and replaced by VOR routes where needed.

The McChord jet-climb corridor was aligned to a heading of 336° magnetic.

Control Procedures.

The equipment at TDC was arranged for a common IFR room operation. The four radar sectors of the Seattle ARTC Center each controlled the same geographical areas as in Phase II. Northbound arrivals to the Seattle terminal area on Victor 99 were held at 5,000 feet until clear of traffic at Shelton. During the simulation, it became apparent that altitudes through the 5,000-foot level were needed at Shelton for Tacoma and McChord departures. Therefore, Seattle arrival traffic on V99 was routed at 6,000 feet or above in later runs.

Seattle approach control had jurisdiction of the arrivals and departures at Boeing and Sand Point as in Phase II. The three clearance limit fixes and vector areas are shown in Figs. 13 and 14. When north landings were being made at SEATAC, the Harper intersection was used as the primary clearance limit. It was necessary to use the area north of Tacoma Municipal jointly by Seattle and McChord approach control. Within this area, Seattle arrivals were held at 3,000 feet and above, while Tacoma and McChord departures were restricted to maintain 2,000 feet.

The McChord operation again was simulated as an approach control tower utilizing 4,000 feet and below within the area shown in Fig. 12. The arrivals and departures at Tacoma were under jurisdiction of McChord approach control. Puget and Rainier intersections were established to serve as clearance limits for Tacoma Municipal and McChord arrivals. Departures were cleared to the Carbonado, Swanson, or Shelton intersections. Traffic between SEATAC and Tacoma Municipal was simulated as a tower en route operation between Seattle and McChord approach control.

Paine was simulated as an approach control tower. Departures and arrivals were cleared on preferential routes as shown in Fig. 12. Jet arrivals made TACAN approaches from a fix 25 miles north of the Paine outer marker on the localizer course and maintained 15,000 feet until clear of Victor 23E.

Traffic at Whidbey Island was controlled in much the same manner as an ARTC Center would operate. However, specific procedures for this operation were not incorporated in the simulation because of time limitations, and also because Whidbey Island is far enough away from the Seattle complex to operate independently.

During this phase, three airport configurations for Tacoma Municipal were tested to determine what effect each runway alignment would have on IFR traffic flow in the area.

Equipment.

The equipment and operational arrangement used in this phase was identical to that used in the Phase II common IFR room tests. The four radar sectors of the Seattle ARTC Center were simulated on two SPANRAD units. Each sector used an associated flight progress board for ANC backup and data handling.

Seattle and McChord approach control arrival and departure positions utilized four scopes located in the Center room.

TEST RESULTS

Phase I.

General.

Analysis of this phase pinpointed four major problems which affect the control of IFR traffic in the Seattle-Tacoma area:

1. Excessive coordination between facilities was required.

2. Two-way traffic flow on the major routes created high workloads for the Center controllers.

3. Convergence of major routes on the Seattle area produced difficulty in climbs, descents, crossings, and radar identifications.

4. The clearance limits in the Seattle-Tacoma complex were poorly located for radar vectoring. Congestion of arrival, departure, and over-traffic in the vector area compelled Seattle arrival control to revert to ANC separation because of inability to secure and maintain identification of radar targets.

Seattle ARTC.

Eastbound IFR departures from Seattle, climbing to the northeast via Monroe, restricted IFR operations at Sand Point NAS. Since Sand Point had no approach control authority, a few aircraft in this area could create a high workload for the Center controllers. The departure route from SEATAC via Monroe was a usable interim route at the traffic densities tested.

The use of radar procedures provided means for a continuous flow of eastbound departures to reach terrain clearance altitudes without the necessity of climbing west of Seattle. Figure 2 shows this route. The control of IFR traffic at Paine AFB and Whidbey Island NAS was expedited by the use of Center radar, however, the present route structure limited the application of radar procedures in this area.

SEATAC and Boeing.

Tests showed that the Harbor Island intersection was too close to the SEATAC north ILS and Boeing Field for a clearance limit from which to use radar procedures. Congestion of arrival and en route traffic over these airports limited the use of radar separation because of difficulty in establishing and maintaining positive radar identification. The procedures for control of Seattle southbound departures were satisfactory. Because of the proximity of Boeing to SEATAC, IFR operations at Boeing always will require very close coordination between the SEATAC arrival and departure controllers, as well as the Boeing tower controllers. The runway alignment at Boeing differs 30° from that of SEATAC. The interference created by this difference in runway alignment makes it very difficult for radar controllers to achieve high arrival and departure rates at these airports.

McChord.

Under the present system, the McChord RAPCON area and control procedures were adequate for the volume of traffic tested, except for the area northeast of McChord used for vectoring aircraft for south landings. This area was too confined to provide spacing adjustments, particularly with high-speed aircraft. The Fort Lewis restricted area (R-503 - R-504 - R-505) and the departure route from SEATAC precluded use of the area west of McChord for arrival vectoring. Figure 2 shows McChord RAPCON area.

Sand Point, Paine, and Whidbey Island.

No changes were found necessary in the Whidbey Island and Paine terminal areas with the traffic densities tested in this phase.

Analysis of the procedures used at Sand Point showed that airspace in the SEATAC and Sand Point areas could be better utilized if operations at Sand Point were controlled by SEATAC approach control.

Phase II.

General.

The route structure used in this phase was much improved over that in Phase I. The segregation of arrival and departure traffic flow was of great benefit to both terminal and air route controllers. As shown in Fig.6, the departure flow to the south and east from Seattle-Tacoma airports was practically restriction-free and ideally suited to radar control. These routes were of particular benefit to high-performance jet aircraft, permitting unrestricted climb to cruise altitudes.

Eastbound departures from the Seattle area could proceed east from Carbonado or continue southbound to Swanson, depending on climb performance of the aircraft. Southbound departures could proceed from Swanson direct to Toledo to take advantage of a low-altitude route or from Swanson direct to Portland for a higher altitude route.

Of necessity, some routes had to remain two-way airways. These routes in most instances were routes with lower traffic densities.

The reversal of traffic flow between Seattle and Portland would necessitate a change in Portland control procedures.

Seattle ARTC.

Controller comments regarding the tests in this phase were unanimously in favor of the modified system when compared with Phase I. In every case, the controllers stated that many of the major problems had been alleviated or totally eliminated. Problems of minor nature were still present but all controllers stated that a full complement of personnel would reduce these problems in actual practice.

The traffic congestion over Seattl- was relieved by providing a clearance limit at the Harper intersection west of SEATAC, and by providing a bypass route (Blue Airway 86) for traffic at Paine and Whidbey Island.

All the terminal clearance limits at SEATAC were adequately separated to provide the sector controllers with independent terminating points for each major arrival route. This greatly reduced coordination between these controllers in the ARTC Center.

Tests indicated that the area now controlled by McChord RAPCON could be controlled from the Seattle ARTC Center provided adequate radar is available. Since there is a high percentage of jet aircraft operating from McChord, it will be necessary for the Center radar to be equipped with radar beacon equipment. The sector will be a very busy one and may require subsequent rearrangement as experience is acquired.

SEATAC, Boeing, and Sand Point.

Phase I tests indicated that the IFR traffic at these airports should be controlled by one facility. Since both Boeing and Sand Point have precision radar, it is feasible for them to accept hand-offs on final approach. By placing Sand Point arrivals under the jurisdiction of Seattle approach control, better use of airspace was realized.

Vectoring areas shown in Fig. 7 were considered necessary for efficient utilization by Seattle approach control to provide radar vectoring on both sides of the ILS course for south landing on Runway 16. The buffer line between Sand Point and Everett ranges established a maximum limit for the SEATAC radar area.

Two Seattle approach controllers vectored aircraft to these airports. One controlled the traffic at Kitsap and the Seattle range. The other controlled the traffic at Harper.

Airport acceptance rates were reduced greatly when north operations were necessary at Boeing and SEATAC due to the following factors:

1. Because of the departure route south from the Seattle LF range, there was not sufficient room to vector arrival aircraft on the east side of Seattle's south localizer course. This required all vectoring to be accomplished on the west side of Seattle.

2. Controllers had to limit the total number of aircraft on the downwind course of this area because there was insufficient room for last-minute spacing adjustments on the base leg course. This was caused by the proximity of the McChord RAPCON area.

3. Aircraft cleared to Harper, destined for Sand Point, were coordinated between controllers and handed off to the radar controller vectoring aircraft from Kitsap and Seattle LF range. Figure 8 shows the vectoring areas used with this landing direction.

Control of departure traffic was satisfactory in these tests. East- and southbound flights taking off south proceeded straight out on course and were able to climb unrestricted under radar control. These flights took off north, crossed the Seattle LF range at 3,000 and 4,000 feet and were tracked 160° from the range under radar control. Upon leaving 5,000 feet, these aircraft transitioned to the normal southbound route. These restrictions reduced the flow of departure traffic by approximately five aircraft per hour.

McChord.

In this phase, the function of McChord RAPCON was reduced to that of an approach control facility. The McChord area was reduced in physical size as shown in Fig. 6. Altitudes controlled also were reduced to 2,000, 3,000, and 4,000 feet.

Lack of space for holding pattern feeder fixes tended to complicate the operations. Seattle ARTCC used Olympia VOR and Toledo LF range as clearance limits for McChord AFB traffic.

The jet recovery route from Hoquiam required altitude restriction at 20,000 feet until clear of V23W.

Departure traffic from McChord was cleared to Shelton intersection, Carbonado intersection, Swanson intersection, and Olympia VOR. As soon as practicable, these aircraft were handed off to Seattle ARTC radar controllers to be integrated into the normal preferential flow of traffic.

In order to obtain an improved flow of arrival and departure traffic in the Seattle terminal area, and to provide bypass routes for traffic to and from the airports north of Seattle, it was desirable to move the McChord jet-climb corridor to 336° magnetic. By so doing, ADC jet aircraft were required to make no turns at low altitude. The only restrictions resulting from this change were a top altitude limit of 10,000 feet at the Harper intersection and a limit of 15,000 feet on V99 airway between Kitsap intersection and Rosedale intersection. These restrictions did not affect operations adversely in these areas.

Paine and Whidbey Island.

Blue 86 was used as a bypass inbound and outbound route from the south for these areas. The use of this airway reduced the traffic congestion considerably in the immediate area.

Common IFR Room Tests.

Phase II comparative tests of separate control agencies versus a common IFR room showed that the latter method was far superior for handling traffic in this complex terminal area.

Coordination procedures were simplified greatly when controllers could talk directly to each other and could make positive transfers of radar target identities visually. Interphone tieups were eliminated. Each controller had a better understanding of the traffic picture in the adjacent sector so that he could make better use of the airspace near his sector boundaries. As a result, traffic delays were reduced greatly, as shown in Fig. 15.

Phase III.

General.

The air route structure used in Phase III is shown in Fig. 12. The basic route system of Phase II is retained, but some routes were added for greater flexibility while others were deleted for lack of usefulness. A comparison of the three systems indicates how the route structure was expanded to eliminate congestion in the terminal areas.

Definite traffic flow improvement in handling satisfactorily a traffic load 85 per cent above present densities was achieved with this route structure mainly because it provided for independent departure and arrival routes to the major terminal areas.

Tacoma Municipal.

As shown in Fig. 12, the location of Tacoma Municipal was restrictive to westbound departure aircraft from McChord AFB, requiring coordination for each of these flights between arrival and departure controllers.

The 003° magnetic runway alignment at Tacoma Municipal restricted westbound departures from Seattle, and limited severely the radar vectoring area from the Harper intersection to the Seattle south outer marker, as shown in Fig. 16. The north boundary of the McChord area presently restricts this radar vectoring area, and the 003° alignment at Tacoma Municipal reduced this area and necessitated altitude restrictions which complicated the operation into SEATAC.

The second runway alignment tested was 348° magnetic. It was necessary to change the alignment approximately 15° because the water area between Vashon Island and the airport site precludes the possibility of placing an outer marker between 348° and 003° magnetic. As shown in Fig. 16, the 348° magnetic alignment was less restrictive to Seattle approach controllers because it provided approximately 2 miles of additional vectoring area. This was considered to be the maximum easterly alignment acceptable from an air traffic control viewpoint.

The third runway alignment test was 336° magnetic, placing it parallel with the instrument runway at McChord. As shown in Fig. 16, this alignment was the most efficient from an air traffic control standpoint for the following reasons:

1. It provided the maximum radar vector area for Seattle approach control.

2. It provided the best solution for establishing Tacoma Municipal operations independent of Seattle.

3. It provided simultaneous, independent arrival operations at Tacoma Municipal and McChord. This would become an important factor when operations at Tacoma Municipal increase to that of a major terminal.

Seattle ARTC.

The over-all operation of the Phase III route layout was superior to previous systems tested. The preferential route system provided improved departure and arrival routes which simplified the use of radar procedures. The bypass routes eliminated traffic congestion over Seattle and expedited the movement of arrivals and departures in the Seattle terminal area.

The Shelton VOR area was congested by high-altitude traffic proceeding to terminals north of Seattle. However, in actual practice, much of the workload required in these tests would be absorbed by high-altitude sectors. This workload could be reduced further by the segregation of departures and arrivals under the jurisdiction of two controllers. Time and personnel limitations prevented any attempt to alleviate this problem during the simulation tests.

The opinions of the controllers who participated in this study indicated that this route structure was capable of accommodating a high traffic volume and was extremely well suited to the use of radar procedures.

SEATAC, Boeing, and Sand Point.

The departure traffic flow basically was the same as that used in Phase II.

Radar vectoring to final approach for north landings was accomplished initially from Harper, Kitsap, and the Seattle VOR, utilizing the vector area west of the Seattle ILS course. This proved to be restrictive for the reasons described in Phase II. Simulation studies indicated that it was feasible to vector arrivals from both sides of the ILS course as shown in Fig. 14. The descent area from the VOR holding pattern was usable, although somewhat restricted. Figure 17 shows a suggested means of increasing the size of this vector area by moving the Seattle VOR approximately 4 miles east of the location used in Phase III. This would not affect departures adversely and would provide more area for vectoring from dual stacks. Aircraft from Kitsap then could be cleared to either holding pattern for subsequent vectoring to final approach.

South landings at these airports were controlled satisfactorily, with one controller vectoring from Harper and another controller vectoring from Kitsap and the Seattle VOR, as shown in Fig. 13.

McChord.

During this phase, McChord RAPCON continued to operate as an approach control facility.

Clearance limits established at Rainier and Puget improved the arrival flow at McChord and permitted segregation of Tacoma Municipal traffic. However, the Fort Lewis restricted area precluded the possibility of establishing clearance limits in more desirable locations. The Puget clearance limit provided a method for vectoring from both sides of the final approach course for south landings as shown in Fig. 13.

The departure vector area between McChord and Carbonado was increased because of the relocation of Airway V23. This provided more area on the east side of McChord for departure aircraft to climb unrestricted and remain clear of V23.

Westbound departures from McChord required close intra-agency coordination because of traffic at Tacoma Municipal.

Jet penetrations and ADC jet recoveries were accomplished from Toledo VOR as shown in Fig. 12. This proved to be advantageous and allowed unrestricted descent under radar control.

Paine and Whidbey Island.

The route structure used in this phase provided these airports with a much improved traffic flow system.

The straight-in TACAN jet penetration at Paine was considered to be the most desirable approach with this route structure.

CONCLUSIONS

1. Excessive coordination is a limiting factor to IFR operations in the present system.

2. The present clearance limits in the Seattle-Tacoma terminal area are poorly located and the vector areas will not accommodate predicted traffic volume.

3. In Phase I, the route for eastbound departures to a fix in the vicinity of Monroe is usable as an interim procedure until the Phase II preferential routes can be implemented.

4. The present route structure is inadequate and limits the Center radar capabilities.

5. The Phase II route structure and preferential one-way route system is more compatible with radar procedures than is Phase I and will accommodate increased traffic volume.

6. Consideration should be given to including the Olympia VOR in the McChord approach control area before implementing Phase II. A suggested method of accomplishing this is shown in Fig. 6.

7. The ADC climb corridor at McChord is less restrictive to IFR operations in Phases II and III when placed on a heading of 336° magnetic.

8. Operational procedure should be considered which would permit jet recoveries from Hoquiam to McChord AFB to cross V99 as low as 15,000 feet in Phase II.

9. The reversal of traffic flow south of Seattle in Phases II and III provides good preferential routings that are adaptable to either radar or nonradar procedures.

10. The clearance limits in the Seattle-Tacoma terminal area provided improved radar vector areas in Phases II and III.

11. The bypass routes that were implemented alleviated traffic congestion over Seattle and expedited traffic movement throughout the area simulated.

12. The base of the restricted area west of Seattle (R-241) is a limiting factor to IFR operations and becomes progressively more restrictive with the advent of commercial jet aircraft.

13. The Fort Lewis restricted area (R-503, R-504, R-505) precludes the possibility of locating satisfactory clearance limits in the McChord approach control area.

14. The recommended location of the Seattle VOR, as shown in Fig. 17, would provide Seattle approach control with a more usable vector area east of the airport for arrivals. It also would provide more flexibility for McChord departures en route to Carbonado and Swanson.

15. The common IFR room concept simplified controller coordination and expedited IFR traffic movements. This type of facility may be necessary to handle the increased complexities of terminal area control which will be produced by the activation of the proposed Tacoma Municipal Airport.

16. The Phase III route structure refined and improved the Phase II system without changing the preferential route pattern.

RECOMMENDATIONS

1. Implement the radar departure route to Monroe as an interim procedure to expedite eastbound departures.

2. Implement the Phase II route structure and preferential route system at the earliest possible date.

3. Retain the McChord RAPCON area and operations in the initial changeover to the Phase II system. McChord RAPCON should continue present operations until the Seattle ARTC Center radar has beacon capability and controllers have attained sufficient radar experience.

4. Remove the departure radar scope from SEATAC Tower and place it adjacent to the arrival scope in the downstairs location.

5. SEATAC approach control should assume jurisdiction of IFR traffic at Sand Point NAS as soon as practicable.

6. The ADC jet-climb corridor at McChord should be realigned on a 336° magnetic heading when Phase II is implemented. Consideration should be given to placement of the corridor beginning at the end of the runway instead of at the control zone boundary.

7. If the Tacoma Municipal Airport is developed on the Peninsula site, it is recommended that the runway be aligned parallel with the instrument runway at McChord. With this alignment, the traffic at the higher density airports would be less restrictive to increases in traffic volume at Tacoma.

8. Study the usage of the Fort Lewis restricted area to determine whether any one or a combination of the following could be accomplished·

a. Remove all restrictions.

b. Lower altitude restrictions.

c. Reduce size of area.

9. Raise the lower limit of restricted area R-241 to a minimum of 21,000 feet to accommodate air traffic at altitudes of 20,000 feet and below.

10. Action should be started to implement the route structure or similar structure as described for Phase III. This route arrangement can be implemented gradually as facilities are provided in the area with no change in the basic traffic flow of Phase II.

TABLE I

DISTRIBUTION OF AIRCRAFT IN TRAFFIC SAMPLES

Phase I Airport	No. Arrivals Per Hour	No. Departures Per Hour	Total Traffic Per Hour
McChord	16	20	36
Seattle-Tacoma	12	13	25
Boeing Field	5	4	9
Sand Point	2	2	4
Paine Field	4	3	7
Whidbey Island	3	5	8
Phase II			
McChord	16	20	36
Seattle-Tacoma	14	14	28
Boeing Field	5	4	9
Sand Point	2	2	4
Paine Field	4	3	7
Whidbey Island	3	5	8
Phase III			
McChord	17	22	39
Seattle-Tacoma	20	21	41
Boeing Field	7	7	14
Sand Point	5	4	9
Paine Field	4	4	8
Whidbey Island	5	6	11
Tacoma Peninsula	6	5	11

SUMMARY

Phase	I	II	III
Total aircraft	169	177	240
Approximate running time	2 hr.	2 hr.	2 hr.
Increase over present traffic density (percentage)	30	35	85
Percentage of jet aircraft	35	35	35

TABLE II

LOCATION IDENTIFIERS

ANN	Annette Island, Alaska
AST	Astoria VOR
AUB	Auburn Intersection
BAN	Bandera Intersection
BDI	Black Diamond Intersection
BFI	Boeing Field, Seattle
BLI	Bellingham, Wash.
BOI	Boise, Idaho
CAM	Camp Intersection
CAR	Carbonado Intersection
CAS	Case Intersection
CLE	Cle Elum Intersection
CLS	Chehalis-Centralia Airport
CLX	Clinton Intersection
CMB	Cumberland Intersection
COS	Colorado Springs, Colo.
CRK	Castle Rock Intersection
CYS	Cheyenne, Wyo.
DEN	Denver, Colo.
DGS	Dungeness Fan Marker
DLS	The Dalles, Ore.
EAN	Easton Fan Marker
EAT	Wenatchee Airport, Wash.
EBY	Neah Bay, Wash.
EDF	Elmendorf AFB, Alaska
ELN	Ellensburg, Wash.
EPH	Ephrata, Wash.
EVE	Everett, Wash.
FBK	Fairbanks, Alaska, Ladd AFB
GEG	Geiger Field, Spokane, Wash.
GFA	Malmstrom AFB, Great Falls, Mont.
GHM	Graham Intersection
GO	Gordon Head, Canada
HAR	Harper Intersection
HBT	Hobart Fan Marker
HIF	Hill Field AFB, Ogden, Utah
HNL	Honolulu
HQM	Hoquiam, Wash.
HRI	Harbor Island Fan Marker
HUM	Humphries Intersection
KIT	Kitsap Intersection

TABLE II (continued)

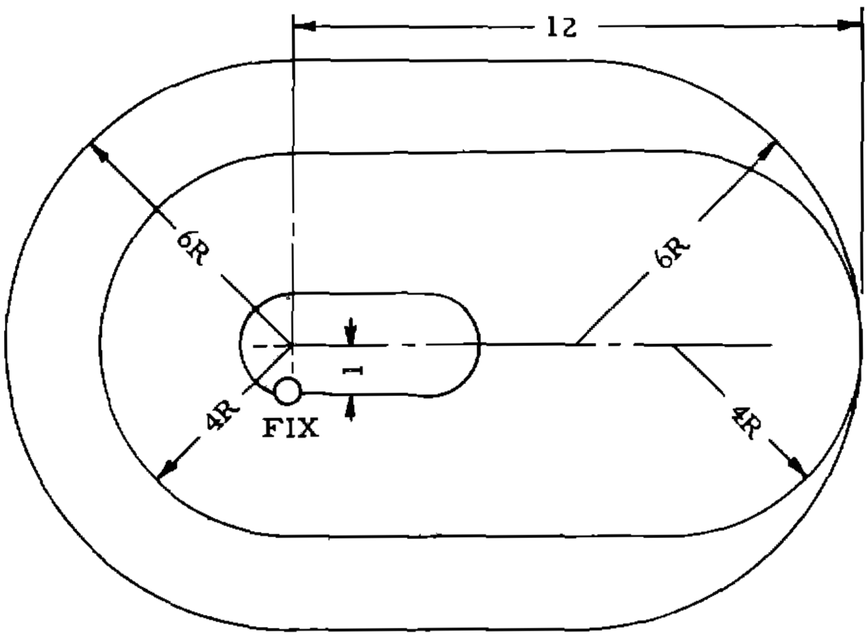
LOCATION IDENTIFIERS

LAX	Los Angeles, Calif.
LEB	Lebam Intersection
LRN	Larson AFB, Wash.
LRY	Lowry AFB, Denver, Colo.
LVS	Nellis AFB, Las Vegas, Nev.
LVW	Longview, Wash.
MCC	McClellan AFB, Sacramento, Calif.
MDK	Mud Lake Intersection
MDW	Midway Airport, Chicago, Ill.
MER	Castle AFB, Merced, Calif.
MFR	Medford, Ore.
MOR	Morton Intersection
MOS	Mossyrock Intersection
MSP	Minneapolis, Minn.
MTS	Mount Stuart Intersection
MVN	Mount Vernon Intersection
MWG	Monroe Intersection
NEJ	Sand Point NAS, Seattle
NGZ	Alameda NAS, Calif.
MKX	Miramar NAS, San Diego, Calif.
NLT	Neilton Intersection
NPE	Buckley NAS, Denver, Colo.
NTB	Los Alamitos NAS, Calif.
NTD	Point Mugu NAS, Calif.
NUU	Olathe NAS, Kan.
OAK	Oakland, Calif.
OLM	Olympia, Wash.
ONT	Ontario, Calif.
PAC	Packwood Intersection
PAE	Paine AFB, Everett, Wash.
PDX	Portland, Ore.
PEN	Peninsula Airport, Tacoma, Wash.
PLM	Palmer Intersection
PRT	Port Intersection
PRW	Port Gamble Intersection
PSC	Pasco, Wash.
PTA	Port Madison
PUG	Puget Intersection
PUR	Purdy Intersection
PUY	Puyallup, Wash.
QUE	Queen River Intersection
RBL	Red Bluff, Calif.
RCA	Ellsworth AFB, Rapid City, S. D.
RCH	Rochester Intersection

TABLE II (continued)

LOCATION IDENTIFIERS

RCK	Ranger Creek Intersection
REN	Renton Intersection
RIV	March AFB, Riverside, Calif.
RLB	Rolling Bay Intersection
ROS	Rosedale Intersection
RNR	Rainier Intersection
SAC	Sacramento, Calif.
SAL	Salmon Intersection
SEA	Seattle-Tacoma International Airport
SFO	San Francisco, Calif.
SHN	Shelton RBN
SKA	Fairchild AFB, Spokane, Wash.
SRF	Hamilton AFB, Calif.
SUN	Sunrise Intersection
SWA	Swanson Intersection
TCM	McChord AFB, Tacoma, Wash.
TDO	Toledo, Wash.
TLR	Taylor Intersection
TON	Bremerton Intersection
VR	Vancouver, British Columbia
VSH	Vashon Intersection
WIP	White Pass Intersection
WIN	Winlock Intersection
WRM	Warm Beach Intersection
WYI	Whidbey Island NAS, Ault Field, Wash.
YJ	Patricia Bay, Canada
YKM	Yakima, Wash.



INNER PATTERN PRESENT TSO-N20A HOLDING
AREA FOR 1-MINUTE PATTERN.
OUTER PATTERN AREA ASSUMED FOR SIMULATION TESTS
ALL DIMENSIONS ARE IN STATUTE MILES.

FIG. 1 HOLDING AIRSPACE RESERVATIONS

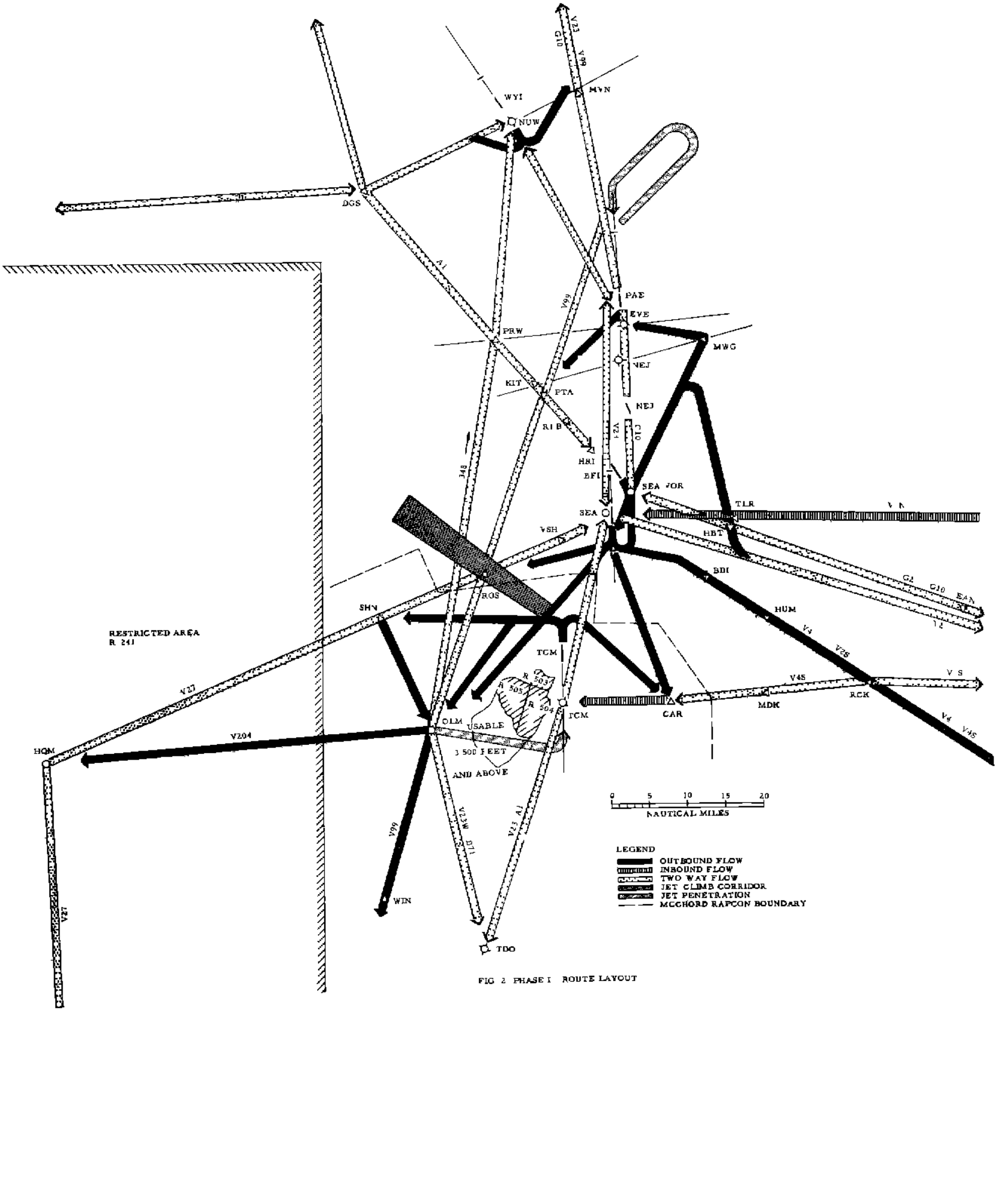


FIG 2 PHASE I ROUTE LAYOUT

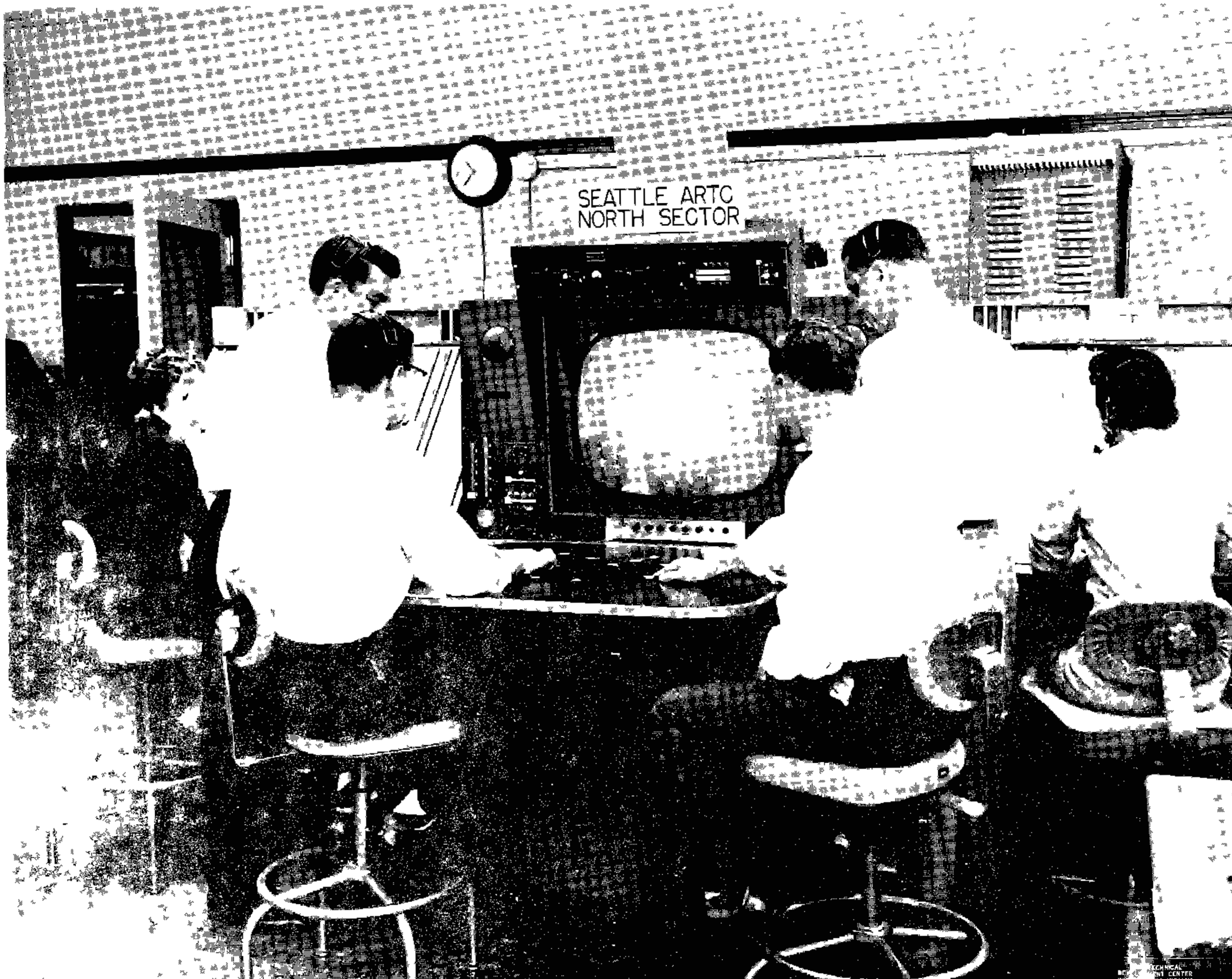


FIG 3 CONTROL ROOM SETUP FOR TYPICAL AIR ROUTE CONTROL SECTOR

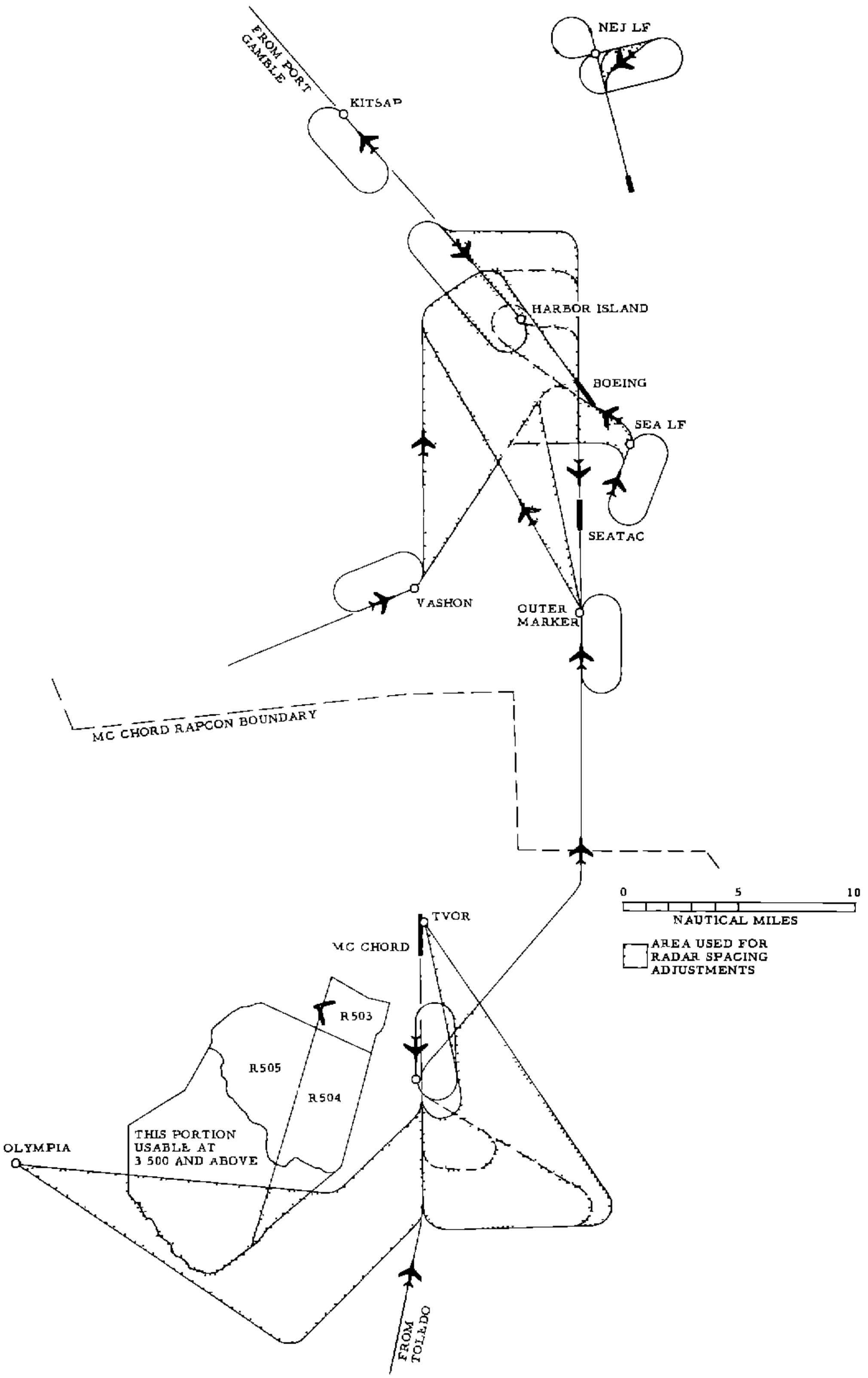


FIG 4 PHASE 1 - APPROACH PATTERNS FOR SOUTH LANDINGS AT ALL AIRPORTS EXCEPT MC CHORD

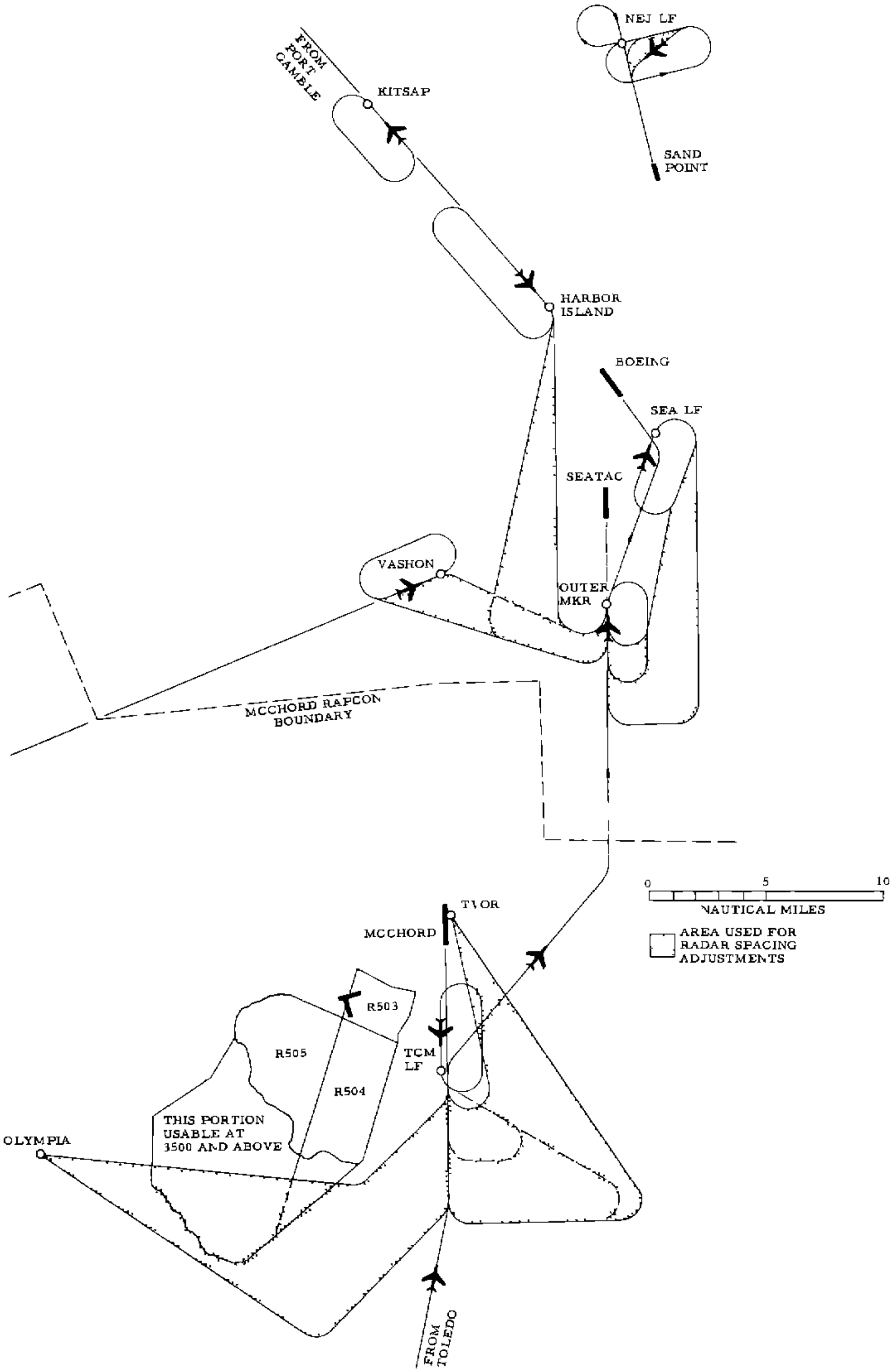


FIG 5 PHASE I - APPROACH PATTERNS FOR NORTH LANDINGS AT ALL AIRPORTS EXCEPT SAND POINT

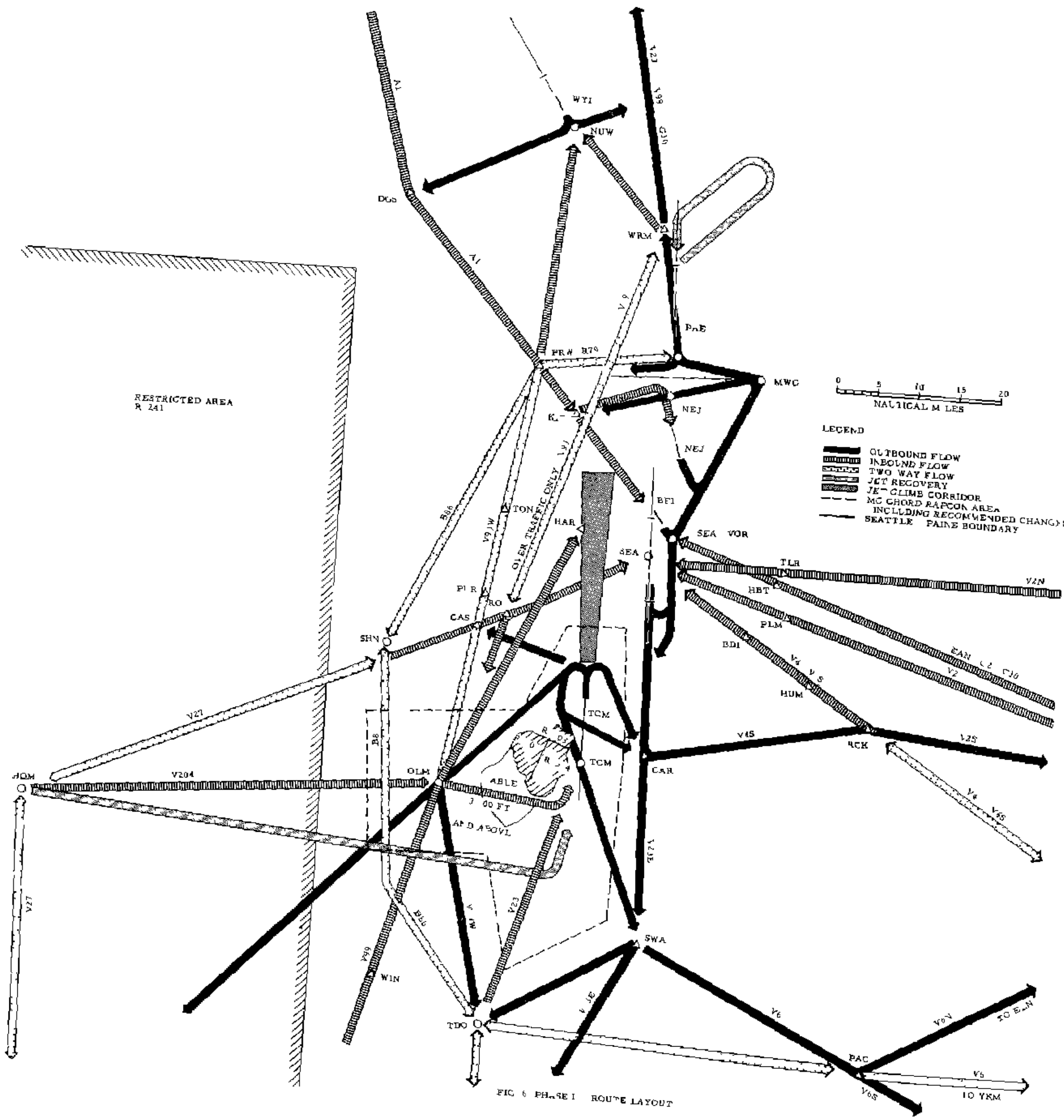


FIG 6 PHASE I ROUTE LAYOUT

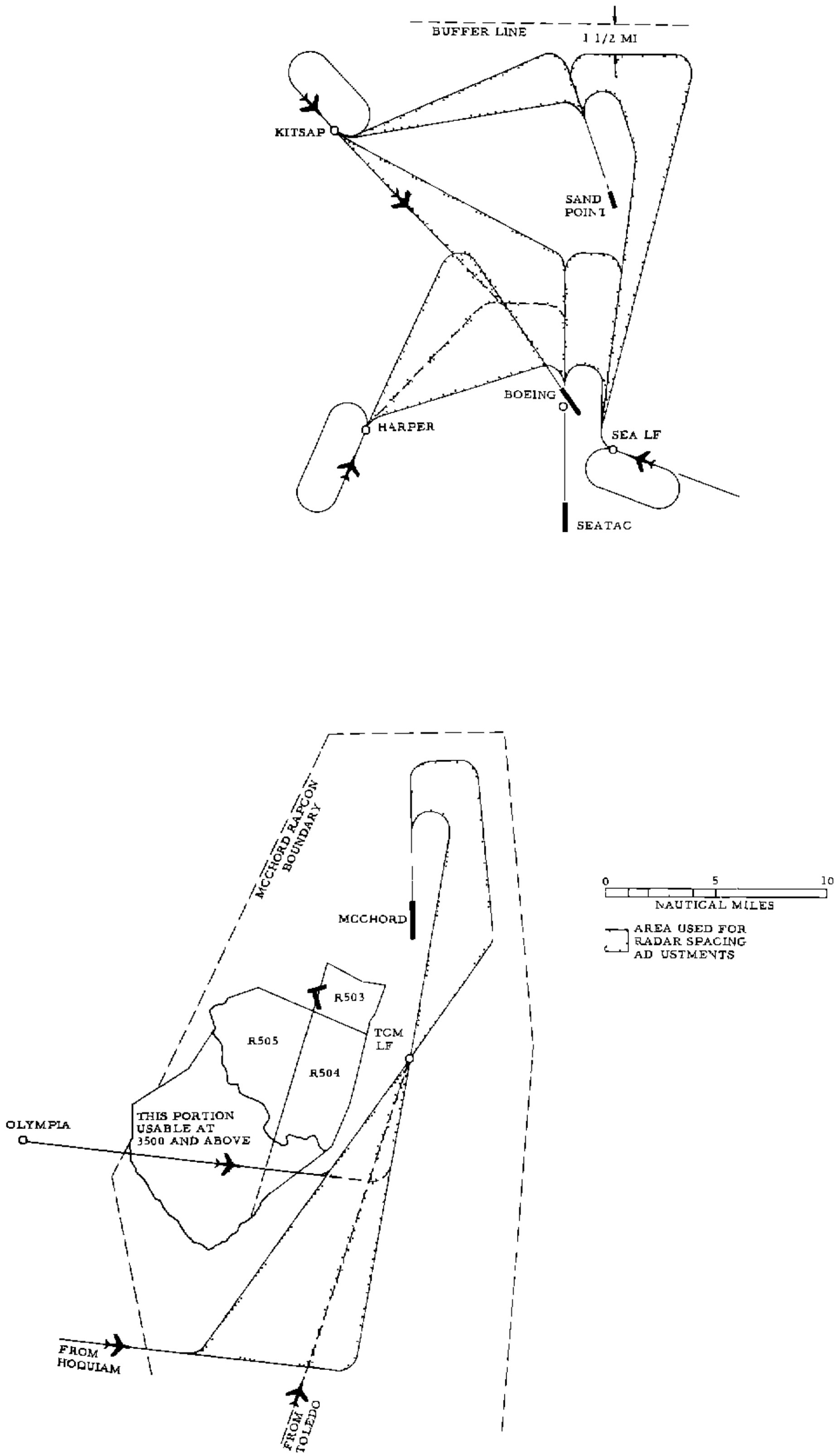


FIG 7 PHASE II APPROACH PATTERNS FOR SOUTH LANDINGS

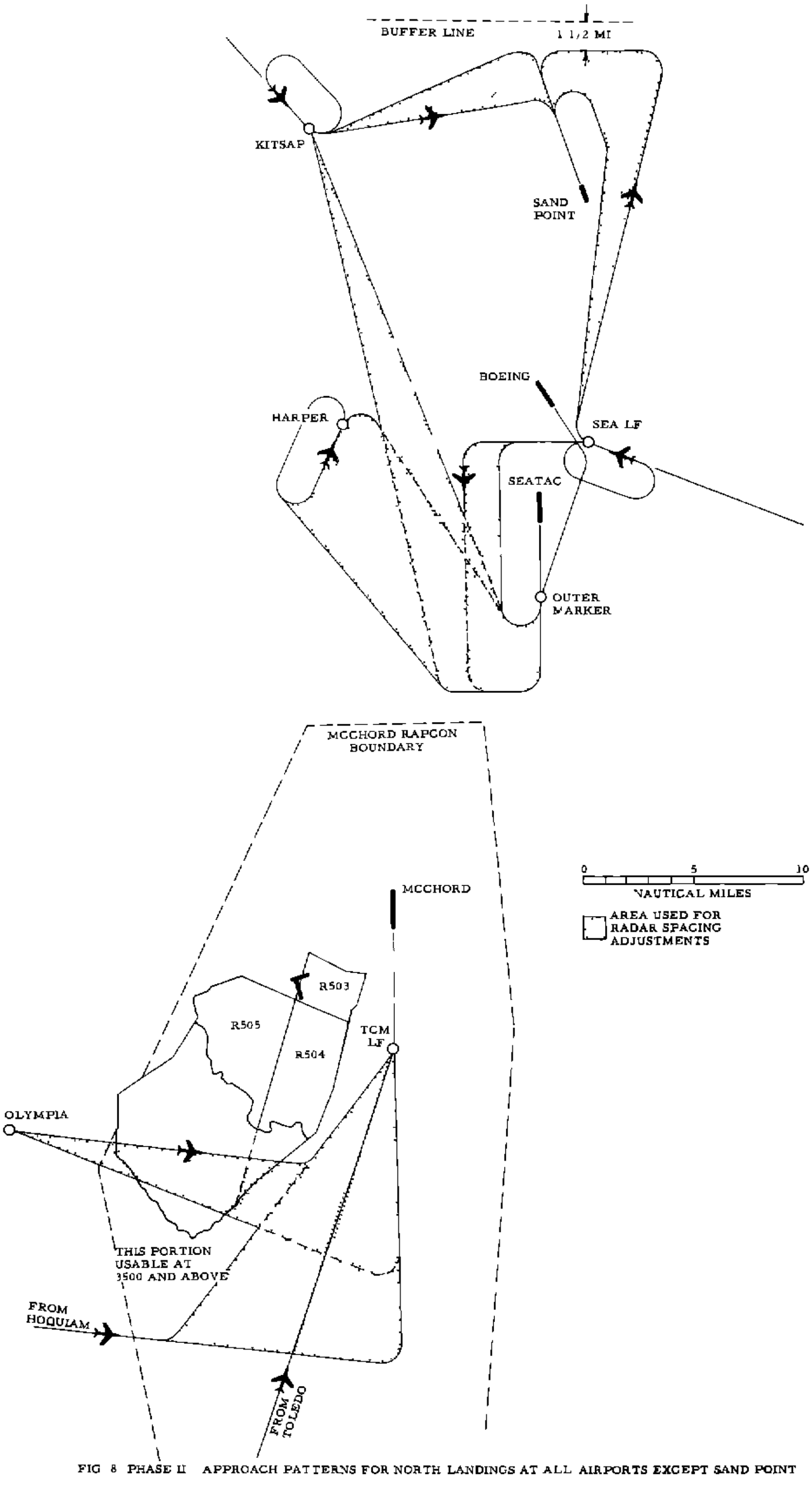


FIG 8 PHASE II APPROACH PATTERNS FOR NORTH LANDINGS AT ALL AIRPORTS EXCEPT SAND POINT

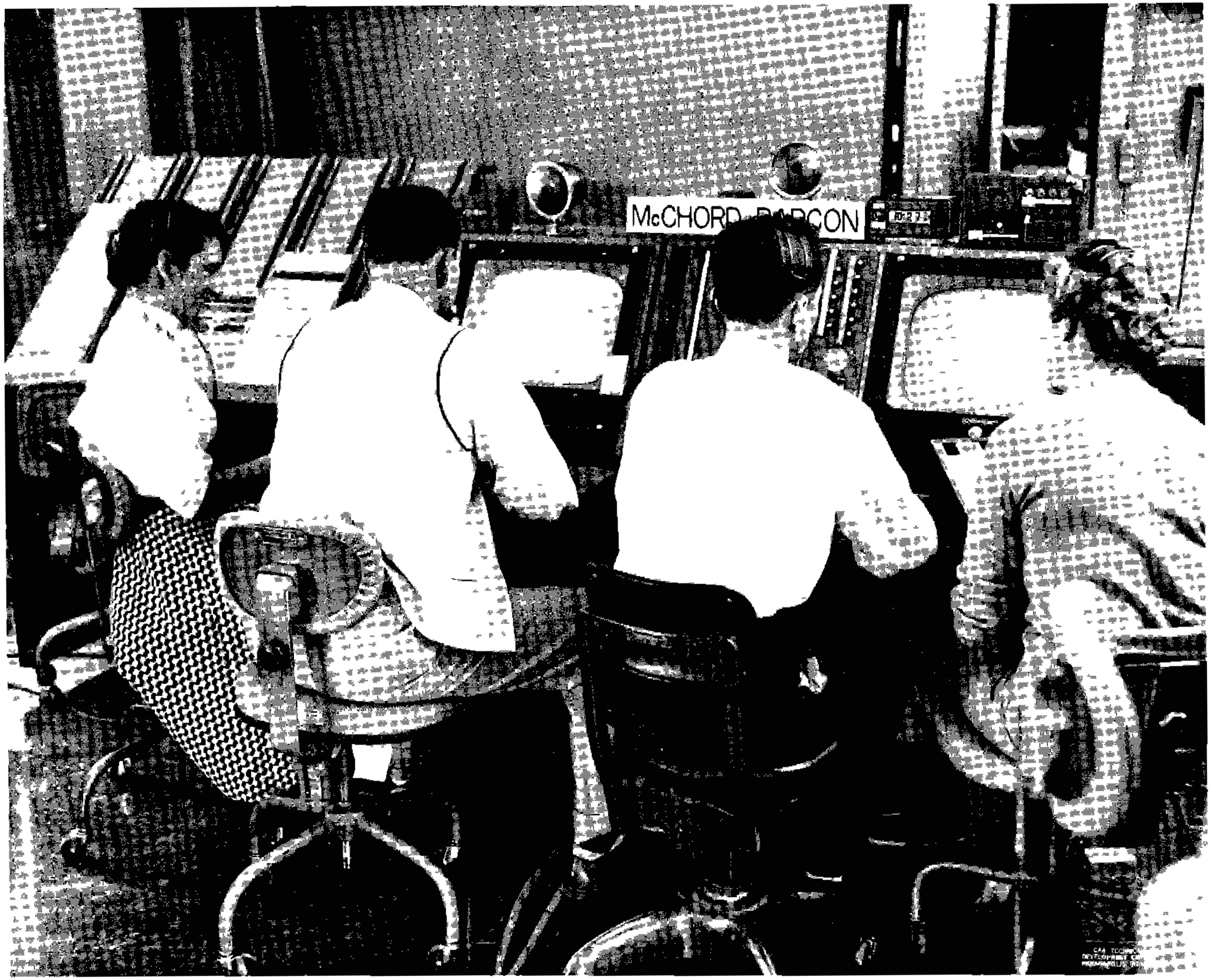


FIG 9 CONTROL ROOM SETUP FOR MCCHORD RAPCON

FIG. 10 CONTROL ROOM SETUP FOR PAINE, WHIDBEY, AND SEATAC APPROACH CONTROL

FIG 11 EQUIPMENT ARRANGEMENT FOR COMMON IFR ROOM

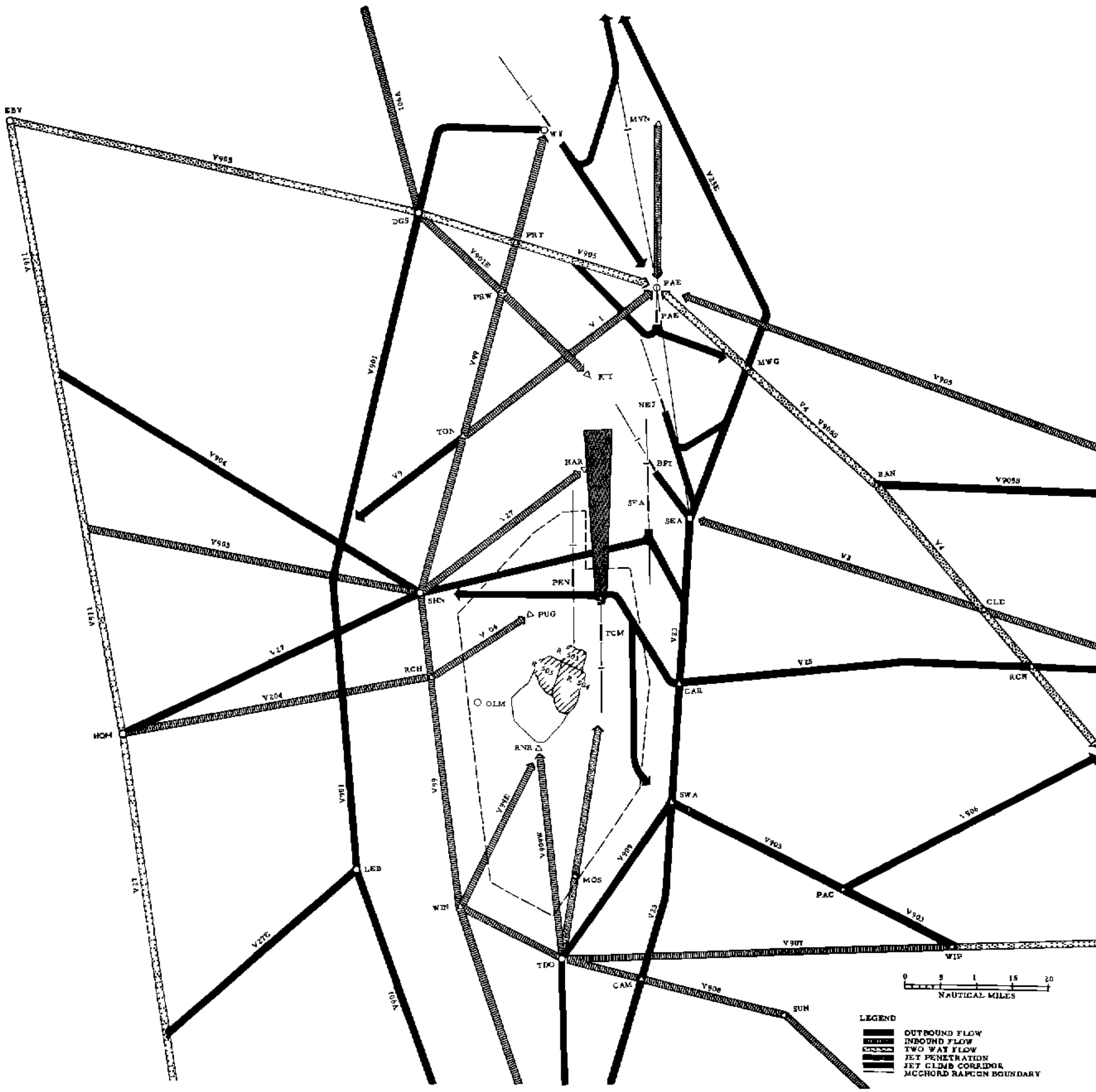


FIG 12 PHASE III ROUTE LAYOUT

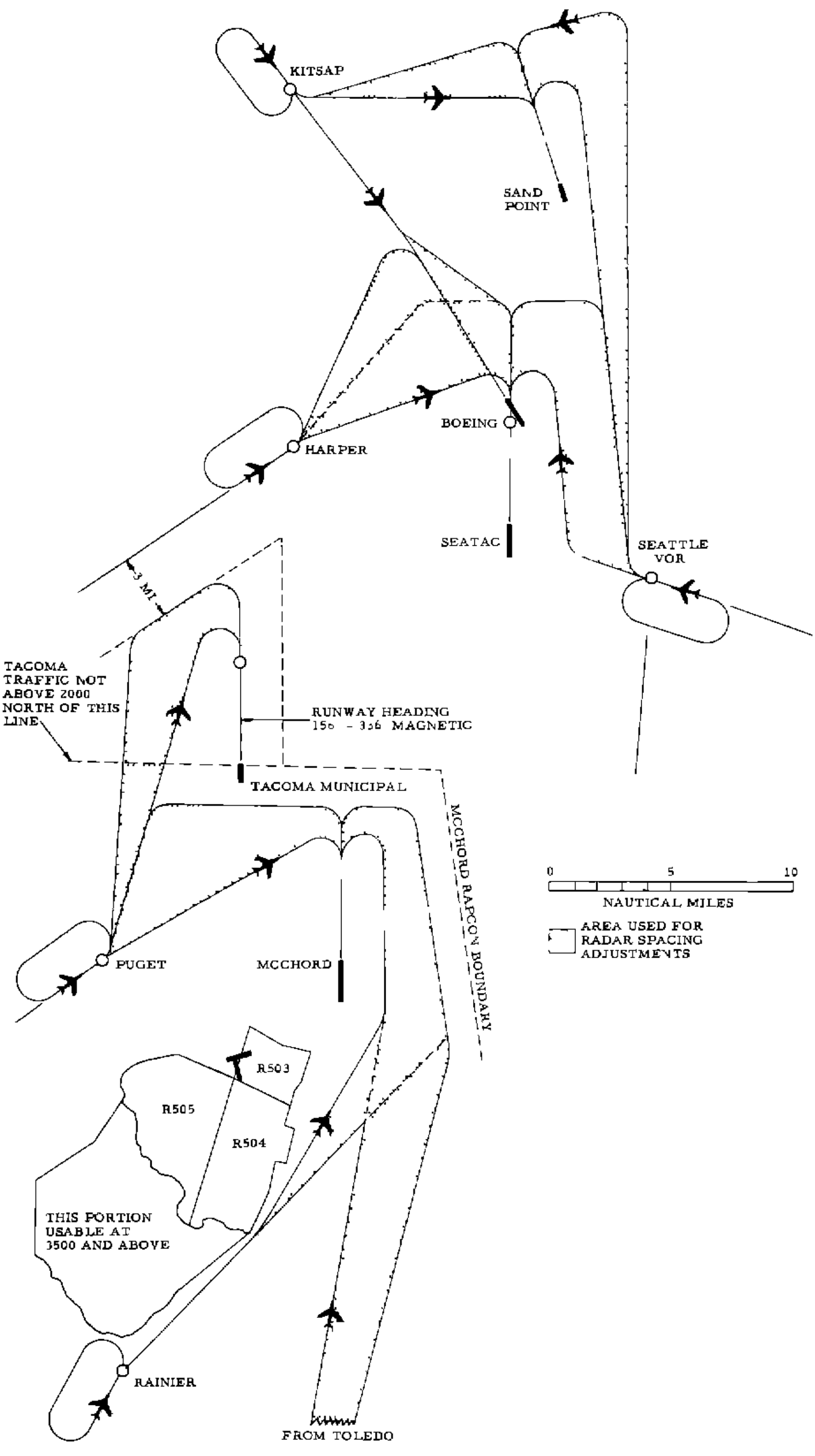


FIG 13 PHASE III - APPROACH PATTERNS FOR SOUTH LANDINGS AT ALL AIRPORTS

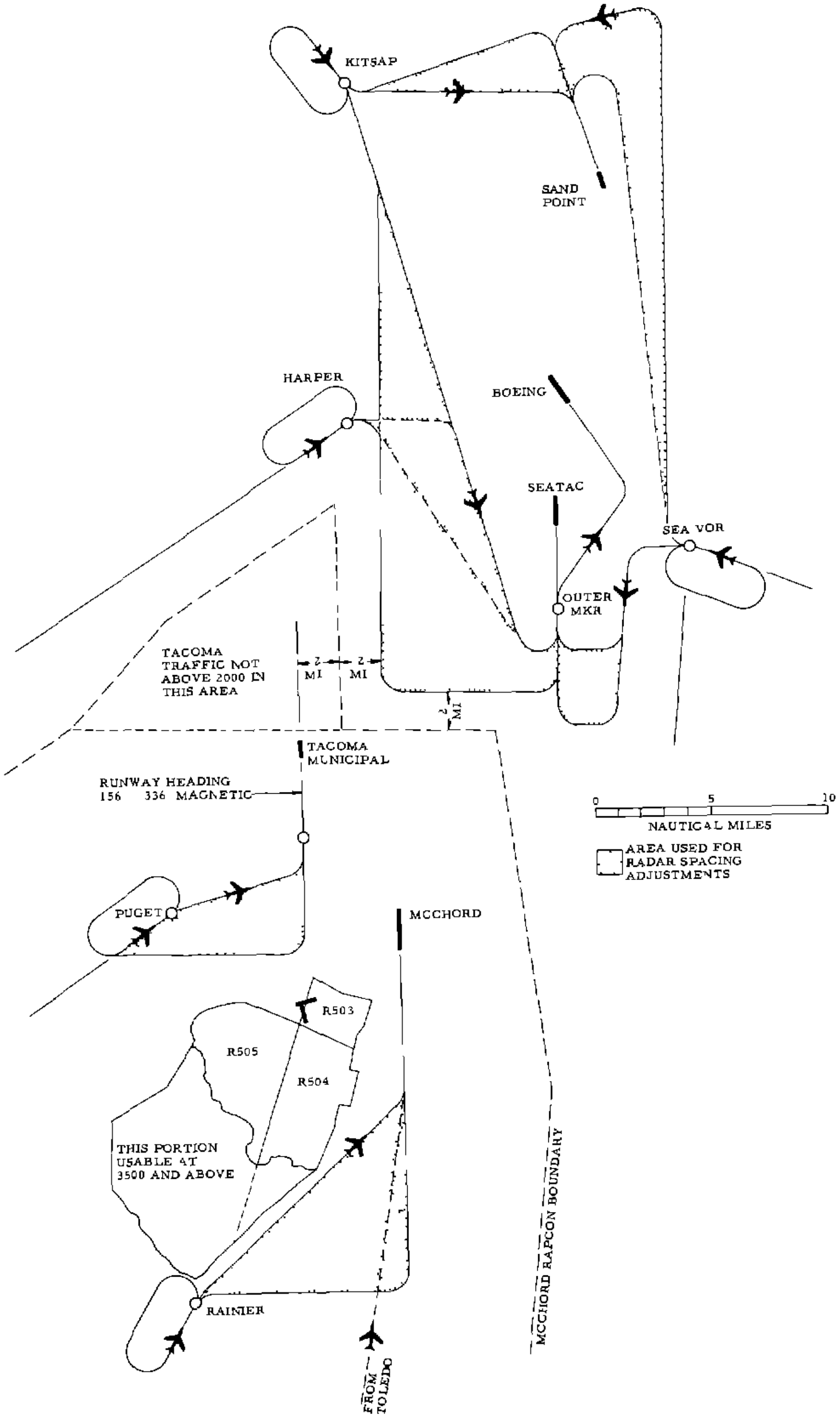


FIG 14 PHASE III APPROACH PATTERNS FOR NORTH LANDINGS AT ALL AIRPORTS EXCEPT SAND POINT

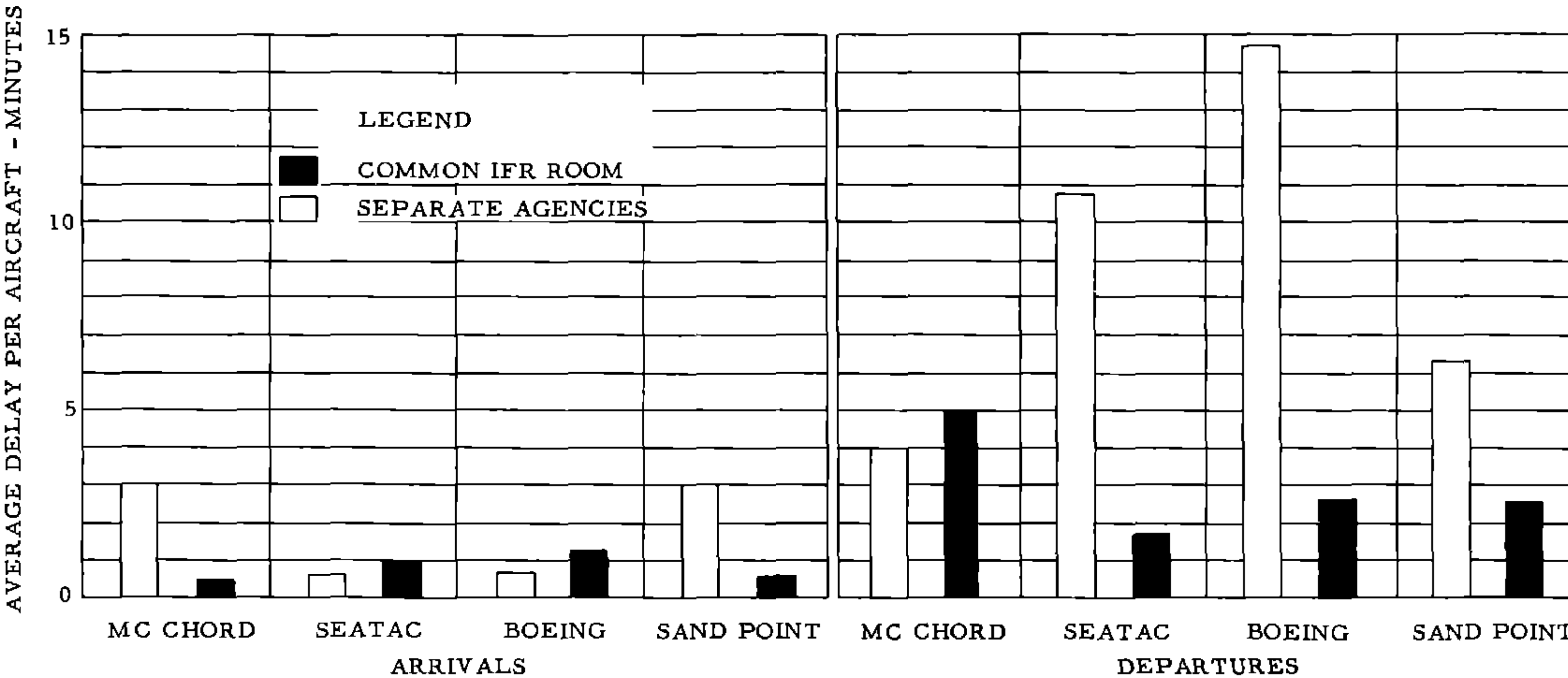
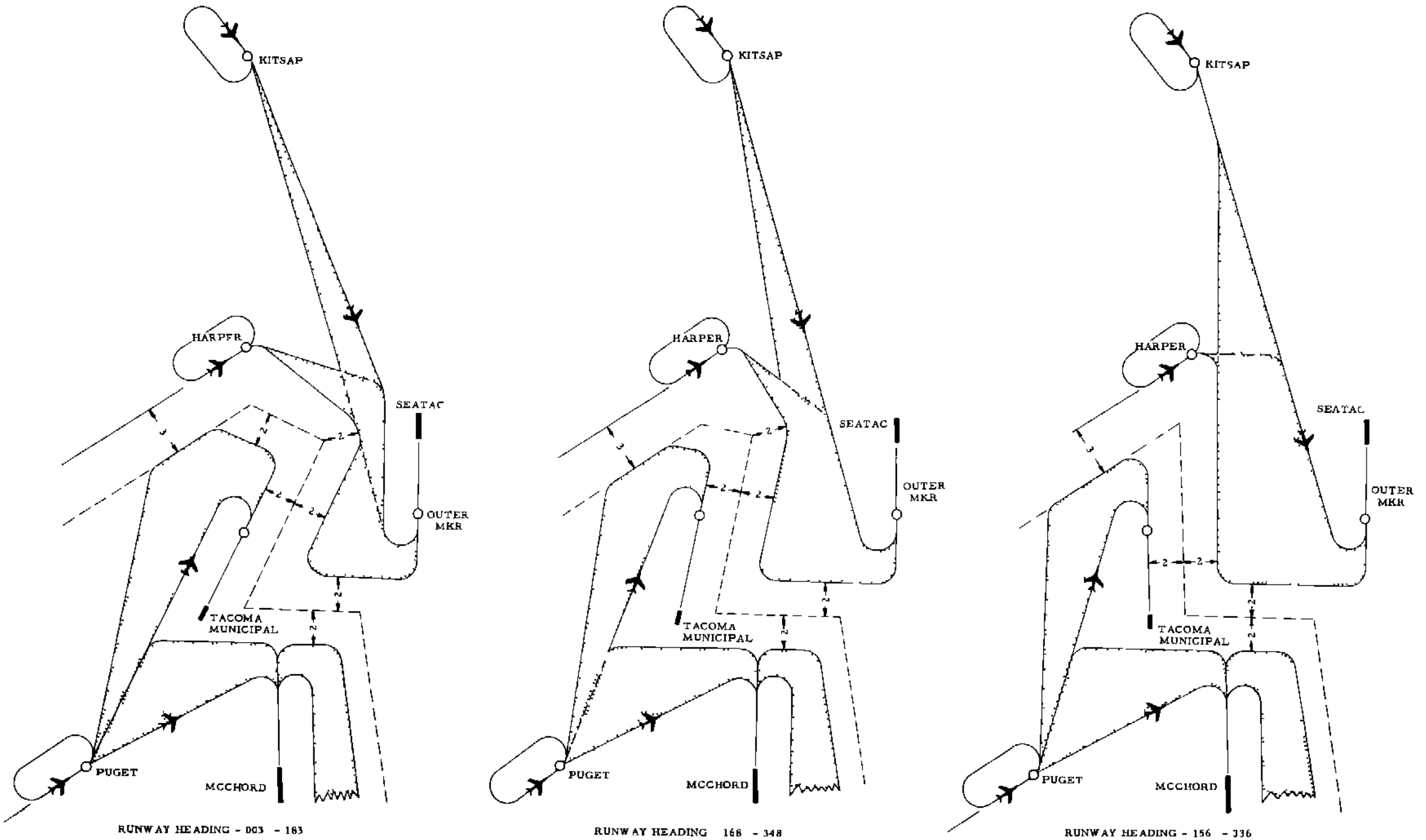


FIG. 15 EFFECT OF CONTROL SETUP ON AIRCRAFT DELAYS - PHASE II



LEGEND

ALL DIMENSIONS IN STATUTE MILES
ALL HEADINGS MAGNETIC

AREA USED FOR RADAR SPACING ADJUSTMENTS

— — MCCHORD RAPCON BOUNDARY

FIG 16 EFFECT OF TACOMA RUNWAY ALIGNMENT ON WEST APPROACH PATTERN FOR NORTH LANDING AT SEATAC - UNDER WORST OPERATIONAL COMBINATION OPERATIONS SOUTH AT TACOMA AND MCCHORD - NORTH AT SEATAC

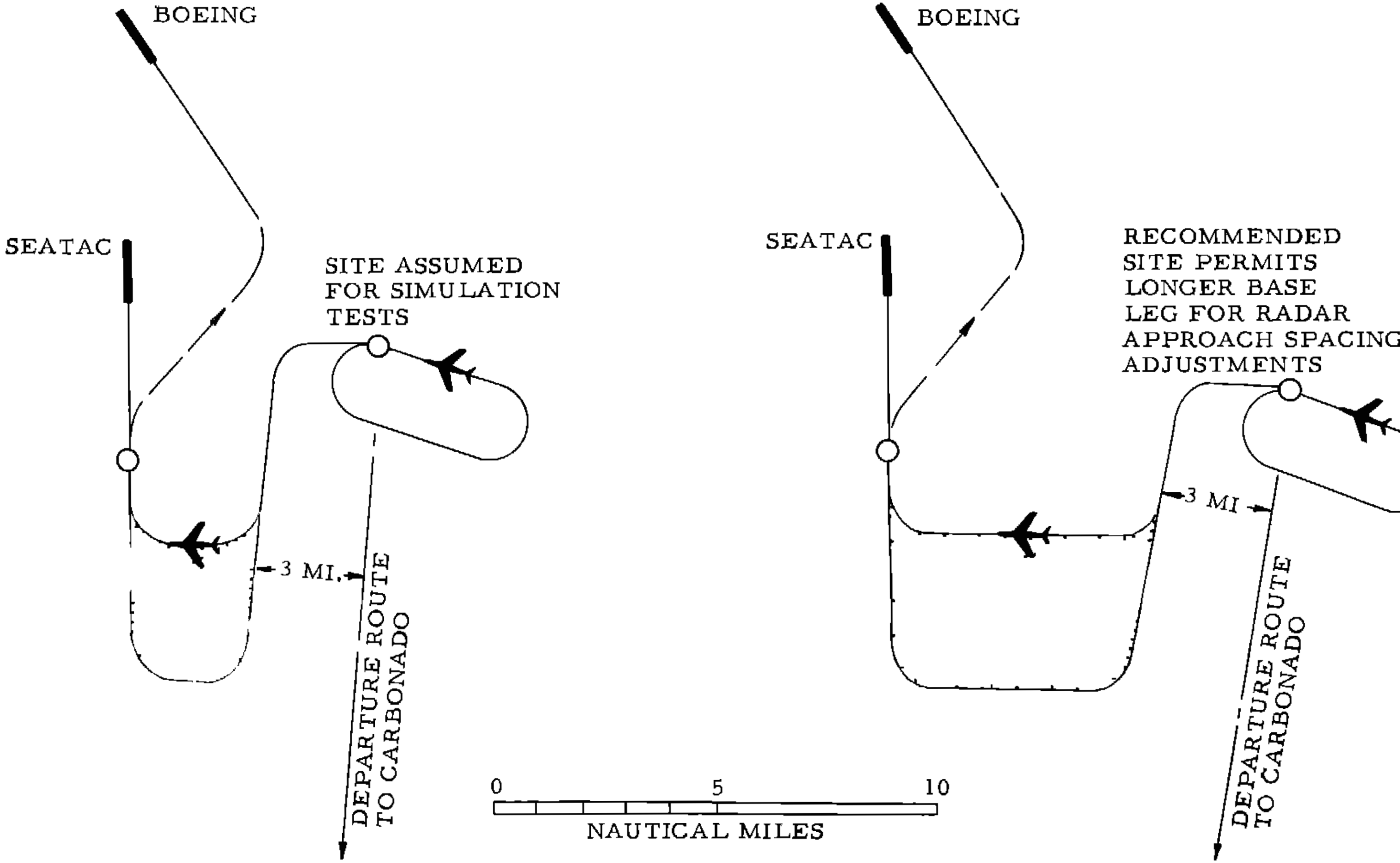


FIG 17 RELOCATION OF SEATTLE VOR