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SIMULATION TESTS OF AIR TRAFFIC CONTROL OPERATIONS IN THE DENVER-COLORADO SPRINGS AREA

by

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SIMULATION TESTS OF AIR TRAFFIC OPERATIONS IN THE DENVER - COLORADO SPRINGS AREA

SUMMARY

This report describes a study of various methods of controlling IFR air traffic in the Denver - Colorado Springs area This study was conducted through the use of simulation facilities located at the Federal Aviation Agency (FAA) Technical Development Center (TDC) at Indianapolis, Indiana

Although simulation studies were conducted for the Denver and Colorado Springs terminal areas, the maximum effort was directed toward establishing the best en route and terminal structure to handle the greatest amount of air traffic within the Denver metropolitan area.

Certain inherent factors existed in this simulation which do not ordinarily exist in studies of other terminal areas. The mountainous terrain immediately to the west of both Denver and Colorado Springs imposed limitations to the radar maneuvering areas available within the terminal control zones at the Denver and Colorado Springs Airports. The high altitude levels necessarily associated with the mountainous terrain were pertinent factors to be considered in the designation of arrival and departure routes and vital to the location of the most functional feeder fixes to handle maximum traffic flows into the airports studied

Operational procedures capable of handling maximum traffic were hampered greatly by the close proximity of the Denver Stapleton Airport and the two military airports serving the Denver area (Lowry AFB and Buckley NAS) The close relative locations of these three airports and their conflicting runway air paths, became a major part of this study

Tests in all phases clearly indicated that the use of all air space within the existant R-195 restricted area is vital to provide a maximum flow of air traffic to and from the Denver terminal area

Test results further indicated that an increase in arrival capacity could be obtained by reducing the number of feeder fixes serving

the Denver, Lowry and Buckley Airports. Arrival and departure traffic at Denver could be greatly expedited by the establishment of preferential airways north and south of Denver to by-pass the terminal area.

Studies of jet type penetrations indicated that such approaches could be greatly speeded up by providing one ideally located feeder fix to serve the three airports in the Denver area This action would also justify the elimination of the present low-frequency range jet penetration procedures

During the last phase of the study, the proposed new Stapleton north-south runway was introduced Several different systems of terminal feeder fixes and departure routings were tested to determine which would be most compatible with traffic operations at the adjacent airports It was found that a runway alignment of 340° "true" at Stapleton, approximately paralleling the north-south runway at Buckley Airport, would produce the least amount of interairport interference and consequently, the least restriction on potential IFR traffic capacity at each of the airports concerned.

Tests conducted for the Colorado Springs area clearly indicated that a relocation of the Colorado Springs VOR station would simplify the route structure and provide a common clearance limit for all arrival aircraft, thereby reducing radar vectoring to a minimum Such relocation would also, in all probability, lower the Minimum Reception Altitude (MRA) on Victor Airway 81 from 11,000 to 9,000 feet In addition, such VOR relocation would eliminate the long departure tunneling which is necessary under current operations

INTRODUCTION

In September, 1958, the FAA Office of Air Traffic Control requested the Technical Development Center to conduct simulation studies of the Denver - Colorado Springs area To gather background material for this study, three TDC controllers spent a week in the Denver area On January 28, 1959, they met with representatives of the Washington Office, the Fourth Regional Office, and local ARTC 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

A combination of factors, which restrict traffic flow and greatly increase the average controller workload per aircraft, are listed below.

1. Mountainous terrain to the west of the area imposes altitude restrictions on approach and departure routes

2. The location of the Restricted Area southeast of the Denver Airport (R-195) restricts arrival and departure routes to a narrow area for use in radar vectoring.

3 The physical layout of the Stapleton Airport and the limitations imposed upon taxiing traffic greatly reduces the traffic capacity of the airport during IFR weather.

4. The use of only one radar arrival controller to vector all approaches from four feeder fixes reduces the traffic flow under the present system.

Simulation Objectives

The objectives of the simulation program were defined as follows

DENVER

1. Test the present arrival and departure procedures at Denver with the addition of the proposed Victor Airway 8 South between Kremling Omni and Denver.

2. Determine the operational ability of the present arrival and departure routes to the north of Denver with a reverse flow of traffic as presently used.

3 Study the merits of conducting ILS approaches to the Stpaleton north-south runway from the south to the north.

4 Determine the effects of using a common IFR room for the multiple airports within the Denver terminal area.

5. Submit recommendations for revisions to the preferential route structure, terminal feeder fixes, relocation of existing VOR facilities and the installation of additional navigational facilities if needed.

During the third week of this program, the Washington Office requested that studies be made on the following additional runway alignments and airport use

A. Conduct ILS approaches at Stapleton and Buckley Airports using east-west runways at both locations.

B. Use northwest-southeast runway at Buckley Field for all air-carrier and military jet operations, and use Stapleton as the general aviation airport.

C. Determine if any increase in terminal traffic capacity can be gained by the construction of a new northwest-southeast ILS all-weather runway aligned 340° true at Stapleton Airport.

With the concurrence of the Washington Office the concept of the Common IFR Room was not studied.

COLORADO SPRINGS

1. Study existing arrival and departure routings and procedures and test airport capacity with and without the use of a TVOR facility at Peterson Field.

2 Submit recommendations for revisions to the preferential route structure, terminal feeder fixes, relocation of existing VOR facilities, and the installation of additional navigational facilities.

Test Assumptions.

The general assumptions, under which these simulation tests were conducted, are as follows

1. These studies would embrace the area within a radius of 80 miles of the Denver Stapleton Airport.

2. Adequate ARTC radar coverage would exist within a 60 mile radius of Denver. In addition, Center radar departure service would be provided for north and eastbound departures from Colorado Springs.

3 Adequate direct air/ground communications would exist throughout the area being simulated.

4. Low-Frequence (L/F) airway systems would be included in simulation studies of Phases I and II.

5. The dimensions of the standard TSO holding pattern airspace would be increased 50% in width, as shown in Fig. 1, to anticipate a regulatory change which is under consideration.

6. 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.

7. The Restricted Area R-195 would be used only for occasional departure aircraft.

8 The rate of climb for departing aircraft would be based on the standards indicated in Table I

Simulation tests were commenced on March 4, 1959, and concluded on March 26, 1959 A total of 70 test runs were made in which approximately 5, 000 aircraft flights were simulated.

EVALUATION METHODS

Measurements.

Traffic delay, airport acceptance rate, and communication data were taken during the simulation tests and used as a means of determining the merits or weaknesses of the various systems tested.

Six controllers from the Denver ARTC Center, two from the Denver Tower, and two from the Colorado Springs 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 portion of the simulation time to training activities to allow all personnel an opportunity to acquaint themselves with the equipment and procedures used in these tests.

A comparative analysis of communications time, number of aircraft contacts, and average delay times for each phase tested, is illustrated in Figs 2, 3, 4, 5, 6, and 7. Variation in controller skill is a factor to be considered when analyzing the difference in test results illustrated. Examination of aircraft delay data showed that the effects of having a particular controller at a certain position during a specific test run could rule out the differences which normally would be expected between the delays of the different systems.

Controller Opinion

During the planning period of this simulation, routes, systems, and procedures were firmly established for studies of Phases I, II, and III. The test studies of the first three phases provided ample opportunity to observe the air traffic flow characteristics of the entire area. As a result, additional refinements and changes were made in route layouts, feeding systems, and control procedures to provide extra phases for study and simulation The effect of the modification to systems used in Phases I, II, and III were evaluated by the test controllers. At the conclusion of the program, a critique was held and the opinions and recommendations expressed by the participating controllers were used to a large extent in the final evaluation of the results of the tests and the recommendations which are summarized elsewhere in this report

Flight progress strips of recent, moderately busy days were obtained from the Denver ARTC Center These strips were analyzed for use in determining the distribution of traffic utilizing the various airways in the area The density of the traffic simulated was approximately 50% greater than that indicated in the analyzed operations. Three traffic samples were used in the tests. Each sample consisted of 79 aircraft operating during a one-hour period. However, approximately 85 minutes were required to simulate all flights to conclusion. Aircraft identifications, types and altitudes were the same in both samples but differed in airway routings, clearance limits, and the locations at which the flights entered into the problem, depending upon the particular phase being tested.

TEST PROCEDURES

Systems Tested.

Nine basic systems, designated as Phase I through Pase IX, were tested These tests were conducted using current rules and restrictions When necessary, the rules and restrictions were revised to improve the system being tested.

Phase I, Figs. 8 and 9, was a study of the en route and terminal system to be used effective June 1, 1959

Phase II, Figs 10 and 11, was a variation of Phase I, modified to reflect a reversal of traffic flow on arrival and departure routes north of Denver

Phase III, Figs 12 and 13, introduced a new north-south runway at Stapleton Airport with all instrument approaches being conducted from south to north R-195 airspace was used for a terminal area feeder fix

Phase IV, Figs 14 and 15, was a variation of Phase I, in which the terminal area feeder fixes were reduced from four to two. Phase IV Modified, Figs 16 and 17, was a variation of Phase IV, in which the eastern half of R-195 was used for control purposes

Phase V, Figs 18 and 19, was a variation of Phase III with all operations remaining clear of R-195 airspace

Phase VI, Figs 20 and 21, was a modification of Phases I and IV, with one terminal area feeder fix located within the airspace presently designated as R-195.

Phase VII, Figs. 22 and 23, was a study of the feasibility of using the Buckley Airport for scheduled air carrier aircraft and military jet aircraft, and Stapleton for general aviation aircraft

Phase VIII, Figs. 24 and 21, was a variation of Phase VI This phase incorporated an instrument landing system at Buckley aligned for approaches from east to west and provided facilities to conduct simultaneous approaches to Stapleton and Buckley Airports

Phase IX, Figs 25 and 26, was a variation of Phase III with the new north-south runway at Stapleton, aligned northwest-southeast

Traffic Samples

Three traffic samples, with the same traffic distribution, were compiled Traffic Sample I was designed to study Phase I, IV, VI, and VIII Sample I-A was designed to study Phase II, Sample II was used to study Phases III, V, VII, and IX. The aircraft routings in Samples I-A and II were revised, as necessary, to coincide with the route structure of the particular phase being tested. Traffic distribution in these samples is shown in Table 2.

Equipment

Denver Approach Control utilized three simulated ASR scopes, as shown in Fig 27 One was used for all arrival traffic from the west and north, one for all arrival traffic from the east and south, and the third scope was used for all departure control at Stapleton, Lowry, and Buckley Airports.

Two scan-conversion radar monitor scopes were installed in another location to simulate the Colorado Springs Tower arrival and departure positions which were simulated as a side-by-side operation, as shown in Fig 28

The two radar sectors of the Denver ARTC Center were simulated using one superimposed panoramic radar display (SPANRAD), as shown in Fig 29 The Colorado Springs radar sector of the Denver Center was simulated using a scan-conversion radar monitor scope as shown in Fig 30

PHASE I

The purpose of simulation in this phase was to conduct simultaneous tests of the Denver - Colorado Springs en route and terminal systems, using only facilities which are expected to be in operation by June 1, 1959

The Denver area portion of Phase I, shown in Figs 8 and 9, was tested with three terminal radar controllers, four ARTC Center controllers, of which two were radar positions, and four data positions

The Center control area was divided geographically by a north-south line over the Stapleton outer marker All Center control in this Phase was predicated on ANC separation, using radar as a supplementary aid only. All airspace west of the north-south dividing line was controlled by an ANC controller whose functions encompassed arrival, departure, and en route control The airspace east of the north-south dividing line was likewise controlled by an ANC controller with similar control responsibilities In addition, individual east and west Center radar controllers, each functioning in a dual capacity of arrival and departure control, provided a supplementary aid to the ANC controller in maintaining separation between aircraft when ANC procedures would not apply The ANC controllers made all initial radio contacts and descended inbound aircraft to the lowest available altitude prior to release to the Center radar controllers. In addition, they were responsible for departure aircraft, after release by the Center radar controller, as well as the issuance of departure clearances at Stapleton, Lowry, and Buckley Airports

All Center radar control was conducted from one SPANRAD display situated between two ANC flight progress sectors, which were patterned after existing sectors in the Denver ARTC Center The control exercised by the east and west radar controllers was conducted on the same SPANRAD which was equipped with air/ground communication facilities, and direct Tower/Center hand-off circuits. To aid in maintaining target identification, SPANRAD target markers were used by the radar controllers for both arrivals and departures Markers for departure traffic carried flight identity, altitudes assigned and requested, and a fix identifier to indicate the route of flight or clearance limit Arrival markers carried flight identity, route, altitude, type, and clearance limit

The Denver approach control area was divided by a north-south line over the Stapleton outer marker in a manner similar to the ARTC Center area. All airspace west of the north-south dividing line was controlled by one radar approach controller who vectored all propeller-driven (prop) arrivals from the perimeter feeder fixes at Dupont and Westminster to the final approach course for landing at Stapleton Airport. In addition, the west arrival controller was responsible for jets penetrating to Lowry and Buckley from the Denver L/F range, until they were released to Ground Control Approach (GCA) The airspace east of the dividing line was controlled by a second arrival controller who vectored prop arrivals from Strasburg and Kiowa and jets from Kiowa to the Stapleton ILS approach course. This system is illustrated in Fig 8. The departure controller cleared and vectored all departures from Stapleton, Lowry, and Buckley Airports until they were released to the west or east Center radar controller, or to the Colorado Springs approach controller.

Denver Approach Control operations were conducted from three simulated ASR scopes, as shown in Fig. 27. One scope was used by the west arrival controller for all aircraft arriving from the west and north. A second scope was used by the east arrival controller for all aircraft arriving from the east and south. The third scope was used by a departure controller who handled all departure traffic from Stapleton, Lowry, and Bucklev Airports

Colorado Springs approach control operations were conducted from two simulated scan-conversion ASR scopes, as shown in Fig 28, with one arrival and one departure controller working from individual scopes

Denver Departures

All departure traffic from Stapleton, Lowry, or Buckley Airports was controlled by one tower radar departure controller, who retained control until radar hand-off to the Center radar man was accomplished. Departures were issued short-range clearances to an altitude and fix that would allow an uninterrupted climb during hand-off from Tower to Center radar. When necessary, blocked altitudes were simulated at appropriate fixes, and departure tunneling was used

Departures with destinations northeast and east of Denver were cleared via Victor Airway 172 to Hayes Center (HCT), Table III, at altitudes assigned by the Center ANC controller. An additional restriction of 6 500 feet was imposed by the tower departure controller until the departure was past the Denver VOR station

Southeastbound departures were cleared via Victory Airway 148 to Thurman Departures on this routing were restricted to an altitude of 8, 000 feet until tower to center radar hand-off was accomplished. The 8, 000 foot restriction was continued by the Center until aircraft was established on V148 six and one-half miles east of the Kiowa VOR

Southbound departures were cleared via two possible routes depending upon whether they proceed via VOR or low-frequency airways VOR departures were routed via Victor Airways 148 and 19-East to Pueblo, and were restricted to an altitude of 8, 000 feet until established on Victor Airway 19-East, ten miles south of the Kiowa VOR South-bound departures, using Amber Airway 3, were cleared to the Colorado Springs Homer and were restricted to 8, 000 feet until clear of the arrival radar vector area

Departures with destinations west of Denver were cleared to the Ward Intersection via Victor Airways 207 and 220 with an altitude restriction of 6, 500 feet until past the Denver VOR station

Northwestbound departures were cleared to Laramie via Victor Airways 207 and 4-North, northbound flights were cleared to Cheyenne via Victor Airway 89-East These departures were also restricted to an altitude of 6, 500 feet until past the Denver VOR

Jet departures were handled in the same manner as conventional type aircraft and, in addition, specific coded departure procedures were used as follows

1. Northeast Departure
   Northeastbound jets were cleared to destination airport via the Denver L/F range and the 030^0 bearing off the L/F range to cruising altitude A restriction of 15, 000 feet was imposed until aircraft was clear of Victor Airway 8

2. Southeast Departure
   Southeastbound jets were cleared via the 110^o bearing off the Aurora Homer and were allowed unrestricted climb to assigned cruising altitude

3. Southwest Departure
   Southwestbounds were routed direct to the Aurora Homer to cross Aurora at 7, 000 feet or above, thence on a 196^o track off Aurora to 16, 000 feet A complete radar monitor was conducted during this procedure to insure terrain clearance

All radar hand-offs of conventional type aircraft between the Tower and Center were accomplished 10 miles from the Denver VOR, with the exception of flights proceeding south or southeast The south and southeastbound hand-off was accomplished 10 miles west of Kiowa for VOR flights and at Parker for flights using Amber Airway 3

Jet departure hand-offs between Tower and Center were affected 10 miles north and northeast of the Denver VOR, 7 miles west of Kiowa, and at altitude of 16, 000 feet when departing via the southwest departure route

Departure routings as described above are illustrated in Fig 9

Arrivals

The ARTC Center cleared all arrivals to four feeder fixes at an altitude of 10, 000 feet and above, with jurisdictional release points as indicated

Clearance Limit		Release Point	
Strasburg	(SG)	Byers	(BX)
Kiowa	(IOC)	Kiowa	(IOC)
Westminster	(WM)	Leaving	11, 000 feet
Dupont	(DUP)	Dacona	(DAC)

Aircraft arriving from the east were cleared to Strasburg, from the south to Kiowa, from the west to Westminster, and from the north to Dupont

Two military jet clearance limits were used, dependent upon the navigational equipment in the aircraft, rather than the direction of flight Jets equipped with low-frequency equipment were cleared to the Denver L/F range station at 23, 000 feet, jets using VOR navigational gear were cleared to the Kiowa VOR at 20, 000 feet

Blocked altitudes of 16, 000 through 22, 000 feet were simulated for east-west en route traffic on Victor Airway 8 Arrival traffic was cleared to the appropriate clearance limit fix and released to approach control in a realistic manner

Since the highest altitude available for use by approach control was 10, 000 feet, military jet aircraft altitudes excepted, all arrivals left the feeder fixes at or below that altitude Aircraft holding at the perimeter fixes above 10, 000 feet were required to descend to the 10, 000 foot level in the holding pattern and were released to approach control leaving 11, 000 feet Military jet aircraft were cleared via the published jet penetration approach paths

The approach control descent area in this study was defined as that airspace bounded on the east by a line originating at the Byers Intersection direct to a point 5 nm north of Kiowa, thence via the east and north edges of R-195 connecting with a north-south line through the Stapleton outer marker to the northern edge of Victor Airway 4 east of the Denver VOR, and via the northern edge of Victor Airway 4 to the Byers Intersection.

Arrivals from Strasburg were not restricted on descent below 10, 000 feet other than by traffic being vectored from the other feeder fixes Arrivals from Kiowa maintained 9, 000 feet until established within the descent area Arrivals from Westminster and Dupont were restricted to 8,500 feet until established within the descent area Arrival radar vector patterns are illustrated in Fig 8 An aircraft spacing chart, shown in Table IV, was readily available for the controller's use, and was provided to assist him in maintaining optimum separation between successive aircraft on radar vector to the Stapleton ILS outer marker

The Stapleton ILS was used as the final approach course for all aircraft landing at Lowry AFB and Buckley Airport These aircraft were vectored to the ILS course and, after passing the Stapleton outer marker, were flown direct to the destination airport, thus simulating the contact or circling type approach now being used at both Lowry and Buckley Military jet-type aircraft, executing a L/F range penetration approach, were considered to have completed the instrument portion of their flight when they passed over the Lowry Airport at the minimum field elevation altitude Equipment and personnel limitations precluded any simulation of GCA procedures

Colorado Springs Departures

All departures at Colorado Springs were controlled by one Tower radar departure controller. Tower control jurisdiction of north and east-bound departures was retained until radar hand-off was effected with the Center Colorado Springs radar position Southbound departures were released from the Tower departure controller to the Center Colorado Springs ANC controller on en route radio frequencies without the benefit or use of a radar hand-off. All departures were issued short-range clearances to an altitude and fix that would allow an uninterrupted climb during hand-off from Tower to Center When necessary, blocked altitudes were simulated at appropriate fixes, and departure tunneling was used

Departures with destinations east of Colorado Springs were cleared direct to Ellicott, thence via Victor Airways 19 and 108 to Hugo, at altitudes assigned by the Center

Southbound departures were cleared direct to Hanover, thence via Victor Airway 19 to the Pueblo VOR or, from Hanover direct to the Pueblo L/F range when routing was via low-frequency airways

Two possible routes were used for northbound departures, depending upon whether they proceeded via VOR or low-frequency airways. A

VOR departure was cleared direct to Ellicott, thence via Victor Airway 19 to Kiowa If flying Amber Airway 3, northbound departures were cleared to the Aurora "H" facility Such Amber Airway 3 flights were required to climb to 9,000 feet on 035° track from the Colorado Springs "H" facility before proceeding northbound on course

Jet departures were handled in the same manner as conventional aircraft and, in addition, were cleared direct to Ellicott and then turned directly on course after passing Ellicott.

All radar hand-offs of east and northbound departures between Tower and Center were effected at Ellicott or when aircraft were abeam the Colorado Springs VOR

Colorado Springs Arrivals

The Denver ARTC Center cleared all conventional arrivals to five feeder fixes at an altitude of 10,000 feet and above, with release points as indicated

Clearance Limit		Release Point
Colorado Springs	VOR	Spur
Colorado Springs	"H"	Spur
Hanover	"H"	Crossing Victor Airway 19-East
Pueblo	LFR	Pueblo LFR (PUB)
Hanover	"H"	Pueblo VOR (PUB)

Arrivals from the east were cleared to Hanover, arrivals from the south were cleared to Hanover or the Pueblo L/F range, arrivals from the north were cleared to either the Colorado Springs VOR or the Colorado Springs "H" facility, dependent upon the navigational equipment being used in the aircraft

Military jets arrivals from the north were cleared to the Colorado Springs VOR or the "H" marker, and from the south to the Pueblo VOR or L/F range Clearance limit altitude was 20,000 feet and above with release to Colorado Springs approach control being affected over the clearance limit fix

The highest altitude available for use by Colorado Springs approach control was 10,000 feet, military jet altitudes excepted. Therefore, all conventional arrivals left the feeder fixes at or below that altitude. All aircraft holding at the perimeter fixes above 10, 000 feet remained under Center Control until leaving the 11, 000 foot altitude level, at which time they were released to approach control. Military jet aircraft were cleared via the published jet penetration approach paths

The Colorado Springs approach control descent area in this study was defined as that airspace bounded on the south by a line originating at the Hanover "H" facility, thence direct to the southeastern edge of R-194, thence north along the eastern edge of R-194 to a point abeam the Colorado Springs "H", thence east on a direct line to the Hanover Homer.

Arrivals from the Colorado Springs Homer were restricted to maintain 9, 000 feet until established within the descent area Arrivals from the remaining feeder fixes were not restricted on descent below 10, 000 feet by other than traffic being vectored from other feeder fixes An aircraft spacing chart, shown in Table IV, was readily available for the controllers' use and was provided to assist in maintaining optimum separation between successive aircraft on a radar vector to the Colorado Springs ILS approach course

PHASE II

The purpose of simulation in this phase was to determine the feasibility of reversing the present traffic flow on the airways north of Denver In Phase II, illustrated in Figs 10 and 11, the airway structure was changed slightly to gain maximum utilization of the airspace and also incorporate the Gill VOR into the airway structure The area north and northwest of Denver was used for departure traffic and the airspace northeast of Denver was used for arrival traffic

The personnel requirements, their responsibilities, and the equipment used in this phase were the same as thosed used in Phase I The geographic dividing line between the Center east and west sectors and between the two Tower arrival positions was defined as a northeast-southwest line extended through the Denver outer marker so as to include the SeeBee Intersection in the West Sector.

Departures.

Departure routings and procedures for southeast and southbound traffic were the same as those used in Phase I. All departure routings simulated in Phase II are illustrated in Fig 11

Departures with destinations northeast and east of Denver were cleared via Victor Airways 160, 220, and 172 to Hayes Center at altitudes assigned by the Center ANC controller All departures along these routes were restricted to an altitude of 9, 000 feet or below until past Roggen

Departures with destinations west of Denver were cleared to the Ward Intersection via Victor Airways 4 and 220 and were required to reach an altitude of 14, 000 feet before turning westbound on Victor Airway 220 Aircraft with a slow rate of climb, not able to reach 14, 000 feet by Longmont Intersection, were cleared to Long's Peak Intersection via Victor Airways 4 and 220-North.

Flights with destinations north or northwest of Denver were cleared to Laramie via Victor Airway 4-North or to Cheyenne via Victor Airways 4-North and 89-West.

Jet departure routings and control procedures used in Phase I were simulated in Phase II studies

All departure radar hand-offs between the Tower and Center were accomplished 10 nm from the Denver VOR

Denver Arrivals.

Arrival procedures and clearance limit fixes remained the same as those used in Phase I, except that the SeeBee Intersection was used instead of Dupont for arrivals from the north and northwest The feeder fixes and vector area used in this Phase are shown in Fig. 10

The approach control descent area, as defined in Phase I, remained the same in studies of Phase II except that the northern extremity of the area was extended to include the SeeBee Intersection

Arrivals from the north were required to maintain 10, 000 feet until over the SeeBee Intersection after which further descent was governed by traffic being vectored from other feeder fixes.

Military jet arrivals were simulated in the same manner as in Phase I

Colorado Springs

The Colorado Springs area study in this Phase was the same as in Phase I, except that the Colorado Springs TVOR navigational facility was used to define routings to Ellicott and Hanover instead of the direct routings simulated in Phase I

PHASE III

The purpose of simulation in this phase was to study future Denver terminal area procedures, with instrument approaches conducted from south to north on an ILS aligned on the proposed north-south runway at Stapleton Airport

The Colorado Springs area study, shown in Figs 31 and 13, included revisions to the airway structure and terminal procedures.

The Denver terminal area of Phase III, illustrated in Figs 12 and 13, was altered to include an additional VOR facility designated as Logan, and approaches to the Buckley Airport were conducted using an ILS on the north-south runway at Buckley. In addition, a new feeder fix, identified as Titan (TI) was established in the airspace presently designated as R-195 to reduce the length of radar vectors as well as to provide more efficient jet penetration procedures.

The Logan VOR, located 18 nm southwest of the Denver Omni, was used for en route navigational purposes as well as a terminal feeder fix In conjunction with the Denver VOR and the Kiowa VOR, Logan was used to establish additional intersections in the Denver terminal area

The Buckley ILS was included in this phase to study simultaneous ILS approaches at Buckley and Stapleton Airports, as well as permit jet penetrations to begin at 15,000 feet instead of 20,000 feet, with the final approach being made on the Buckley ILS.

The airway structure and procedures used in this study were similar to those used in tests of Phase I, except for the following revisions. A Victor Airway 152 was designated between Thurman, Logan, and Kremling, Victor Airway 4-North was designated between Denver and Goodland, and Victor Airway 160 was designated between Logan and Gunnison In addition, low-frequency airways were not included in the system Victor Airway 152 was used as the arrival route for aircraft from over Thurman and Kremling Victor Airway 4-North was used as a departure route for a southeastbound traffic Victor Airway 160 was used for arrival traffic from Los Angeles

The Denver area of Phase III, shown in Figs 12 and 13 was tested with three terminal radar controllers four ARTC Center controllers, of which two were radar positions, and four data positions

The Center control area was divided geographically by a north-south line extending along the eastern edge of Victor Airway 207, to the Denver VOR, thence along the 180° radial of the Denver VOR, to, and including, the eastern edge of Victor 81 All airspace west of the north-south dividing line was controlled by an ANC controller, whose functions encompassed arrival, departure, and en route control The airspace eas of the north-south dividing line was likewise controlled by an ANC controller with similar control responsibilities In addition, individual east and west Center radar positions were provided, each functioning in a dual capacity of arrival and departure control The two radar postions afforded supplementary aid to the ANC controllers in providing separation between aircraft when ANC procedures would not apply The ANC controllers made all initial radio contacts and descended inbound aircraft to the lowest available altitude prior to release to the Center radar controller In addition, they were responsible for the issuance of departure clearances at Stapleton, Lowry, and Buckley Airports as well as separation of departure aircraft after release by Center radar control

All Center radar control was conducted from one SPANRAD display located between two ANC flight progress sectors The control exercised by the east and west radar positions was conducted on the same SPANRAD which was equipped with air/ground communications facilities and direct Tower/Center hand-off circuits To aid in maintaining target identification, SPANRAD target markers were used by the radar controllers for both arrivals and departures as in previous tests

The Denver approach control area was divided into an east-west area with the Stapleton localizer course defining the area of jurisdiction All airspace west of the localizer course was controlled by one radar approach controller who vectored all arrivals from the Logan VOR feeder fix to the Stapleton final approach course The east controller was responsible for vectoring all aircraft from the Titan Intersection to the Stapleton ILS, and for military jet penetrations from Kiowa to the

Buckley Airport. This system is illustrated in Fig 12 The departure controller cleared and vectored all departures from Stapleton, Lowry, and Buckley Airports until they were released to the west or east Center radarman or to the Colorado Springs approach controller

Denver Approach Control operations were conducted from three simulated ASR scopes, similar to Phase I, as shown in Fig 27

Denver Departures

All departure traffic from Stapleton, Lowry, and Buckley Airports was controlled by one Tower radar departure controller as in Phase I. The use of short-range clearance limits and blocked altitudes was also simulated in this phase Departure routings in this system eliminated the need for tunneling for north, northwest, west, and southeastbound traffic However, south and southwest bound departures required tunneling at 8, 000 feet until clear of the Logan arrival radar vector area

All departure clearance limits and routings used in Phase I were also simulated with this system, with the following exceptions.

1 Southeastbound departures were cleared via Victor Airway 4-North to Goodland at altitudes assigned by the Center ANC controller

2 All southbound departures utilized Victor Airway 81 routing with a clearance limit at Colorado Springs Amber 3 airway was not used in this phase

3 Southwestbound departures were cleared to Gunnison via Victor Airways 81 and 148

4 An additional routing for westbound departures was studied in this phase, namely, Victor Airway 207 to Gill VOR, thence Victor Airway 202 to Ft. Collins

Jet departures were handled in the same manner as conventional aircraft and, in addition, southbound jets were cleared via the Denver VOR 180° radial until intercepting Victor Airway 81.

All radar hand-offs between the Tower and Center were accomplished 10 miles from the Denver VOR, with the exception of south and southwest-bound flights Hand-offs of south and southwestbound departures were accomplished at the Parker Intersection.

Departure routings, as described above, are illustrated in Fig 13

Denver Arrivals

The ARTC Center cleared all prop and civil jet aircraft to two feeder fixes at 10, 000 feet and above with jurisdictional release points as indicated.

Clearance Limit		Release Point	
Logan	(LOG)	Superior	(SP)
		South Platte	(SO)
		Leaving 11, 000 feet	
Titan	(TI)	Strasburg	(SG)

Arrivals from the east and south were cleared to Titan, while those from the southwest, west, and north were cleared to Logan.

All military jet arrivals were cleared to the Kiowa VOR at 15, 000 feet and were released to Approach Control over Kiowa

Blocked altitudes of 16, 000 through 22, 000 feet were simulated for east-west en route traffic on Victor Airway 8 Arrival traffic was cleared to the appropriate clearance limit fix and were released to approach control in a realistic manner

Since the highest altitude available for use by approach control was 10, 000 feet, military jet aircraft altitudes excepted, all arrivals left the feeder fixes at or below that altitude Aircraft holding at the perimeter fixes above 10, 000 feet were required to descend to the 10, 000 foot level in the holding pattern before being vectored to the final approach course Military jet aircraft were cleared via the published jet penetration approach paths

The approach control descent area in this study was defined as that airspace bounded on the east by a line originating at the Titan Intersection extending to the Kiowa VOR, on the south by the 265° radial of Kiowa extended to the point of intersection with the Stapleton localizer course, on the west by a line from the intersection of the 265° radial of Kiowa and the Stapleton localizer direct to the Logan VOR, and on the north by a line from the Logan VOR direct to the Titan Intersection

Arrivals from Logan maintained 9,000 feet until east of Logan and established within the descent area. Arrivals from Titan were not restricted on descent below 10,000 feet other than by traffic being vectored from the other feeder fixes. Arrival radar vector patterns are illustrated in Fig. 12. An arrival spacing chart, shown in Table IV, was used by the arrival controllers as in previous phase studies to maintain optimum separation between successive aircraft while on radar vector to the Stapleton or Buckley ILS outer markers The Stapleton and Buckley Airports were both equipped with ILS' in studies of this phase. Flights that were landed at Lowry Airport in tests of Phases I and II were landed at Buckley Airport in this Phase Verbal coordination was effected between arrival controllers when the West controller vectored a flight from Logan to the Buckley ILS

Military jet arrivals were controlled by the east radar arrival controller The limited distance available for descent between Kiowa and the Buckley ILS localizer course necessitated changing the initial penetration altitude from 20,000 to 15,000 feet. The use of the 15,000 feet altitude at Kiowa also enabled the approach controller to exercise full radar control over jet arrivals from the penetration fix until approach was completed The penetration path was defined as the 278° radial of the Kiowa Omni and the Buckley ILS course Jet arrivals were restricted to 15,000 feet until 5 miles west of Kiowa before starting descent and were required to intercept the Buckley localizer at 9,000 feet.

Colorado Springs Area

In this phase, the Colorado Springs VOR was relocated and the airway structure was revised to obtain a more efficient traffic control configuration The low-frequency airway, Amber 3, between Pueblo and Denver was not included in the airway structure of this phase.

The Colorado Springs VOR was relocated from its present location 10-1/2 nm northeast of Peterson Field to a point 10-1/2 nm southeast of Peterson Field, and the airway structure was aligned accordingly Victor Airway 19 was realigned to overlay the airspace used as Victor 19-East in Phase I and II Victor Airway 81-East was designated as an alternate airway between Colorado Springs and Pueblo

Departures

All departures at Colorado Springs were controlled by one Tower radar departure controller as in Phase I Tower control jurisdiction of north and eastbound departures was retained until radar hand-off was affected with the Center Colorado Springs radar position Northbound departures were cleared to Kiowa via Victor Airway 83 at altitudes specified in the Center clearance Departures with destinations east of Colorado Springs were cleared to Hugo via Victor Airway 108-North at altitudes assigned by the Center

Southbound departures were cleared to Pueblo via direct Tructon and Victor Airway 19 at altitudes assigned by the Center. When arrival traffic was a factor, these departures were restricted to maintain a 9, 000 feet until clear of the Colorado Springs VOR holding pattern air-space area

Jet departures were handled in the same manner as conventional aircraft The departure routings described above are illustrated in Fig 13

Radar hand-offs of eastbound and northbound departures between the Tower and the Center were affected 15 nm from the Colorado Springs VOR

Colorado Springs Arrival

The Denver Center cleared all conventional arrivals to the Colorado Springs VOR at 10, 000 feet and above Arrivals from the north were cleared via Victor 81 and were released at the Black Forest Intersection Arrivals from the east were cleared via Victor Airway 108 to the Tructon Intersection and were released to approach control over Tructon Arrivals from the south were cleared via Victor Airway 81-East via Edison Intersection and were released at the point

Military jet arrivals from the north and northeast were cleared to the Colorado Springs VOR. Jets from the east and south were cleared to the Pueblo VOR The clearance limit altitude was 20,000 feet and above, and release was made to Colorado Springs approach control when arrival reported over the clearance limit fix.

The highest altitude available for the use of Colorado Springs approach control with conventional aircraft was 10,000 feet Therefore, all prop arrivals departed the Colorado Springs VOR at or below that altitude All aircraft holding above 10,000 feet remained under Center control until leaving the 11,000 foot altitude level, at which time they were released to approach control Approach control insured that military jet aircraft were cleared via the published jet penetration approach paths

The Colorado Springs approach control descent area in this phase was defined as the airspace bounded on the north by a line extending from the ILS outer marker direct to the Omni station, on the east by the Colorado Springs 166° radial extended to a point 15 nm south of the Omni station, thence on the south by a direct line to the ILS localizer course, and on the west by the ILS localizer course extended to the outer marker.

Arrival feeder fixes and radar vector areas used in studies of this phase are illustrated in Fig 32

PHASE IV

Phase IV is a modification of Phase I, and is illustrated in Figs 14 and 15

Studies in this phase were conducted with the following alterations to the Phase I system

1 The Strasburg Intersection was relocated 5 nm east of its position in Phase I to provide separation from jet penetration paths of the Kiowa VOR, heading 335° to the final approach course

2 All jet penetrations were conducted from the Kiowa VOR

3 Arrivals from the north, northwest, and west were cleared to the Denver VOR holding pattern instead of to the Dupont and Westminster Intersections as tested in Phase I

Personnel requirements, responsibilities, procedures, and equipment used in tests of this phase were the same as those used in Phase I

Departures

Departure routings and procedures were the same as those outlined in Phase I

Arrivals

The ARTC Center cleared all arrivals to two feeder fixes at an altitude of 10,000 feet and above, with jurisdictional release points as indicated

Clearance Limit		Release Point	
Denver VOR	(DEN)	Dacona	(DCN)
		Empire	(EM)
Strasburg	(SG)	Byers	(BX)
		Kiowa	(IOC)

Aircraft from the east and northeast were cleared to Strasburg via Victor Airway 8-South over Byers, and via Victor Airway 4 over Byers, from the south, arrivals were cleared to Strasburg via Victor Airway 19 or 19-East over Kiowa and a 006° radial off the Kiowa VOR, from the west, inbounds were cleared over Kremling via Victor Airway 8-South to the Denver Omni, from the north and northwest, via Victor Airway 4 to the Denver Omni

All jet aircraft were cleared to the Kiowa VOR from which point penetrations were conducted

PHASE IV - MODIFIED

Phase IV Modified, is illustrated in Figs 16 and 17.

The changes reflected in this phase are as follows

1. The Strasburg Intersection was relocated to a position south of the Stapleton ILS localizer course and together with the Denver VOR served as the feeder fixes for all arrival traffic landing at Stapleton, Lowry, and Buckley Airports

2 Victor Airway 4-North was designated and was used as a departure route for eastbound and southeastbound traffic

3 Victor Airway 152 was designated between Thurman and relocated Strasburg and was used as an arrival route for traffic from the east.

4 The Kiowa VOR jet penetration procedure was redesignated in order to utilize the airspace now included in the eastern half of R-195

The personnel requirements, responsibilities, procedures and equipment used in tests of this phase were the same as those used in Phase I

Departures

Departure routings and procedures were the same as those outlined in Phase I, except that southeastbound departures were cleared to Goodland via newly designated Victor Airway 4-North

Arrivals

The ARTC Center cleared all prop and civil jet aircraft to two clearance limits at 10,000 feet and above, with jurisdictional release points as indicated

Clearance Limit		Release Point	
Denver	(Den)	Dacona	(DCN)
		Empire	(EM)
Strasburg	(SG)	Byers	(BX)
		Kiowa	(IOC)

Arrivals from the west were cleared to the Denver VOR from over Kremling via Victor Airway 8-South Empire to the VOR, and were released to approach control over Empire Intersection or leaving 11,000 feet

Arrivals from the north were cleared via Victor Airway 4 to the Denver VOR and were released to approach control at Dacona

Traffic from Chicago, Kansas City, St Louis, and other points east or northeast of Denver were routed via Victor Airway 152 over Byers Intersection to Strasburg, with release to approach control being made at Byers

Arrivals from the south were cleared over Kiowa to the Strasburg Intersection and released to approach control at the Kiowa VOR

Tower en route control traffic from Colorado Springs, as well as all military jet arrivals, were cleared to the Kiowa VOR and were released to approach control at Kiowa The prop arrivals were recleared, by approach control, over Kiowa to the Strasburg feeder fix from which radar vectors were commenced

Military jet arrivals were cleared to the Kiowa VOR at altitudes of 15,000 feet and above All military jets penetrated from Kiowa to the Stapleton ILS localizer course, departing Kiowa on a heading of 320° Jets penetrating in this phase maintained 15,000 feet until 5 miles northwest of Kiowa This penetration procedure utilized the airspace within the eastern half of R-195 and the 320° heading provided separation from the Strasburg holding pattern airspace area Jets landing at Lowry or Buckley Airports simulated circling approaches to Buckley, and either circling or GCA approaches at Lowry after they had passed the Stapleton outer marker

The Colorado Springs area was not included in tests of this phase

PHASE V

The purpose of simulation in this phase was to study future Denver terminal area procedures under the same conditions tested in Phase III. In addition to simulating instrument approaches on an ILS aligned with a new north-south runway at Stapleton, military instrument approaches were conducted aligned with the northwest-southeast runway at Buckley Airport A further objective of this Phase was to test the feasibility of simultaneous northwest ILS approaches at Stapleton and Buckley Airports, with all jet penetrations and radar vectors conducted within airspace that was clear of R-195 A study of the Denver Terminal area in Phase V, illustrated in Fig 18, will show that the localizer course of the Buckley ILS does infringe upon small portions of the west and southwest corners of R-195 However, penetration and radar vector airspace remained outside of R-195

No studies of the Colorado Springs area were included in this Phase

Terminal system Phase III, was altered to provide a feeder fix capable of serving both Stapleton and Buckley, and by its location provided holding pattern airspace which would remain clear of R-195 This demand was achieved by locating Box Elder on the 269° radial of Kiowa at a point 20 miles west of the Kiowa VOR

The airway structure and procedures used in this phase were similar to those used in Phase IV and are illustrated in Fig 19

Personnel requirements, responsibilities and equipment used were the same as in previous phases

Departures

All departures clearance limits and routings used in Phase III were also simulated in this phase Departure tunneling was used only for south and southwestbound departures which were restricted to 8,000 feet until clear of the Logan arrival radar vector area

Arrivals

As in tests of previous phases, the ARTC Center cleared all prop and civil jet aircraft to two feeder fixes at 10,000 feet and above, with jurisdictional release points as indicated

Clearance Limit		Release Point	
Logan	(LOG)	Superior	(SU)
		South Platte	(SO)
Box Elder	(BE)	Leaving 11,000 feet	
		Kiowa	(IOC)

The Denver approach control area was divided into an east-west area with the Stapleton localizer course defining the area of jurisdiction All airspace west of the localizer course was controlled by one radar approach controller who vectored all arrivals from the Logan VOR to the Stapleton final approach course The east controller was responsible for vectoring all aircraft from the Box Elder Intersection to the Stapleton and Buckley ILS courses, and for military jet penetrations from Kiowa to Buckley

Arrivals from the east and south were cleared via Kiowa direct to Box Elder, while those from the north, west and southwest were cleared to Logan

All military jet arrivals were cleared to the Kiowa VOR at 20,000 feet and were released to approach control over Kiowa Jets arriving from the north and northwest proceeded via the Denver VOR direct to Kiowa This routing required passing over R-195 and such arrivals remained at altitudes above 22,000 feet until clear of the restricted area Jet arrivals descended to 15,000 feet in the Kiowa holding pattern before departing on jet penetration to the Buckley ILS approach course

PHASE VI

The purpose of simulation in this phase was to study terminal operations using a two-stack feeder system to serve the east-west ILS runway at Stapleton Arrival simulation of military aircraft landing at Lowry and Buckley Airports was conducted utilizing the Stapleton ILS loaclizer course, with approaches being made to the Stapleton outer marker From the outer marker, circling approaches were made to Buckley, arrivals landing at Lowry conducted circling approaches from the Stapleton outer marker or were released to GCA

The geographical division of the Center and Approach Control area was the same as that studied in Phase I The terminal area simulated is illustrated in Fig 20. The airway structure of Phase I was modified to include Victor 4-North, as in Phase III, to provide an additional north-east departure route, and is illustrated in Fig 21.

The personnel requirements, their responsibilities, and the equipment used in this phase were the same as those used in Phase I

Departures

All departures from Stapleton, Lowry, and Buckley Airports were controlled by one Tower radar departure controller, as in previous tests Short-range clearance limits were used via routings which provided uninterrupted climb during radar hand-off from Tower to Center radar

Again in this phase, the use of the Denver VOR as a terminal arrival feeder fix required that east and northeastbound departures be tunneled at 6,500 feet until clear of the omni holding pattern airspace area. Southbound departures were cleared via Victor 81, southwestbounds were cleared via Victor 81-Victor148 to Gunnison. Jet departures were handled in the same manner as in Phase III tests, except southbounds were cleared directly on course to Victor Airway 81

Arrivals

The ARTC Center cleared all prop and civil jet aircraft to two feeder fixes at 10,000 feet and above, with jurisdictional release points as indicated

Clearance Limit		Release Point	
Denver	(DEN)	Dacona	(DCN)
		Empire	(EM)
Titan	(TI)	Kiowa	(IOC)
		Leaving 11,000 feet	

Arrivals from the west were cleared to the Denver VOR via Victor Airway 8-South and were released to approach control at Empire Intersection

Arrivals from the north and northwest were cleared to the Denver VOR via Victor Airway 4 and were released to approach control at Dacona.

Traffic arriving from points east and northeast of Denver were routed via Victor Airway 148 over Kiowa to the Titan Intersection, and were released to approach control over Kiowa

Arrivals from the south were cleared via Victor Airway 19 over Kiowa to Titan and were released to approach control at Kiowa

Military jet arrivals were cleared to the Kiowa VOR at altitudes of 20,000 through 23,000 feet All military jets penetrated from Kiowa to the Stapleton ILS localizer course, departing Kiowa on a heading of 335° off the Kiowa Omni All military arrivals to Lowry and Buckley simulated circling approaches to Buckley, and either circling or GCA approaches at Lowry, after they had passed the Stapleton ILS outer marker

PHASE VII

Phase VII, shown in Figs 22 and 23, used the same basic clearance limits and route structure as Phases III

The changes reflected in this phase were as follows

1 Buckley Airport was used for all scheduled air carrier and military jet aircraft The ILS at Buckley was aligned on the northwest runway General aviation aircraft used the Stapleton Airport and were cleared for approach via the existing east-west ILS

2 A VOR facility, designated as Logan, was located southwest of the Buckley Airport and became the primary clearance limit for all arrivals from the west and northwest

Departures

Departure routings and procedures were the same as those outlined in Phase III

Arrivals

The ARTC Center cleared all props and civil jet aircraft to two clearance limit fixes at altitudes of 10, 000 feet and above, with jurisdictional release points as indicated

Clearance Limit		Release Point	
Logan	(LOG)	Superior	(SU)
		South Platte	(SO)
		Leaving 11, 000 feet	
Titan	(TI)	Strasburg	(SG)

Military jet aircraft were cleared to the Kiowa VOR at 15, 000 feet and executed the same penetration approach as in Phase III

Arrivals from the southwest, west, and northwest were cleared to the Logan VOR, as in Phase III

Arrivals from the east and south were cleared to the Titan Intersection, as in Phase III

The approach control descent area in this phase was defined as that airspace within the following limits

> Beginning at a point 5 nm miles west of the Kiowa VOR, the descent area was bounded on the south by the 270° radial of the Kiowa VOR, on the west by the eastern edge of Victor Airway 81 to the Logan VOR, then by a line extended due north to a point six nm north of the Stapleton ILS localizer course, then on the north by a line paralleling the Stapleton ILS course to a point directly north of the Titan Intersection, then on the east by a line extended direct to the point of origin, 5 nm west of Kiowa

Arrivals at Logan maintained 9,000 feet until established within the descent area, whereas, arrivals from Titan were not restricted on descent below 10,000 feet except by arrivals being vectored from Logan or jet aircraft on penetration

PHASE VIII

The purpose of simulation in this phase was to test the feasibility of east-west approaches to an ILS facility at Buckley Airport, conducted simultaneously with east-west ILS approaches at Stapleton Airport All air carriers and itinerant traffic, prop and jet type, landed at Stapleton All military traffic landed at Buckley

The terminal system used in this phase is illustrated in Fig 24

Personnel requirements, equipment and operational procedures used were the same as those used in Phase VI

PHASE IX

Phase IX, shown in Figs 25 and 26, was a modification of Phase III The difference between the two systems was the alignment of the north-south runway at Stapleton Airport and the relocation of the Logan and Titan clearance limits

TEST RESULTS

PHASE I

DENVER

The Center functions in this phase, Fig. 9, were conducted without any appreciable difficulty except for the operations west of Stapleton Airport The low-frequency jet penetration, the Westminister feeder-fix and the en route Amber Airway 3 over-traffic operations were conducted in the area west of the Stapleton Airport Consequently, when a jet was executing a low-frequency penetration, it was necessary to stop aircraft on Amber Airway 3, and also refrain from clearing any arrivals to Westminster. Likewise when the en route flights were operating on Amber 3 the jet aircraft could not penetrate to the Lowry AFB, nor could aircraft holding at Westminster descend through the altitude of an en route flight

The approach controllers using Phase I, shown in Fig 8, were hampered in maintaining a steady, well-spaced flow of traffic during radar vector operations from the feeder-fixes. The west radar arrival controller cleared and vectored the arrivals from Dupont, Westminster, and the L/F Range The Dupont Intersection did not pose any particular problem. The arrivals from Westminster were required to leave the fix at 10, 000 feet, and were vectored south of the Stapleton ILS localizer course. This procedure demanded the controller's attention at all times to insure that the aircraft remained clear of R-195 airspace Jet arrivals could not be cleared for a penetration approach while an aircraft was holding at Westminster or until the Westminster arrival was clear of the jet approach path

The East radar arrival controller cleared and vectored the arrivals from Strasburg and the Kiowa VOR The arrivals from Strasburg, being established on the localizer course 27 miles from the airport, presented spacing difficulties These aircraft were vectored to the north of the localizer to provide spacing and were then returned to the final approach course. Prop aircraft at Kiowa were maintaining 9, 000 feet and 10, 000 feet and the jet aircraft were maintaining 20, 000 feet and above The props, upon being cleared to depart Kiowa, were under radar control jurisdiction for 40 miles of flight These flights intercepted the localizer course 20 miles east of the airport and then presented the same spacing problems as the Strasburg arrivals The Kiowa jet penetration procedure, likewise, presented spacing problems on the localizer course inasmuch as they intercepted the final approach course 15 miles east of the outer marker.

The north and northeastbound departure routes proved entirely satisfactory. Only the southeastbound departure route presented any problem for the departure controller The route via the western and southern edges of R-195 via the Kiowa Omni required considerable vectoring as well as an altitude restriction of 8, 000 feet for approximately 40 miles.

COLORADO SPRINGS

The ARTC Center functions in the Colorado Springs area were similar to those experienced in the area west of Stapleton Airport. The en route traffic operating in the Colorado Springs area had to be rerouted or stopped when jet arrivals were making penetration approaches

The approach controller in this phase, illustrated in Fig 31, was required to vector the prop arrivals for distances of 20 to 30 miles. Prop arrivals were required to hold at the feeder fixes until jet arrivals were established on the localizer course, and en route traffic, which would conflict with an arrival jet, was also held clear of the approach path until the jet aircraft was established on the localizer course.

The Tower-Center radar hand-off procedures on north and northeastbound departures reduced departure delays to a minimum Use of Amber Airway 3 for en route traffic necessitated individual departure aircraft tunneling.

PHASE II

DENVER

The ARTC Center operations in this phase were affected in the same manner as in Phase I En route traffic on Amber Airway 3 and Victor Airway 81 were held north and south of Denver, at Dacona and Parker respectively, each time a low-frequency penetration was in progress. The reversed flow of arrival and departure traffic on airways north of Denver in this Phase did not function as smoothly as the flow tested in Phase I While the use of Victor Airway 4 was operationally sound for fast climbing departures, slow-climbing aircraft were penalized by a circuitous routing to Loveland and thence via Victor Airway 220-North to western destinations A routing via Victor 220-North was necessary in such cases to reach an altitude of 14, 000 feet before turning westbound on course The use of the SeeBee Intersection as a feeder fix for arrivals from the north and northwest, instead of Dupont as used in Phase I, imposed a long tunneling penalty on northeastbound departures in order to provide separation from arrivals on Victor Airway 81 to SeeBee

The approach controllers using this system, illustrated in Fig 10, were hampered in maintaining a steady, well-spaced, flow of traffic during radar vector operations from the perimeter fixes Radar approaches conducted from Westminster required very lengthy vector paths and maneuvering within a limited amount of airspace Although Fig 10 illustrates the vector area from Westminster to the south of the Stapleton localizer course, vectors were also simulated to the north of the localizer with a right-turn into the final approach course In either instance, such radar vectors were lengthy, restrictive, and very difficult to conduct in order to maintain a steady and consistent flow of traffic with approaches off SeeBee and arrivals being vectored by the East controller from Strasburg and Kiowa

The close proximity of SeeBee and Strasburg reduced the area available for radar spacing north and east of the Stapleton outer marker. As illustrated in Fig 10, the Strasburg feeder fix was located at a considerable distance from the outer marker and was aligned with the extended course of the ILS localizer All separation between approaches from SeeBee and Strasburg were affected in maneuvering area north of the localizer course and required excessive coordination between the two arrival controllers This meant, of course, that once an arrival had been committed for a straight-in approach and had departed Strasburg, approaches from SeeBee had to be delayed or maneuvered into a position behind the Strasburg arrival An additional problem was imposed by jet penetrations conducted from the Kiowa VOR Because of R-195, penetrations joined the Stapleton localizer course approximately 15 miles out from the outer marker Therefore, to attain radar spacing between approaches from SeeBee and Strasburg and the jet penetration from Kiowa, an excessive number of clearances and complete radar monitor throughout the entire approach was necessary As the traffic increased, it was not possible to feed arrivals in a systematic manner to maintain a steady well-spaced flow of arrival traffic on the final approach course from the feeder fixes used in this system.

COLORADO SPRINGS

The ARTC Center operations and restrictions were the same as those used in Phase I.

Approach control operations showed no appreciable improvement over Phase I. Radar vectors from the Colorado Springs VOR and Hanover remained lengthy and, in all instances, props were held at the feeder fixes until jets completed penetration and were established on the ILS localizer course. En route traffic at altitudes in confliction with jet arrivals were likewise held short of the jet penetration airspace until the jet was established on the final approach course.

The use of a TVOR facility, located on Peterson Field, plus radar service, did much to improve departure operations.

Little use was obtained from a newly located VOR facility identified as Pinion The Colorado Springs terminal area is illustrated in Fig. 31

PHASE III

DENVER

Phase III provided several features which did not exist in the previous systems. The use of the Logan VOR, was a terminal as well as an en route aid, enabled the designation of the most functional feeder-fixes for the approach controllers and additional routings for the Center controllers

The Center functions in this phase, shown in Fig 13, were conducted without any appreciable difficulties Arrivals from the east were cleared via Thurman, Victor Airway 152 to Strasburg The final portion of this route provided 55 miles of unrestricted descent area An additional arrival route from the West, over Gunnison to Logan, featured 75 miles of unrestricted descent area The Kremling arrival route from the west provided 55 miles of descent area Jet penetration procedures, of beginning approaches from Kiowa at 15, 000 feet instead of 20, 000 feet, presented few noticeable problems in this study.

The approach controllers area, shown in Fig 12, was reduced to a minimum The west radar controller vectored all flights from the Logan VOR for final approach to Stapleton or Buckley Airports The location of Logan simplified the controller's duties to the extent that the aircraft was given a heading on which to leave Logan, one turn to a base leg and a final interception turn to the ILS course

The east radar approach controller cleared and vectored all aircraft from Titan Intersection and the military jets from Kiowa Operations off Titan were conducted similar to those off Logan, with the aircraft leaving Titan on the initial heading, turning to base leg and one final turn for ILS interception The Kiowa VOR penetration allowed the controller to use complete radar separation between the jet penetrations and those arrivals being vectored from Titan Minimum verbal coordination was affected between the two arrival controllers without difficulty

This system provided an eastbound departure route that proved beneficial to both the controllers and the pilots The eastbound aircraft were cleared via Victor Airway 4-North to Goodland All departure aircraft routings were thereby confined to the area northeast of Stapleton except for the single southbound routing via Logan Standard tunneling procedures were used for the southbound flights whereas, the remaining aircraft departed without climb restrictions

COLORADO SPRINGS

The elimination of the low-frequency air route structure, and the relocation of the Colorado Springs VOR, simplified the terminal and en route procedures in this area The Center was provided individual northbound and southbound airways and secondary clearance limits along each route of flight.

With the relocation of the Colorado Springs VOR, shown in Fig 32, a common clearance limit was provided all aircraft and the terminal radar vector area was confined to one area The relocation of the VOR furthermore enabled the arrival controller to provide optimum spacing between aircraft

Relocation of the Colorado Springs VOR also provided excellent departure routes with little or no tunneling required The southbound departure route in this phase was the only routing that presented a problem of any consequence This was due to the limitations imposed on southbound flights because of the mountainous terrain to the west of the arrival vector area to the south

PHASE IV

As a result of the tests in Phase I and II, this system incorporated the departure and arrival routes north of Denver as used in Phase I studies By reverting to the west departure routings via Victor Airway 207 to Hudson and Victor Airway 220 to the Ward Intersection, sufficient altitude was gained by all departures to allow crossing Longmont at 14, 000 feet and above The departures to Laramie and Cheyenne were routed via Victor Airway 207 to the Gill VOR, thence via either Victor Airway 4-North to Laramie or via Hereford to Cheyenne Figs 4, 5, and 6, illustrate the departure delays incurred in these tests and clearly indicate the efficiency of the Phase IV departure routings Departure tunneling, climb restrictions and conflictions with arrival and en route traffic was encountered on the southeast and south bound departure routes

The approach control functions was more efficient in tests of this phase as indicated in Figs 4, 5, 6 33, and 36 The reduction in the number of feeder fixes used reduced the communications and controller workload These data are illustrated in Figs 2 and 3

PHASE IV - MODIFIED

During the course of the simulation tests, information was received that airspace action had been proposed to rescind the eastern half of R-195 This rescission would provide sufficient airspace for additional improvements using the present navigational facilities Phase IV Modified incorporated the southeast departure routing, Denver Victor Airway 4-North to Goodland and the arrival route from the east, Hayes Center, Thurman, Victor Airway 152 to Denver. These two routings had proven practicable during the Phase III tests

The Center functions, illustrated in Fig 17, were improved through the use of these arrival and departure routes Both of the routings provided sufficient distance for unrestricted descent and climb

The redesignation of the jet penetration procedure and the relocation of the Strasburg Intersection provided the east arrival controller with more latitude in interspersing arrivals from Strasburg with those from the VOR fix This is shown in Fig. 16

The Tower departure procedures were simplified and improved through use of the Victor Airway 4-North routing This departure routing provided minimum tunneling and unrestricted climb after clearing the holding airspace area at the VOR In addition, all departures, except those proceeding southbound, were placed in the same geographical area on the departure controller's scope, and concentration on target identification was simplified

PHASE V

The ARTC Center East sector functions were a modification of the Phase III operations With the Box Elder Intersection, shown in Fig 19, being used as a clearance limit, the flights from the east were cleared via Thurman, Victor Airway 148 over Kiowa to Box Elder The jet penetration flight path occupied the same airspace west of Kiowa Therefore, prop arrivals were held east or south of Kiowa when a jet was released to approach control This system of alternately clearing either a prop or a jet to the approach control facility showed a noticeable increase in the Center controller workload

The approach control area, illustrated in Fig 18, was also modified in the east sector The location and use of Box Elder as a feeder-fix did not materially affect the terminal radar portion of this system However, the procedure of alternately releasing prop or jet arrivals to approach control resulted in long periods of waiting by the east arrival controller for holding aircraft at Kiowa to be cleared over to Box Elder The maximum delay to arrivals, therefore, was greater in this phase than in Phase III, as illustrated in Fig 4

PHASE VI

Modification of Phase IV resulted in the Phase VI system This system, illustrated in Figs 20 and 21, was tested to determine if any benefits might be derived from the use of R-195 airspace if such airspace was available for traffic control purposes

The ARTC Center functions in this phase were similar to those in Phase IV The use of Titan instead of Strasburg as a feeder-fix on the east side of the terminal area presented no difficulties and indicated advantages over Phase IV, by a simplification of the vector area available from Titan, thereby enabling the controller to maintain a closer interval between arriving traffic In addition, communication workload was decreased as indicated in Figs 2 and 3

PHASE VII

The Center procedures and airway route structure tested in this phase are illustrated in Fig 23, and were basically the same as those studied in Phase III

The convergence of the Stapleton and Buckly ILS courses in this system reduced the operating efficiency of the approach controllers, and increased their coordination problems and over-all control work-load Logan and Titan continued to serve this system as the feeder-fixes for west arrivals at Denver and northwest landings at Buckley. However, their location was altered slightly in this phase in order to provide the most efficient traffic flow possible into the Buckley Airport Traffic distribution in this study included 22 arrivals into Buckley and 7 into Stapleton

The west terminal radar controller vectored both Stapleton and Buckley arrivals from the Logan VOR holding fix The east radar arrival controller vectored props from Titan to both Buckley and Stapleton, plus jets from Kiowa to Buckley

Two vector paths were possible from Logan to the Stapleton final approach course From Logan to the Stapleton ILS, conducted to the north of the localizer course with a right-turn in, required a lengthy vector path In addition, such arrivals were restricted until clear of the Buckley missed approach path and required constant radar monitor by the controller until established on an interception path to the ILS course An alternate vector path was provided via the Buckley ILS course to the Buckley outer marker, then via a further vector to the Stapleton localizer course with a left-turn in This operation also required the attention of the west controller until arrival was established on a course to intercept the Stapleton final approach course In addition, this type of radar vector required constant coordination with the east controller in order to provide both altitude and radar separation with prop arrivals from Titan landing at either Stapleton or Buckley Airport, and those jets penetrating from Kiowa into Buckley Airport

The east arrival controller was confronted with the same co-ordination problems with respect to his arrivals being vectored direct from Titan to the Stapleton final approach course or from Titan to the Buckley ILS, and his jet arrivals from Kiowa landing Buckley

Over-all operations into Buckley were handled efficiently by both east and west arrival controllers However, the greatest difficulty encountered was the inability to establish a definite spacing pattern between an aircraft on the Buckley final approach course and one on the final approach course at Stapleton, in order to provide separation between the two arrivals in the event of a missed approach at Buckley Such separation spacing was obtained by delaying the Buckley arrival until the Denver arrival was definitely established on the localizer course at Stapleton and was in such a position as to no longer be a factor with the Buckley arrival in the event that a missed approach was executed This type of operation left much to be desired in the way of efficient and expeditious operations

The departure procedures, although basically the same as those used in Phase III, presented one major problem Separation between departures and arrivals required a very high degree of coordination between the departure controller and both arrival controllers This was necessary, particularly, to provide separation between a Buckley departure taking off northwest and an arrival at Stapleton landing to the west

PHASE VIII

The Center control procedures in this system were the same as those used in Phase VI The route structure is illustrated in Fig 21

The approach control functions of Phase VI were modified, as shown in Fig 24, to include an east-west ILS at Buckley Airport, thereby making it possible to conduct simultaneous east to west ILS approaches at Buckley and Stapleton Airports The approach controllers were able to maintain a steady flow of traffic to both airports without excessive coordination The results of this study, Fig 33, indicated that this was the most efficient east-west operation

PHASE IX

Modification of Phase III produced the Phase IX system In Phase III, the alignment of the proposed Stapleton southeast-northwest runway was 350° magnetic, as requested by the City of Denver In Phase IX, studies were conducted using a Stapleton southeast-northwest runway aligned 330° magnetic in accordance with the Washington proposal The realignment of the northwest runway in this phase placed the Buckley and Stapleton ILS courses in a more parallel proximity than the configuration tested in Phase III The terminal and en route airway structure of Phase IX was basically the same as Phase III, and is illustrated in Figs 25 and 26 Titan and Logan continued to serve as the terminal feeder fixes and were relocated to positions approximately 4nm southeast of locations used in Phase III studies

Center functions were the same as in Phase III, except that an additional 1,000 feet of altitude was available for control of aircraft in the holding pattern at Logan, as a result of relocating Logan in this phase The Phase IX location of Logan placed it in a position which eliminated the need of terrain restrictions which were present in the Phase III tests

Approach control radar vector operations were conducted within a smaller adjustment and maneuvering area, and the paths to the Buckley ILS from Logan and from Titan to Stapleton were reduced in length

A comparison of data information, including average arrival times, communications channel loading, and control messages, is illustrated in Figs 2, 3, 34 and 35 Such data comparison indicated that the Phase IX system configuration was the most efficient for the conduct of dual ILS approaches at Buckley and Stapleton Airports during north operations

CONCLUSIONS

The conclusions of this simulation are placed in two classifications, namely, those reached as a result of studies of existing facilities and those concerning the construction of a new runway at Stapleton Airport

Denver Terminal Area

1 The acceptance rate of Stapleton Airport will remain low with the present surface facilities Fig 37 illustrates the limitations imposed on taxiing aircraft and the lack of turnoffs on the IFR runway

2 The entire simulation study was tested using two tower radar arrival controllers One arrival controller, as presently operating at Denver, could not have handled the traffic simulated in these tests

3 The Phase I arrival and departure routes as tested are less restrictive than the Phase II routes

4 Amber Airway 3, used primarily for en route traffic in this study, disrupted the Denver Center west sector control procedures

5 Immediate improvement in terminal traffic movement can be realized by reducing the number of arrival feeder fixes as tested in Phase IV

6 R-195, as presently designated, precludes any further improvements after implementation of Phase IV system Any airspace action on R-195 could result in further improvements through implementation of procedures as tested in Phase IV Modified and Phase VI

7 The procedure developed and tested for southeastbound departures, Denver-Victor Airway 4-North Goodland, when instituted, will be beneficial to both control and pilot personnel alike

8 The revised arrival route from the east, Hayes Center, Thurman to Denver separated the arrival and en route traffic 150 miles east of Denver, whereas, the present Akron Victor 8-South route is a distance of 75 miles The use of the Hayes Center-Thurman routing allows the ANC controller to exercise considerable control of the arrivals and enables the Center radar controller to direct his efforts to final altitude assignments nearer the terminal area

9 A more efficient operation can be obtained through deletion or redesignation of the low frequency jet penetration procedures

10 Preferential one-way north and southbound airways, which conformed with the terminal flow, improved the over-all utilization of the Center radar

11 Altitude saturation at the Kremling VOR was encountered during the initial studies of this area The designation of an airway between Gill VOR and Meeker VOR for departure aircraft, and an arrival airway from Gunnison to Logan VOR alleviated some of this congestion Further relief, at Kremling, was gained by the designation of an airway from Gunnison, Colorado Springs to Goodland for the use of traffic en route from Los Angeles to Chicago

12 Standardization of departure routes, including jet type aircraft, reduced coordination within the Center and expedited departure movement

Colorado Springs Area

1 The Airway structure and clearance limits used in Phase I are incompatible with any increased traffic volume at Peterson Field Phase III would more efficiently serve either Peterson Field alone or together with Butts Army Air Field under peak traffic conditions

2 The relocation of the Colorado Springs VOR in the Phase III system would, in all probability, lower the minimum reception altitude on Victor Airway 81 to 9,000 feet north of Colorado Springs In addition, this relocation reduced the approach control workload by allowing flights to proceed closer to the airport on their own navigation, thereby reducing the length of the radar vector path The advantage of this type of operation became more pronounced as the traffic volume increased

3 The relocation of the Colorado Springs VOR, and the use of the TVOR for definition of the departure routes, enabled departing aircraft to proceed on course with little or no tunneling

RECOMMENDATIONS

It is recommended that

1 Immediate steps be taken to implement a second radar arrival position in the Denver approach control facility

2 The present Dupont and Westminster feeder fixes be discontinued and a two-stack feeder system be implemented immediately utilizing the Denver VOR and the Strasburg Intersection as simulated in Phase IV studies and illustrated in Fig 14

3 All military jet penetrations be conducted from the Kiowa VOR location and that, in addition, until such time as all military aircraft are omni-equipped, a homing facility be installed at the location of the Kiowa Omni for low-frequency jet penetrations

4 In conjunction with recommendation (1) above, the 077° radial of the Denver VOR be designated as Victor Airway 4-North between Denver and Goodland, Kansas, to provide an unrestricted departure route for east and southeast departures

5 The restricted area R-195 be cancelled immediately and that the airspace within the boundaries of R-195 be made available for control purposes

6 In the event all of R-195 airspace is not made available for control purposes, the eastern half portion of this area, at least, should be cancelled

7 Subject to airspace utilization as set forth in (5) and (6), either Phase IV Modified or Phase VI terminal and airway systems should be implemented to gain maximum operating efficiency for east-west operations in the Denver Terminal Area

8 In conjunction with (7) above, Victor Airway 152 be designated and be implemented as a preferential arrival route from Thurman to the Strasburg holding pattern

9 Victor Airways 160 and proposed 4-North be utilized for jet departure routes

10 The Colorado Springs VOR be relocated southeast to a point 7 nm east of the Colorado Springs outer marker on a bearing 091° magnetic from the Colorado Springs outer marker

11 Caution Area C-455 be cancelled immediately

12 The TVOR located at Peterson Field, Colorado Springs, be commissioned immediately to aid departure operations

13 A preferential west to east cross country routing be established via Gunnison-Colorado Springs-Goodland

14 In the event that a new north-south runway is constructed at the Denver Stapleton Airport, a VOR facility be installed at or near the location of the Logan VOR as used in Phase IX, illustrated in Fig 25

15 Procedures and route structure of the type developed in Phase IX should be implemented when a north-south runway is constructed at Stapleton Airport

TABLE I

RATES OF CLIMB USED IN DENVER-COLORADO SPRINGS SIMULATION TESTS

Denver Elevation-5300 Feet

Colorado Springs Elevation-6200 Feet

RATE OF CLIMB FOR DEPARTURES

DC-3 - 500 FPM to 10,000 feet then 300 FPM

Convair or Viscount - 750 FPM

DC-6 or Constellation - 750 FPM to 12,000 feet then 500 FPM

DC-7 - 750 FPM to 15,000 feet then 500 FPM

C-119 or DC-4 - 500 FPM

T-33 - 2500 FPM

T-86 or F-100 - 3000 FPM

TABLE II

DISTRIBUTION OF FLIGHTS IN TRAFFIC SAMPLES

	ARRIVALS		DEPARTURES		TOTAL	
	Prop	Jet	Prop	Jet	Prop	Jet
Denver	22	2	21	2	43	4
Lowry	2	3	2	1	4	4
Buckley		2		2		4
	24	7	23	5	47	12
Colorado Springs	8	2	8	4	16	6
EN ROUTE OVER TRAFFIC					8	

TABLE III

LOCATION IDENTIFIERS

AG	Agate
AKO	Akron VOR
AUR	Aurora "H"
BE	Box Elder
BFC	Black Forest
BX	Byers
COS	Colorado Springs VOR & Peterson Field
CYS	Cheyenne VOR
DEN	Denver VOR & Stapleton Field
DUP	Dupont
ED	Edison
ELL	Ellicott "H"
EM	Empire
EKR	Meeker VOR
FS	Fondis
FT	Fort Collins
GDR	Garden Ranch "H"
GIL	Gill VOR
GL	Gill Intersection
GLD	Goodland VOR
GO	Golden
GUC	Gunnison VOR
GV	Grover
HCT	Hayes Center VOR
HF	Hereford
HGO	Hugo VOR
HNR	Hanover "H"
IOC	Kiowa VOR
KE	Keenesburg
LG	Longmont
LOG	Logan VOR
LP	Longs Peak
LRY	Lowry AFB
LV	Loveland
NN	Nunn
NPE	Buckley NAS
PE	Payton
PEF	Peterson TVOR
PF	Pinecliff
PI	Pike
PIN	Pinon VOR
PK	Parker
PN	Pinon Intersection
PUB	Pueblo VOR
PZ	Platte
RG	Roggen
RLG	Kremmling VOR
RU	Rush
SB	SeeBee
SG	Strasburg
SNY	Sidney VOR
SO	South Platte
SP	Spur
SU	Superior
TI	Titan
TR	Tructon
TXC	Thurman
WD	Ward
WG	Wiggins
WK	Watkins
WM	Westminister
YO	Yoder

TABLE IV

OPTIMUM AIRCRAFT SPACING CHART

DISTANCE, APPROACH GATE TO TOUCHDOWN, 5 MILES

AIRCRAFT SEQUENCE NO 1	NO 2	OUTER MARKER SEPARATION (MILES)
S	M	5 1
S	F	5 5
S	J	6 6
M	S	3 1
M	F	4 5
M	J	5 8
F	S	3 0
F	M	3 5
F	J	5 2
J	S	3 0
J	M	3 0
J	F	3.0
Same Type		4 0

AIRCRAFT CATEGORY	APPROXIMATE APPROACH SPEED (MPH)	(KNOTS)
S - Slow	120	104
M - Medium	140	122
F - Fast	150	130
J - Jet	180	156

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (continued)

LIST OF ILLUSTRATIONS (continued)

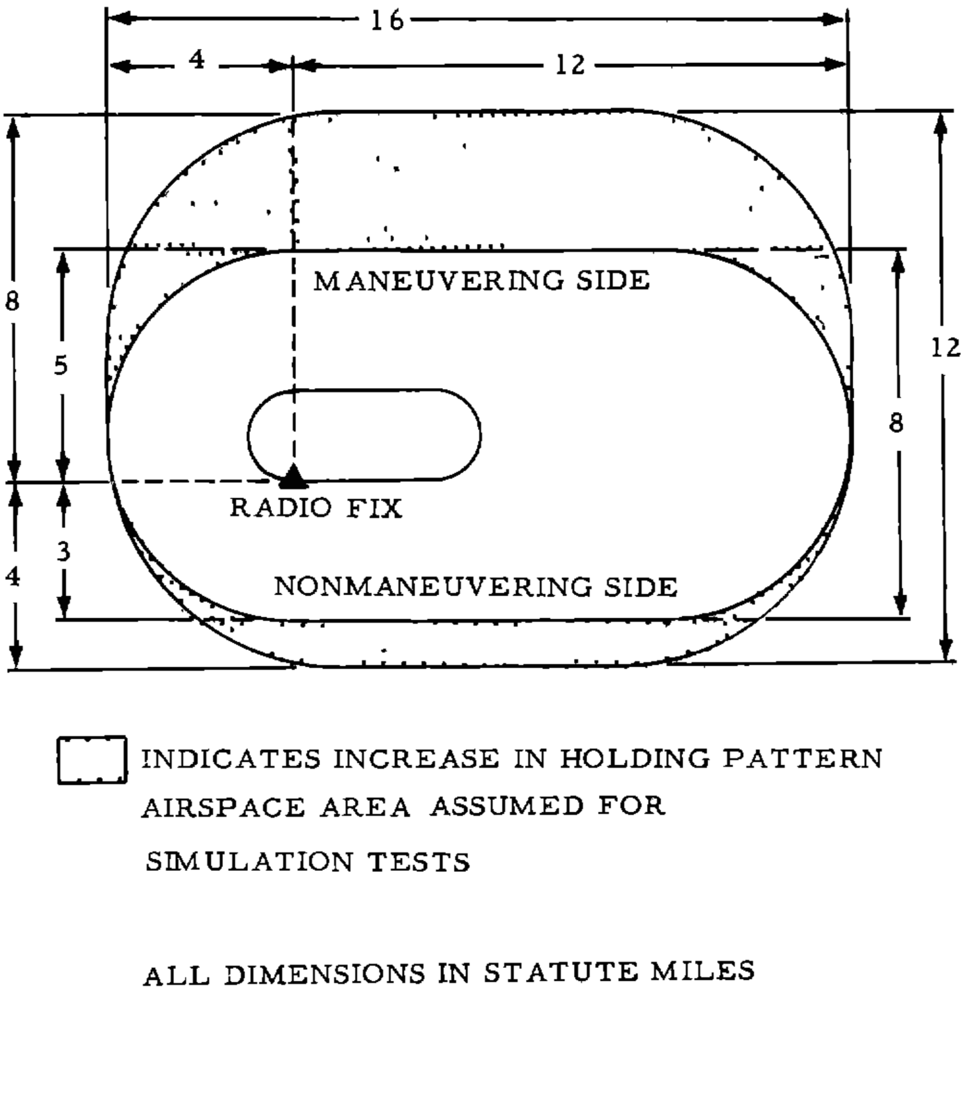


FIG 1 - TSO-N20A HOLDING PATTERN AIRSPACE AREA

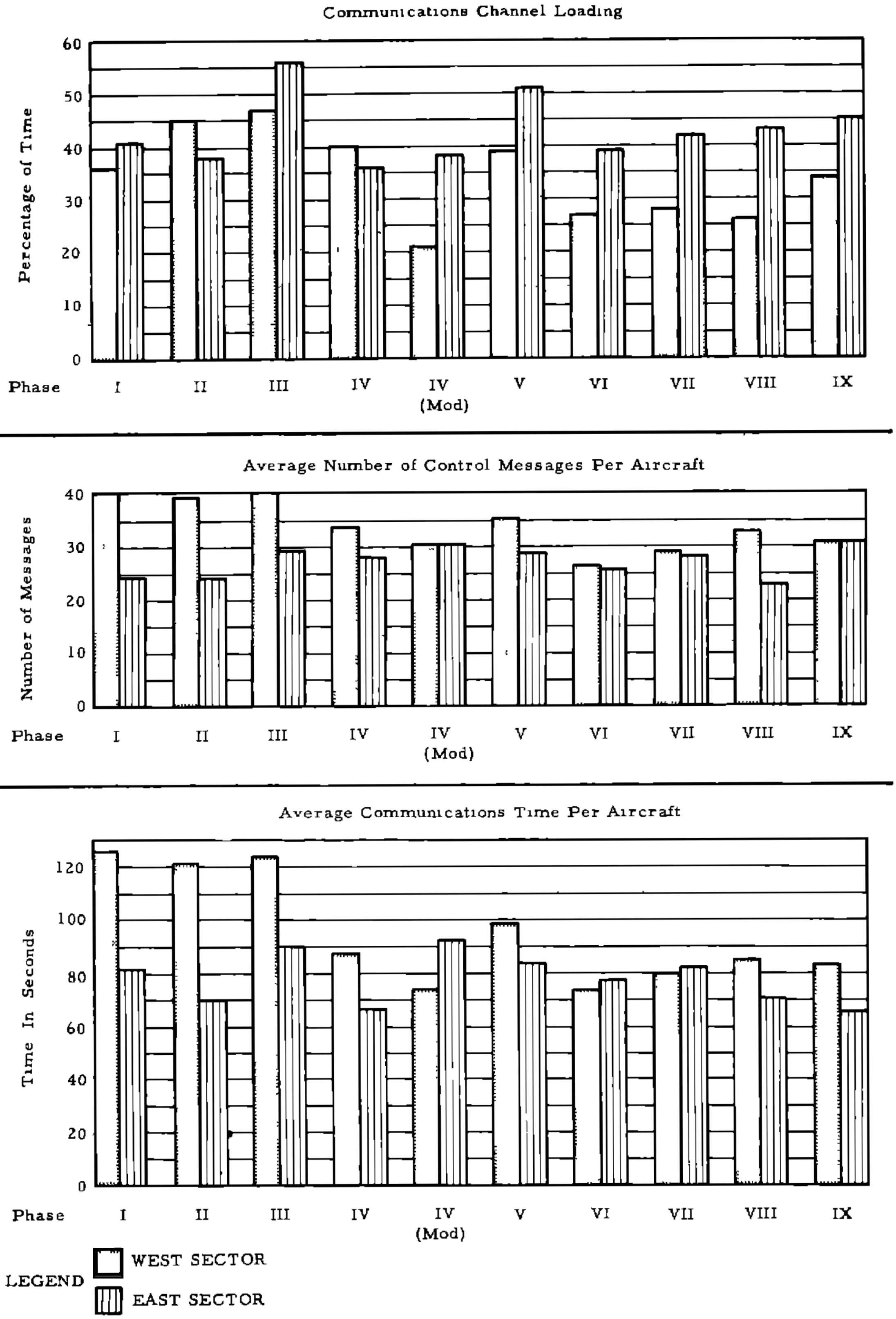
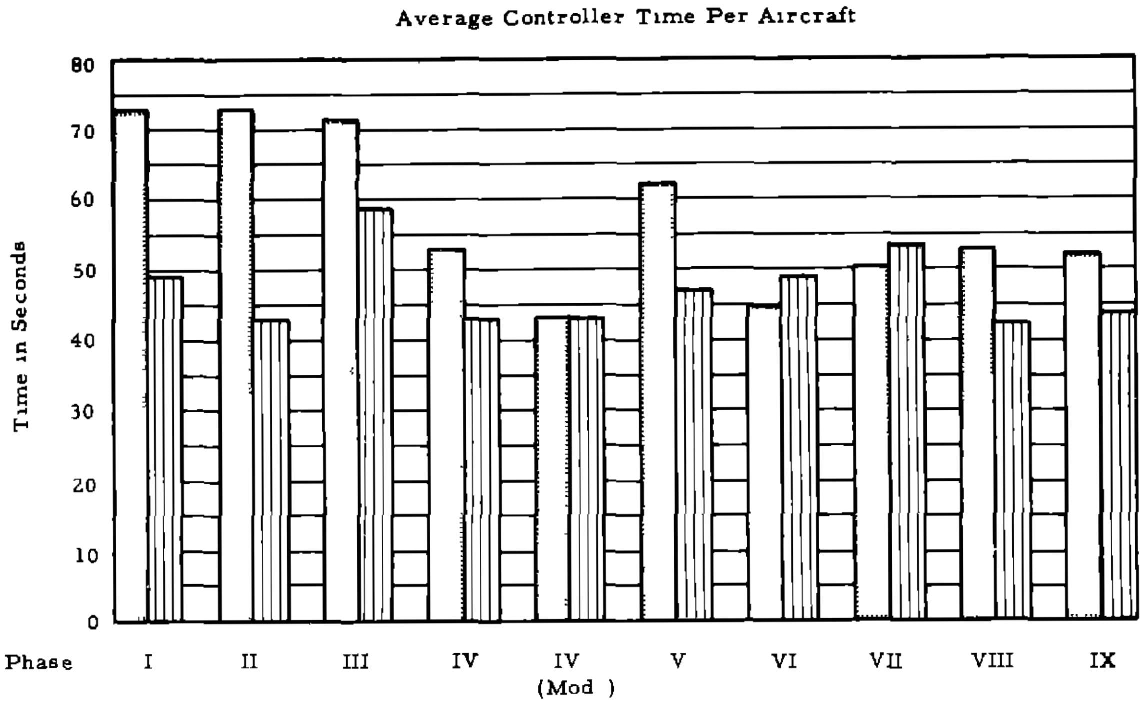


FIG. 2 - COMMUNICATIONS DATA - DENVER TERMINAL AREA RUNS



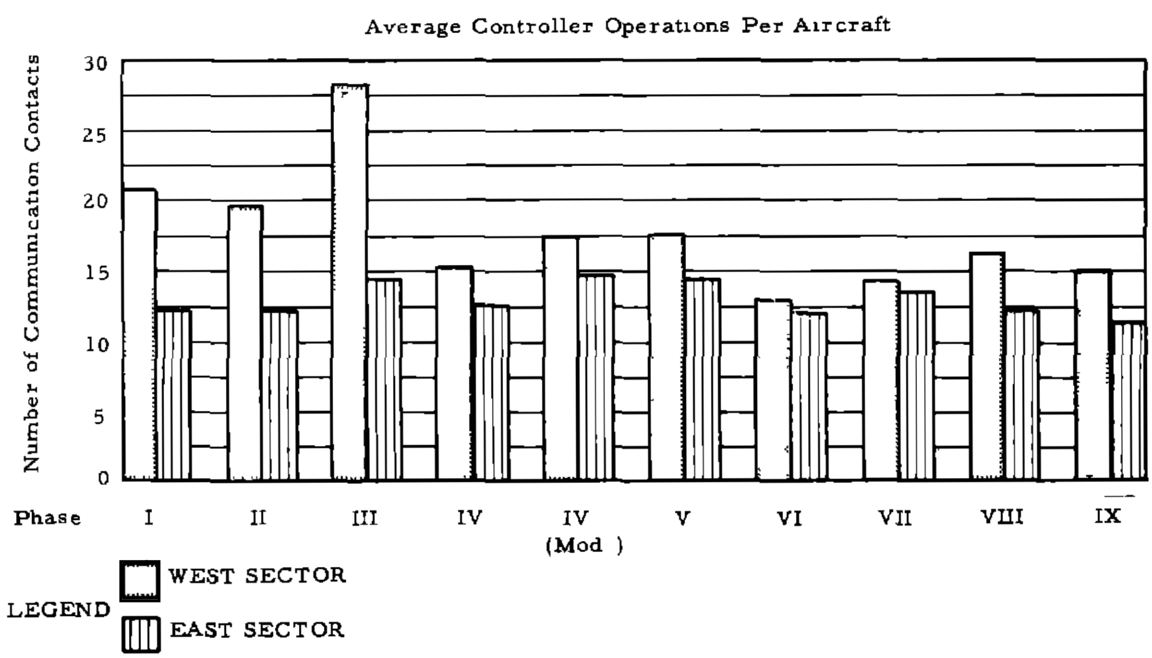


FIG 3 - CONTROLLER OPERATIONS AND COMMUNICATIONS DATA

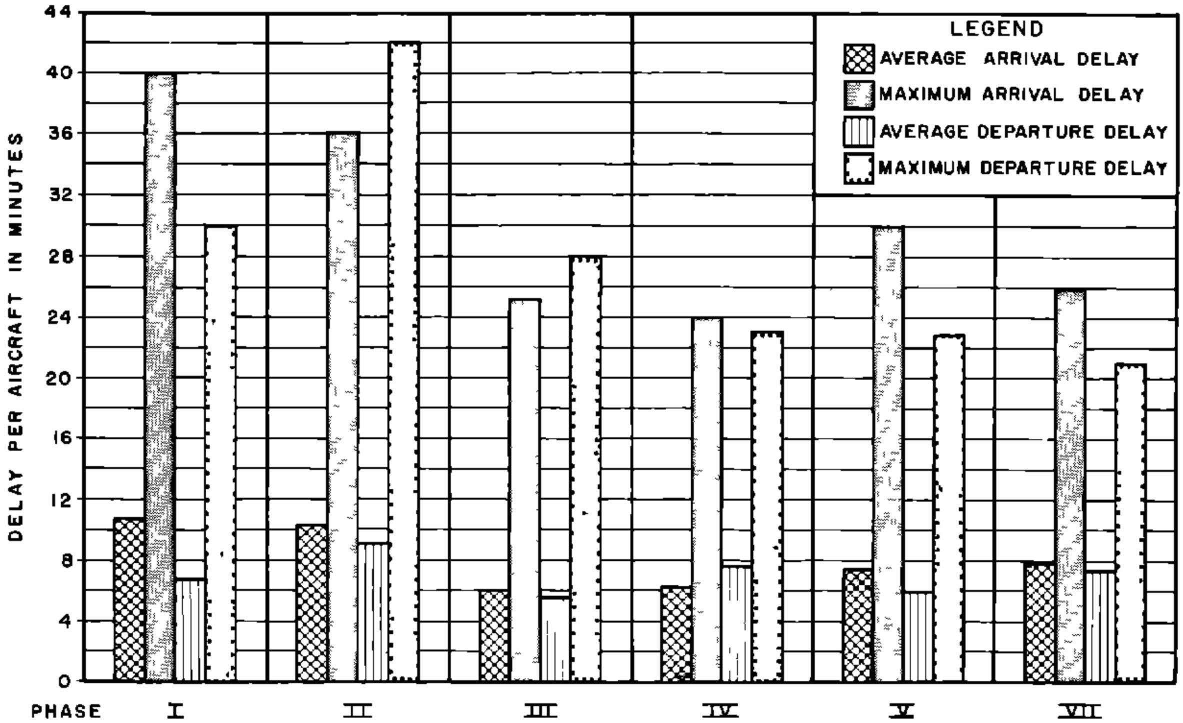


FIG 4 - ARRIVAL AND DEPARTURE DELAYS - STAPLETON FIELD

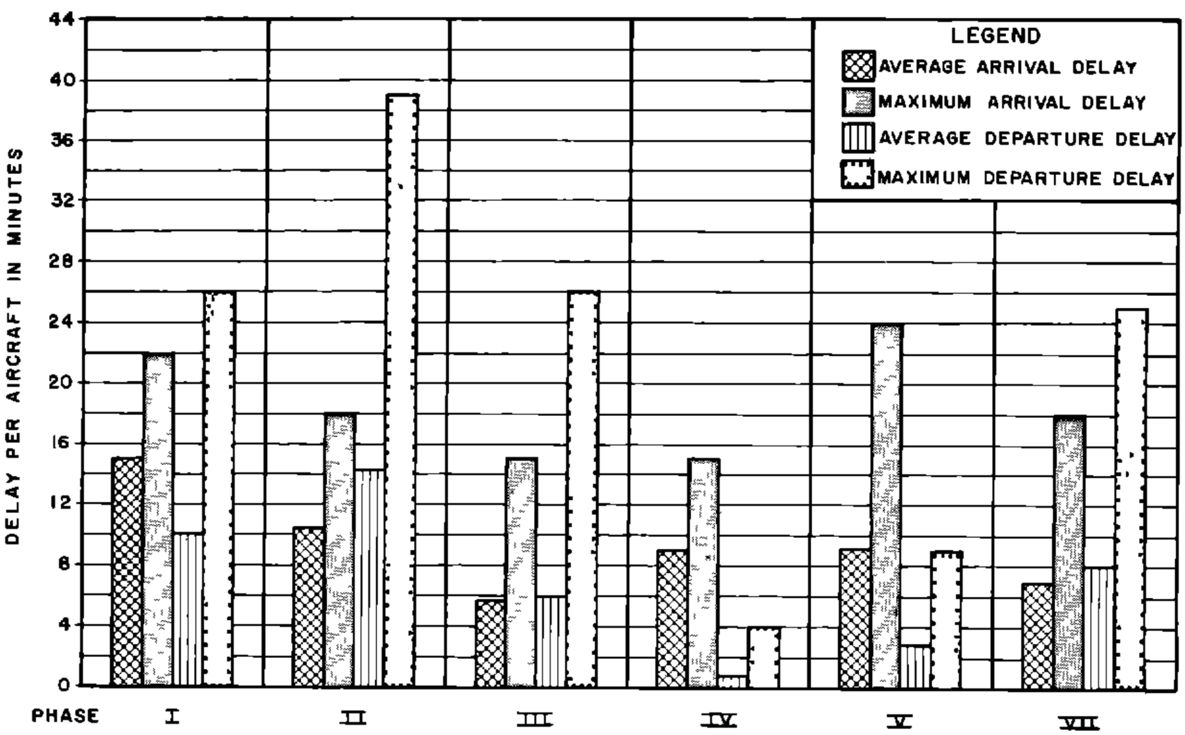


FIG 5 - ARRIVAL AND DEPARTURE DELAYS - BUCKLEY FIELD

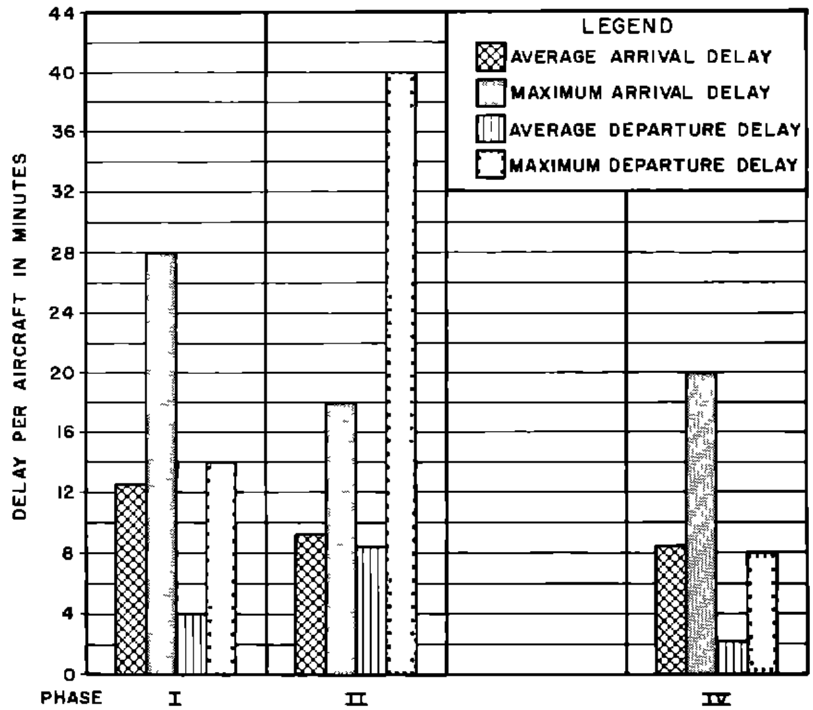


FIG 6 - ARRIVAL AND DEPARTURE DELAYS - LOWERY AIR FORCE BASE

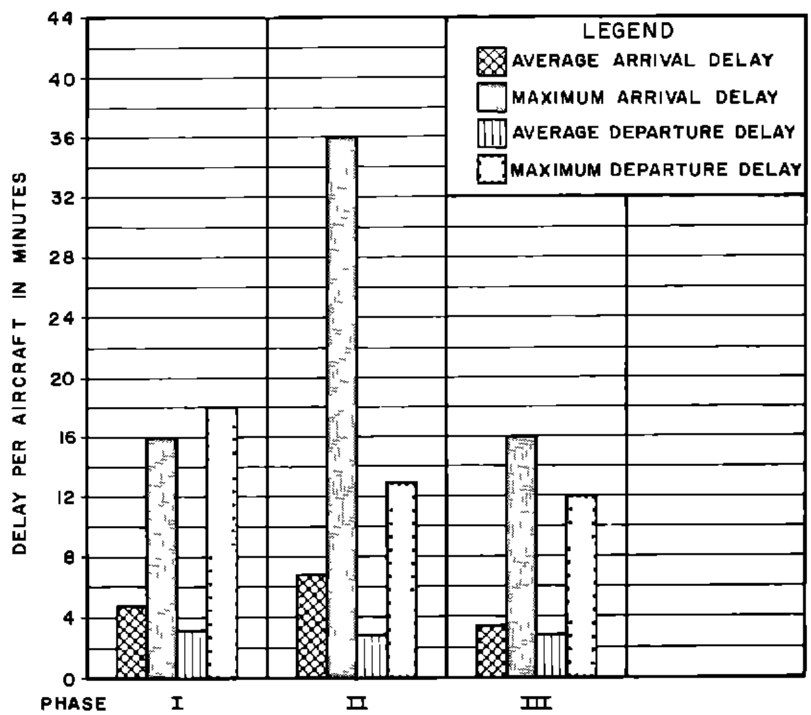


FIG 7 - ARRIVAL AND DEPARTURE DELAYS - COLORADO SPRINGS

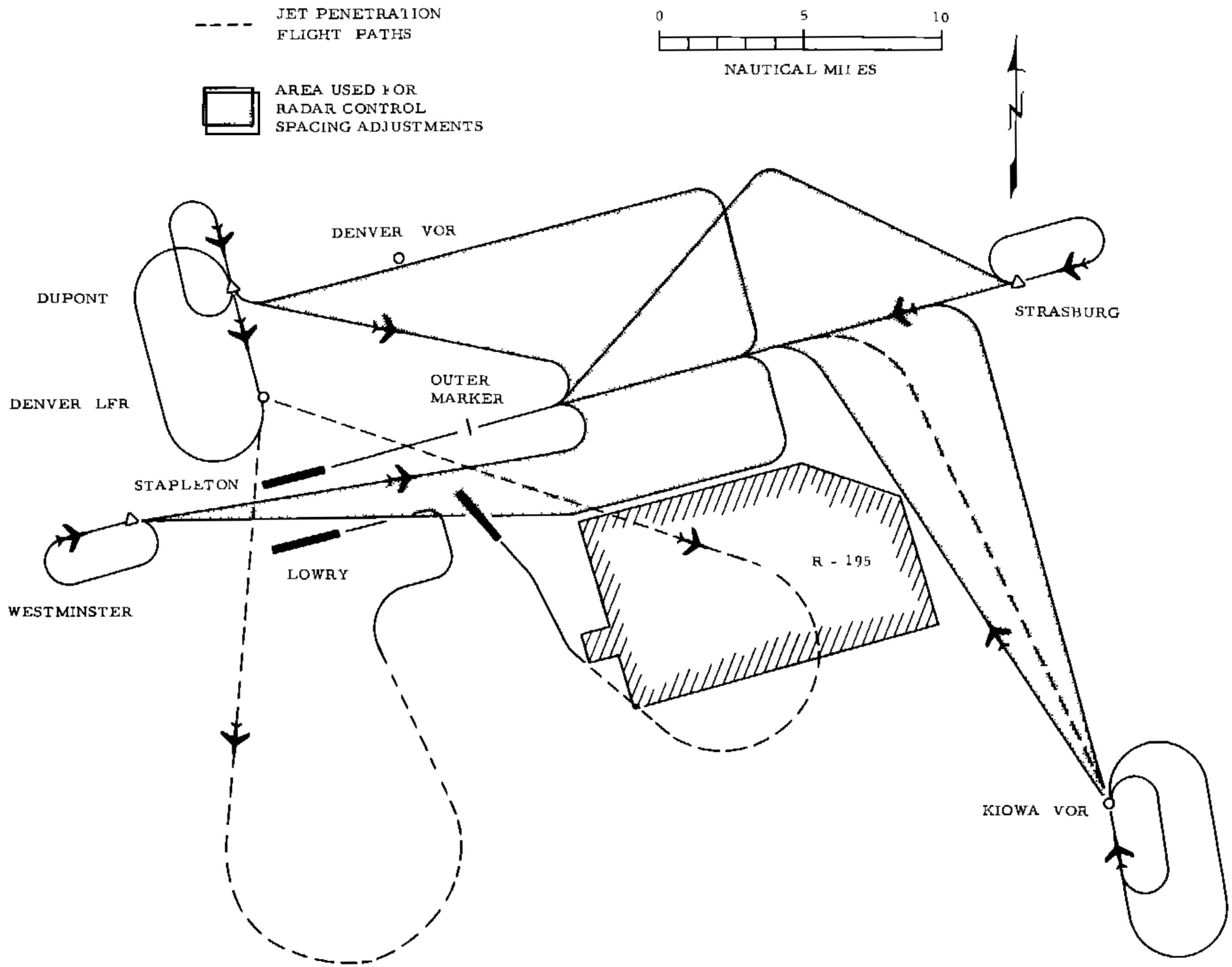


FIG 8 - DENVER TERMINAL AREA - PHASE I APPROACH FIXES AND RADAR VECTOR PATTERNS

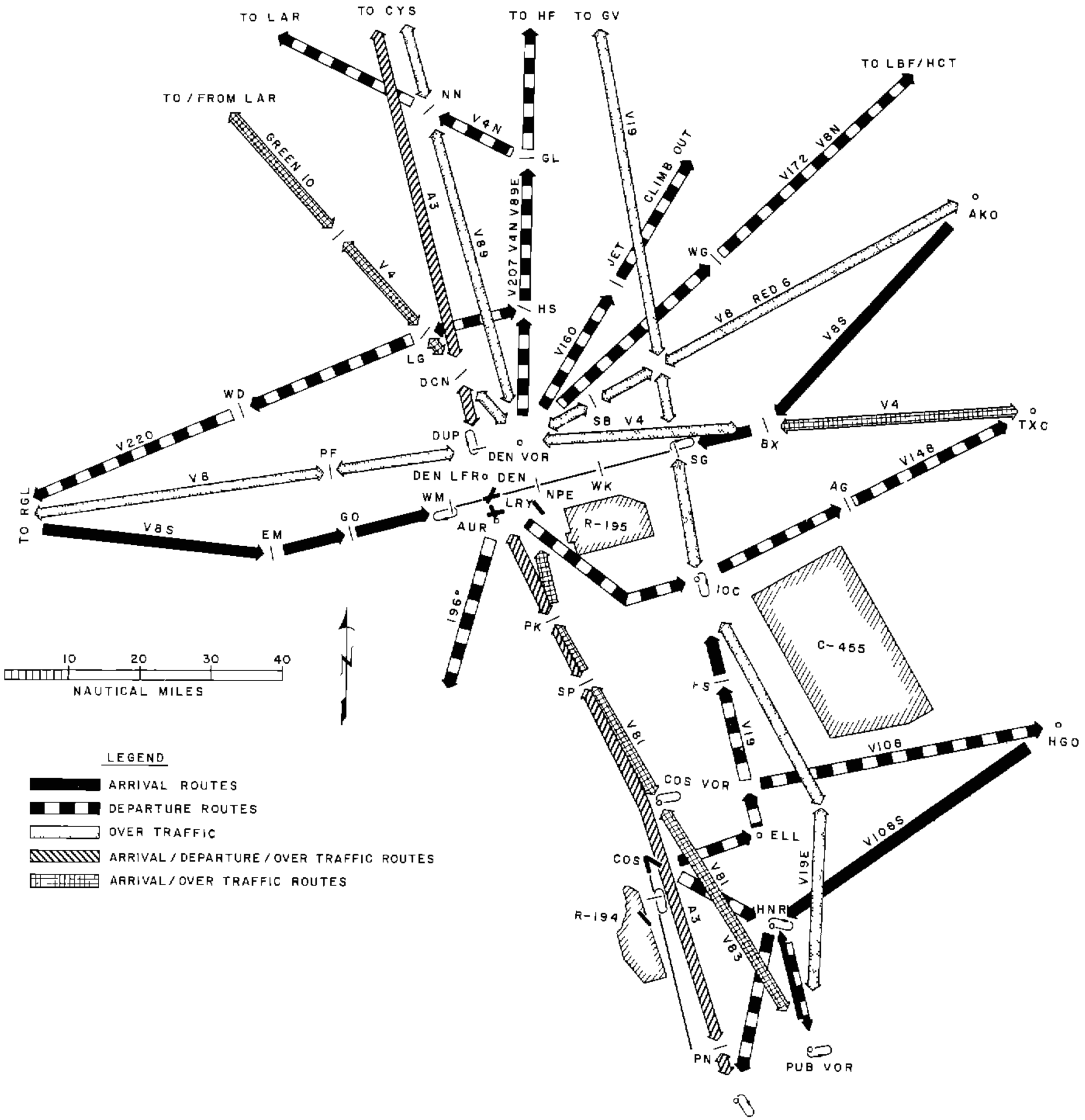


FIG 9 - ROUTE STRUCTURE - PHASE I

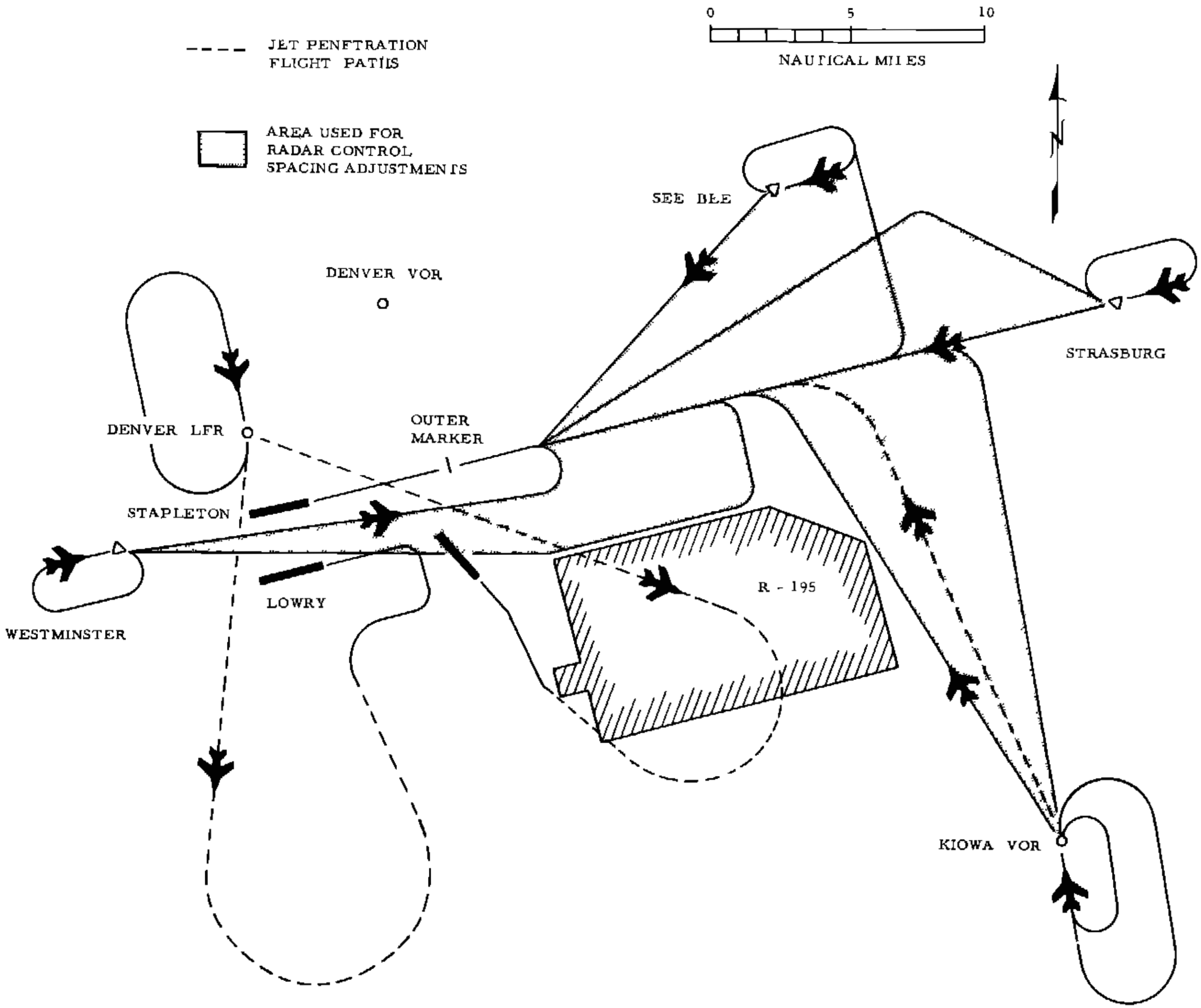


FIG. 10 - DENVER TERMINAL AREA - PHASE II APPROACH FIXES AND RADAR VECTOR PATTERNS

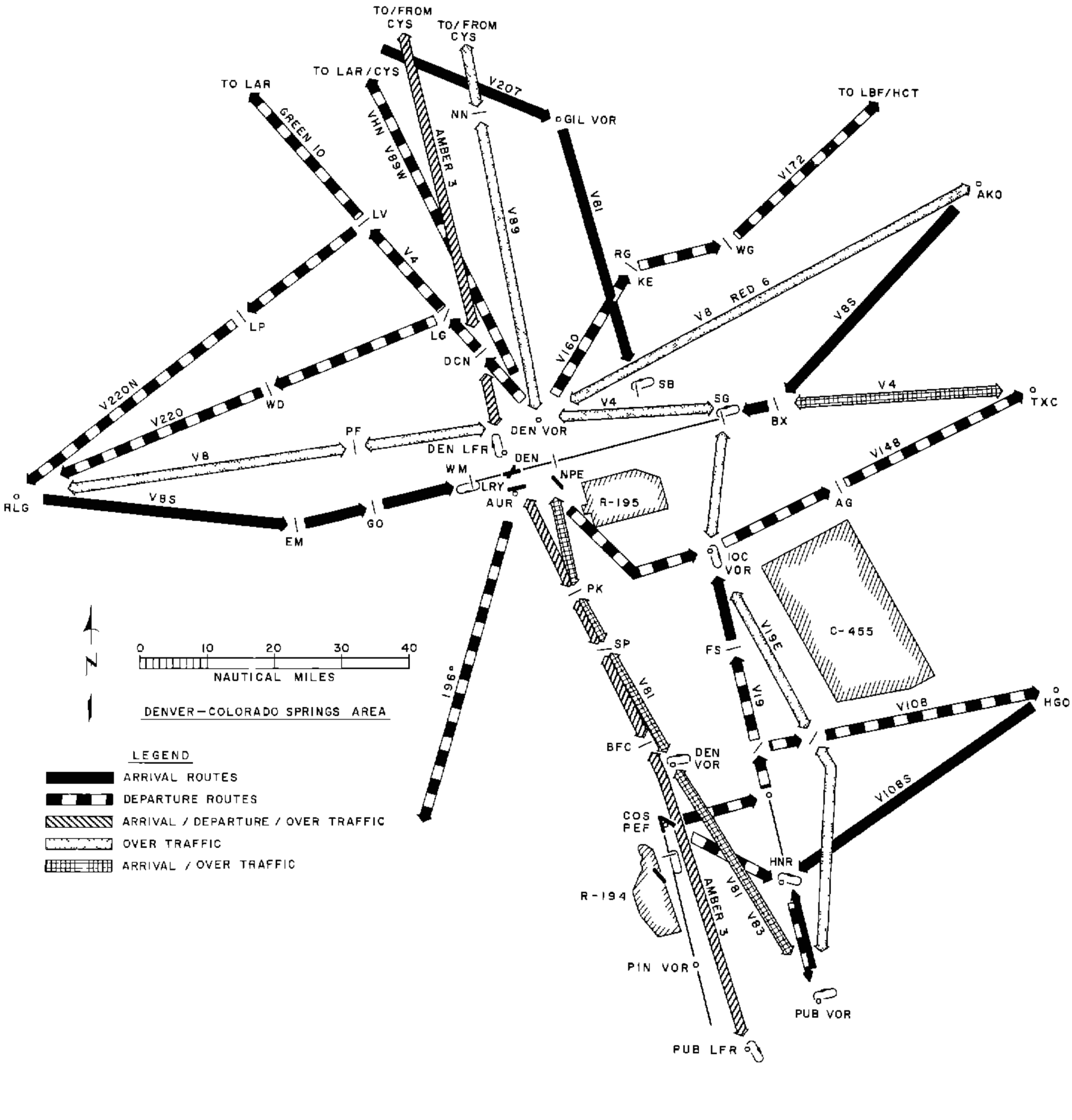


FIG 11 - ROUTE STRUCTURE - PHASE II

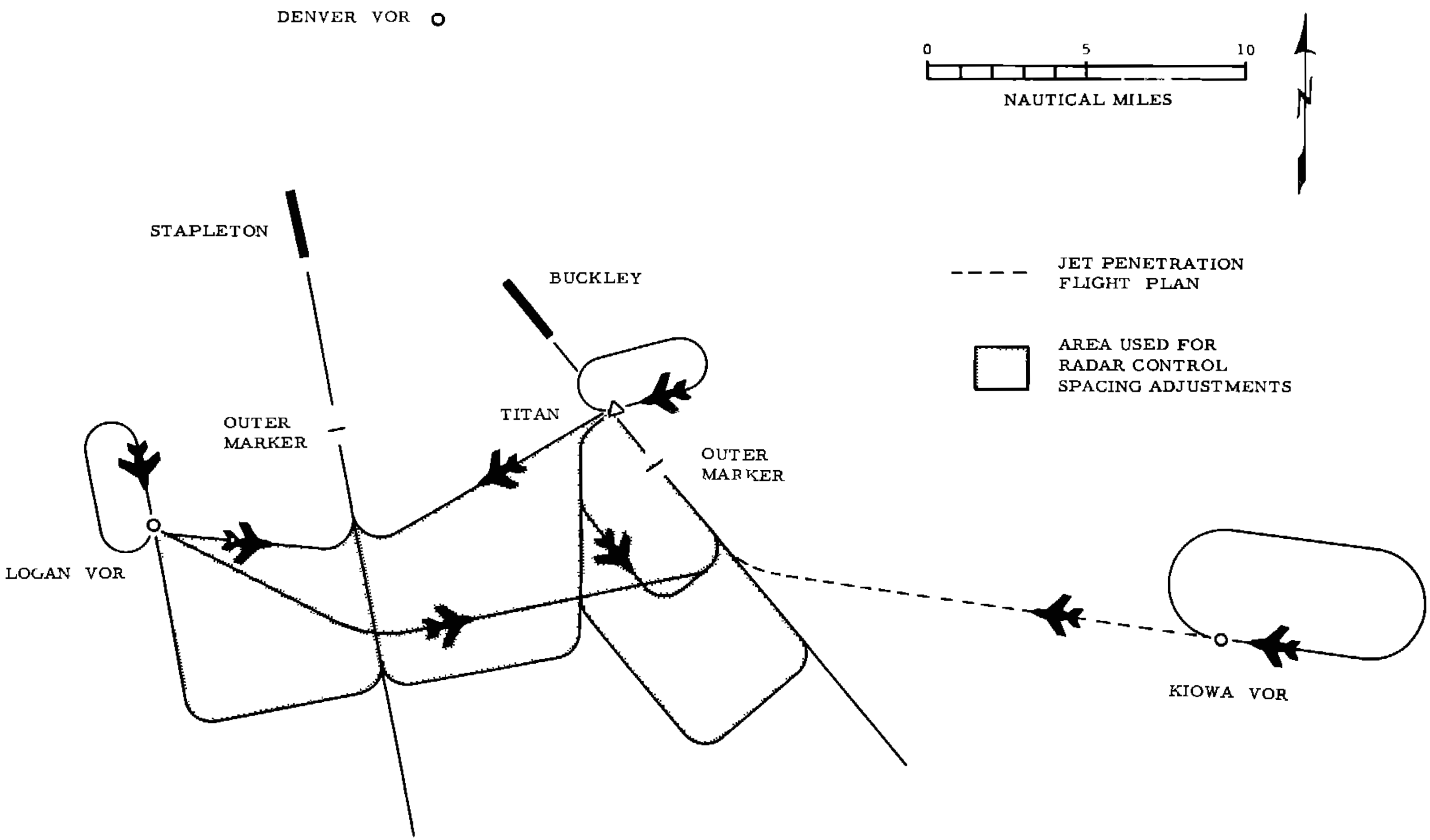


FIG 12 - DENVER TERMINAL AREA - PHASE III APPROACH FIXES AND RADAR VECTOR PATTERNS

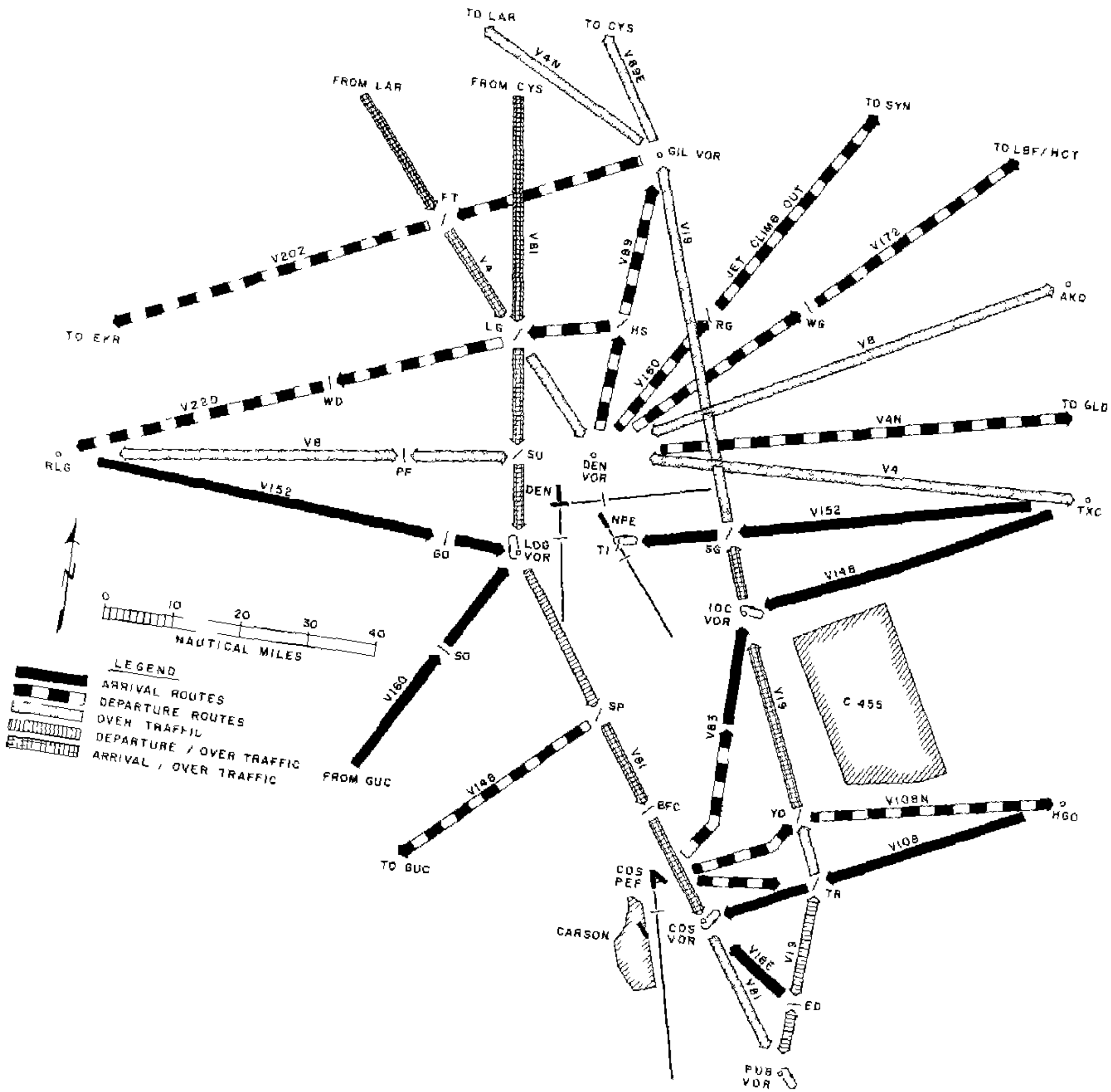


FIG 13 - ROUTE STRUCTURE - PHASE III

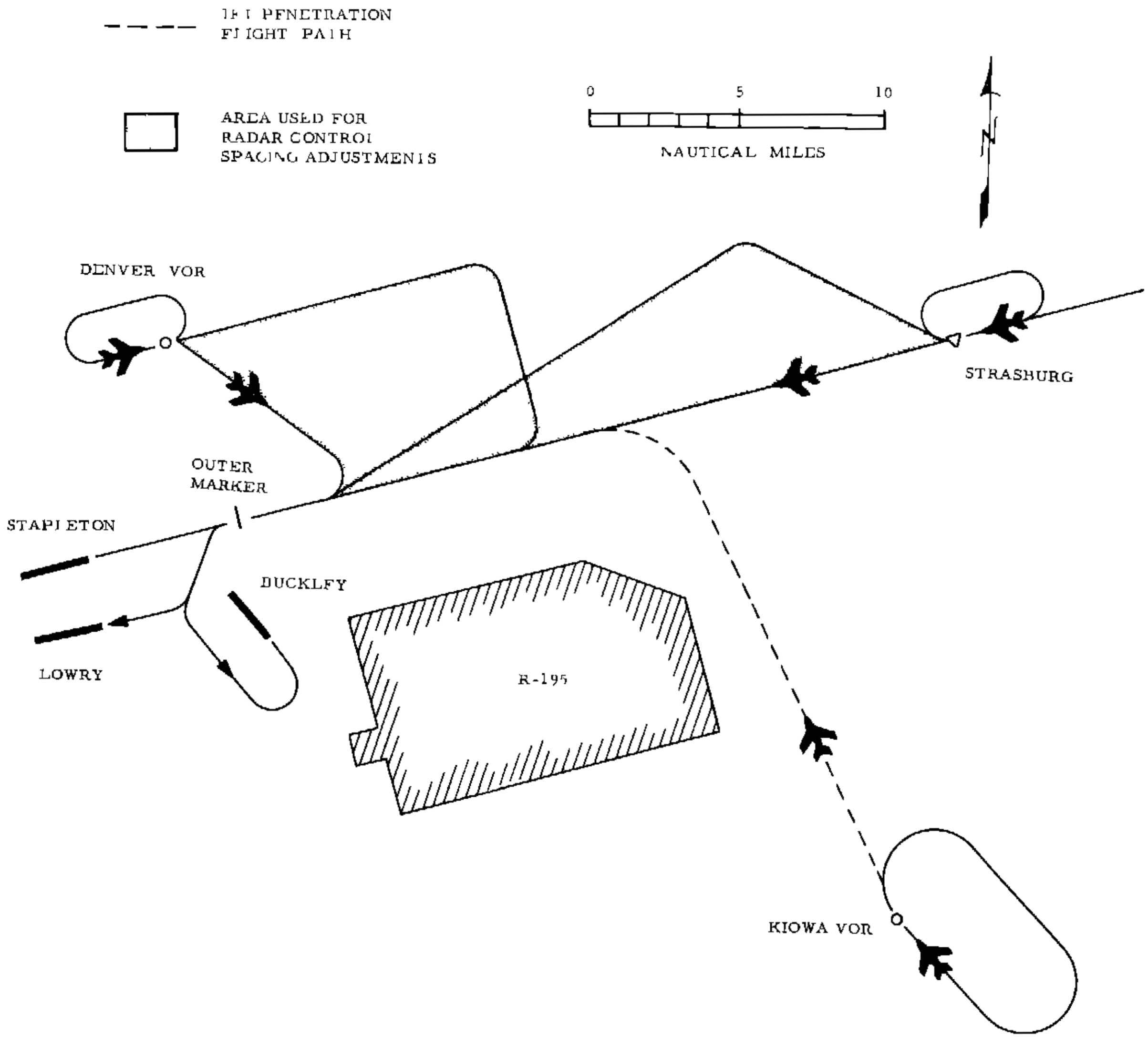


FIG 14 - DENVER TERMINAL AREA - PHASE IV APPROACH FIXES AND RADAR VECTOR PATTERNS

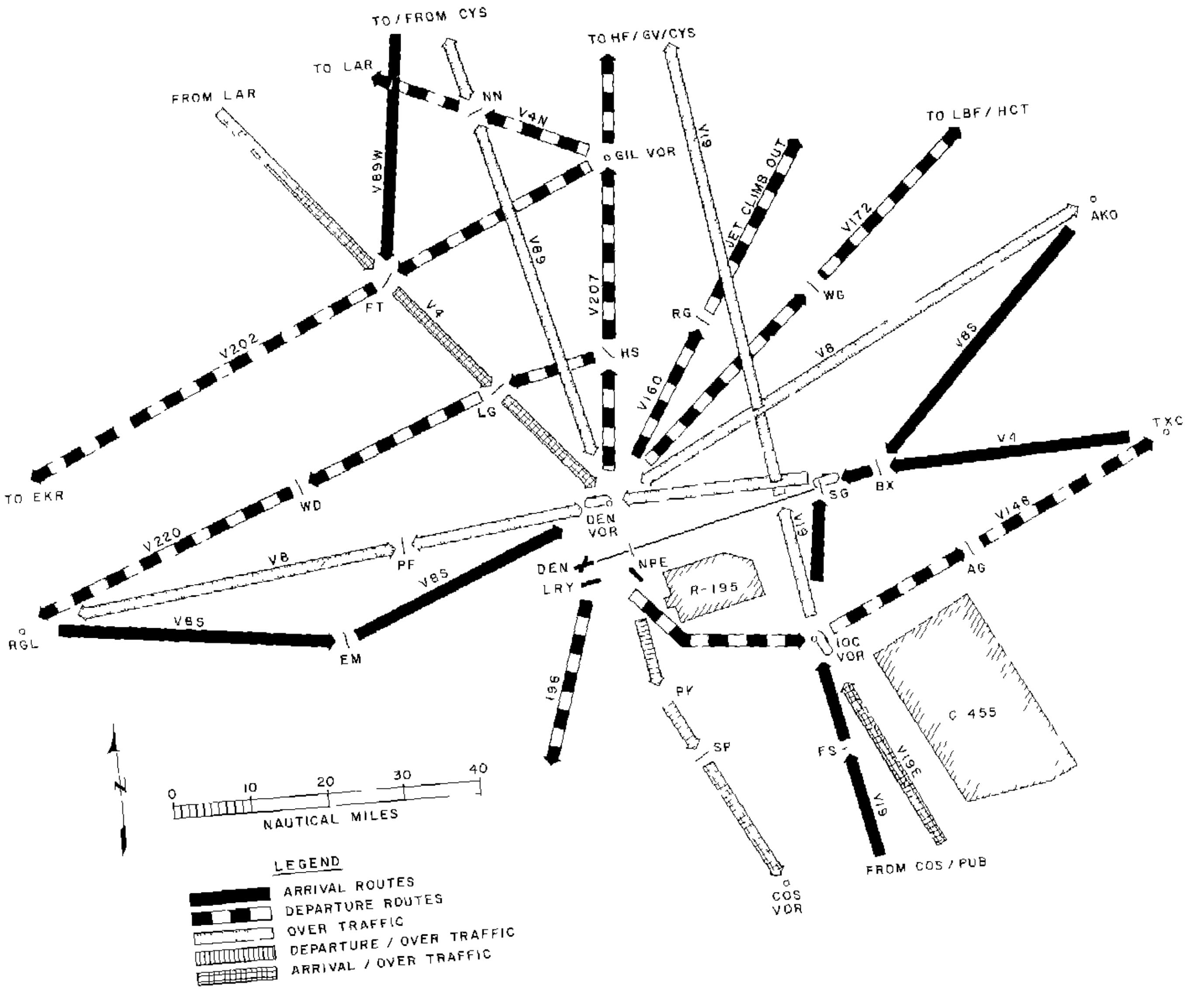


FIG 15 - ROUTE STRUCTURE - PHASE IV

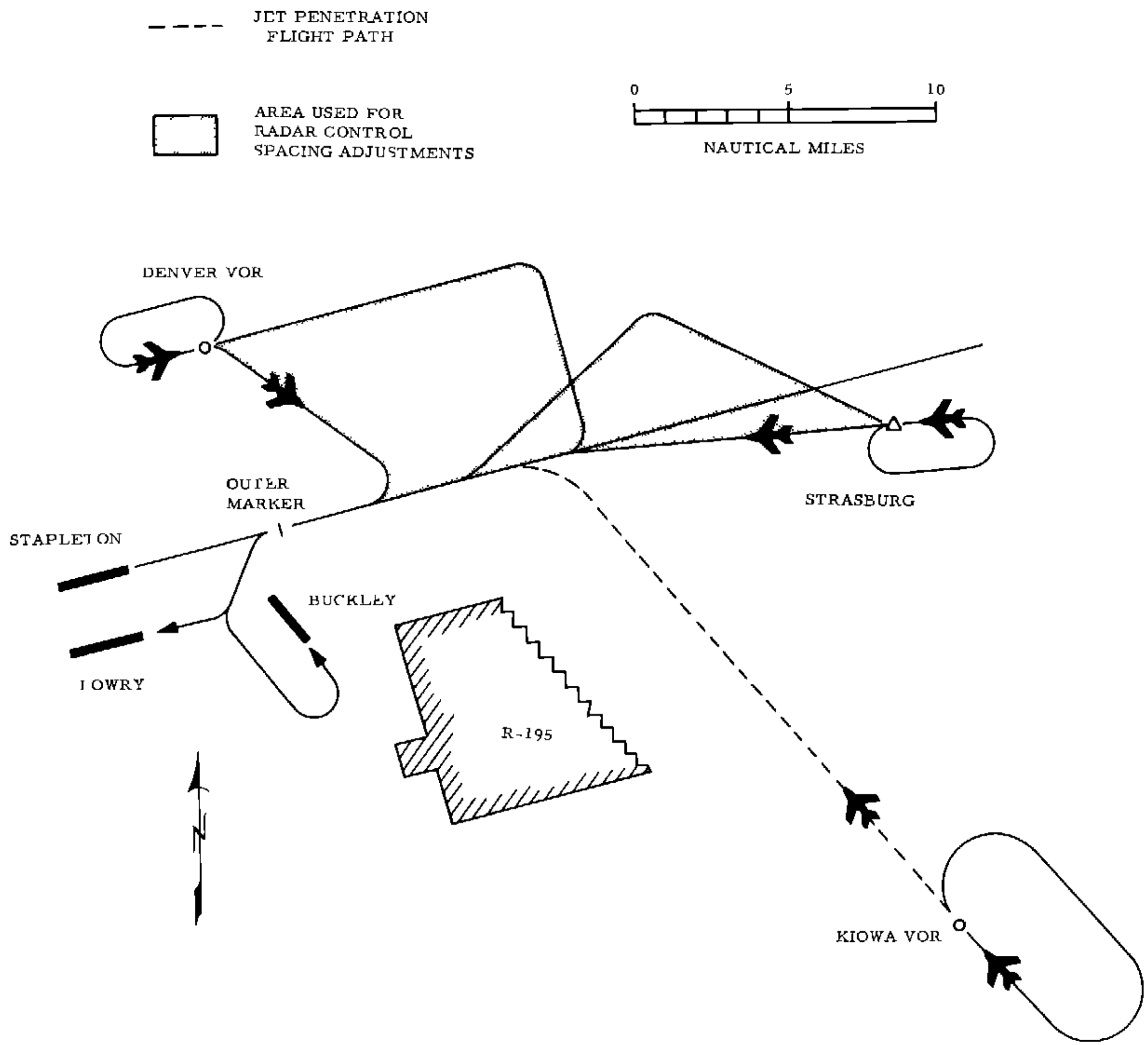


FIG 16 - DENVER TERMINAL AREA PHASE IV MODIFIED APPROACH FIXES AND RADAR VECTOR PATTERNS

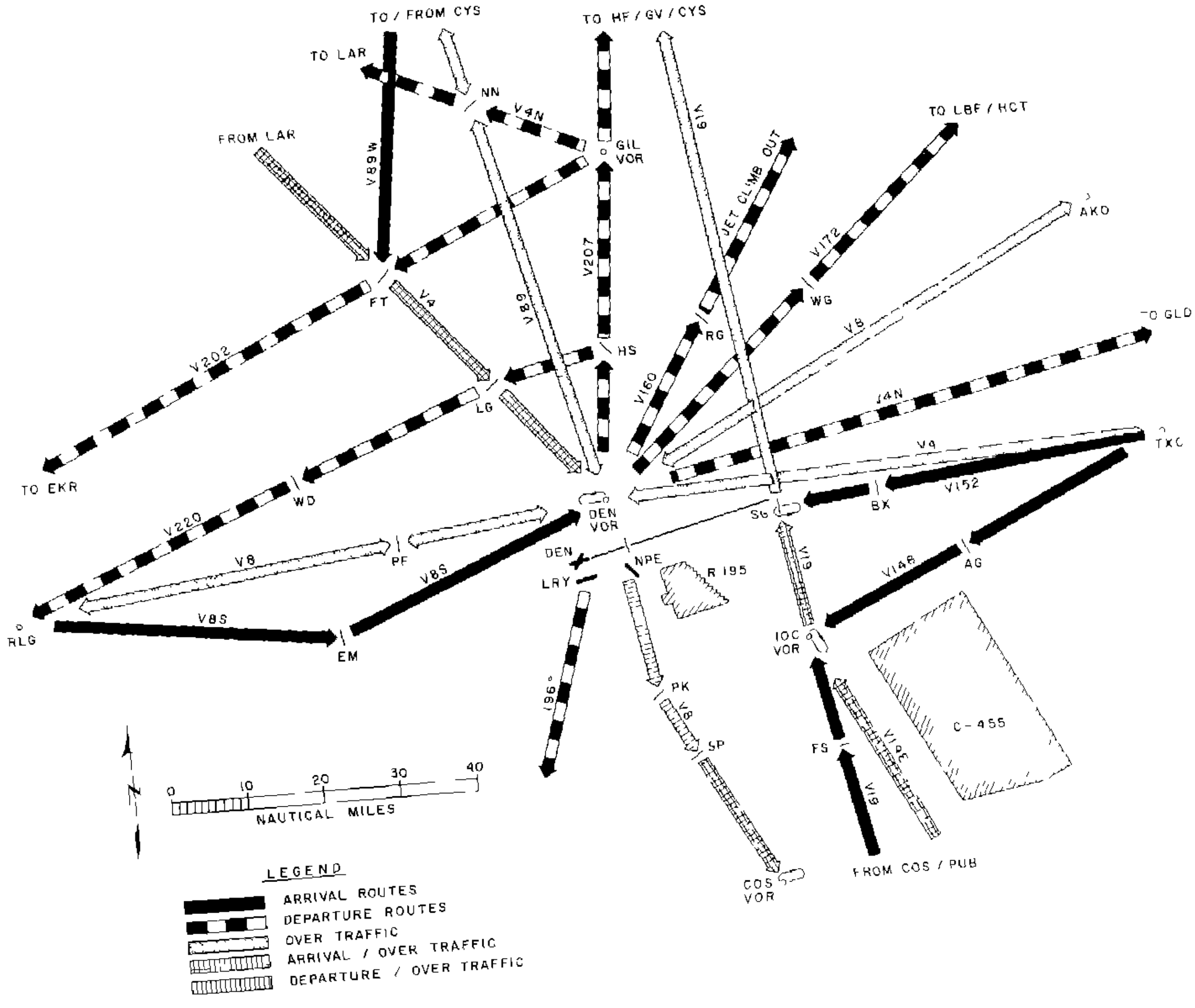


FIG 17 - ROUTE STRUCTURE - PHASE IV - MODIFIED

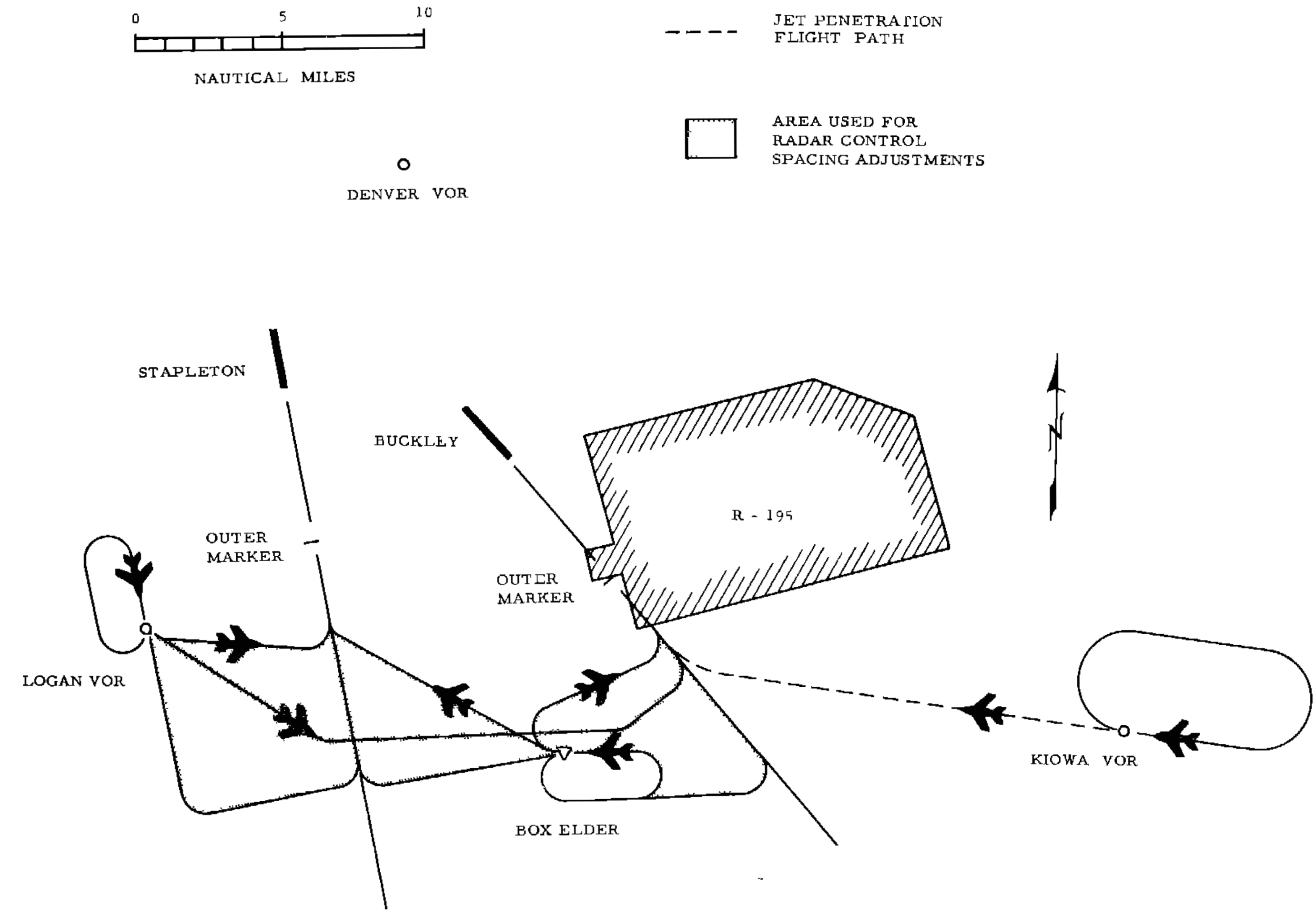


FIG 18 - DENVER TERMINAL AREA - PHASE V APPROACH FIXES AND RADAR VECTOR PATTERNS

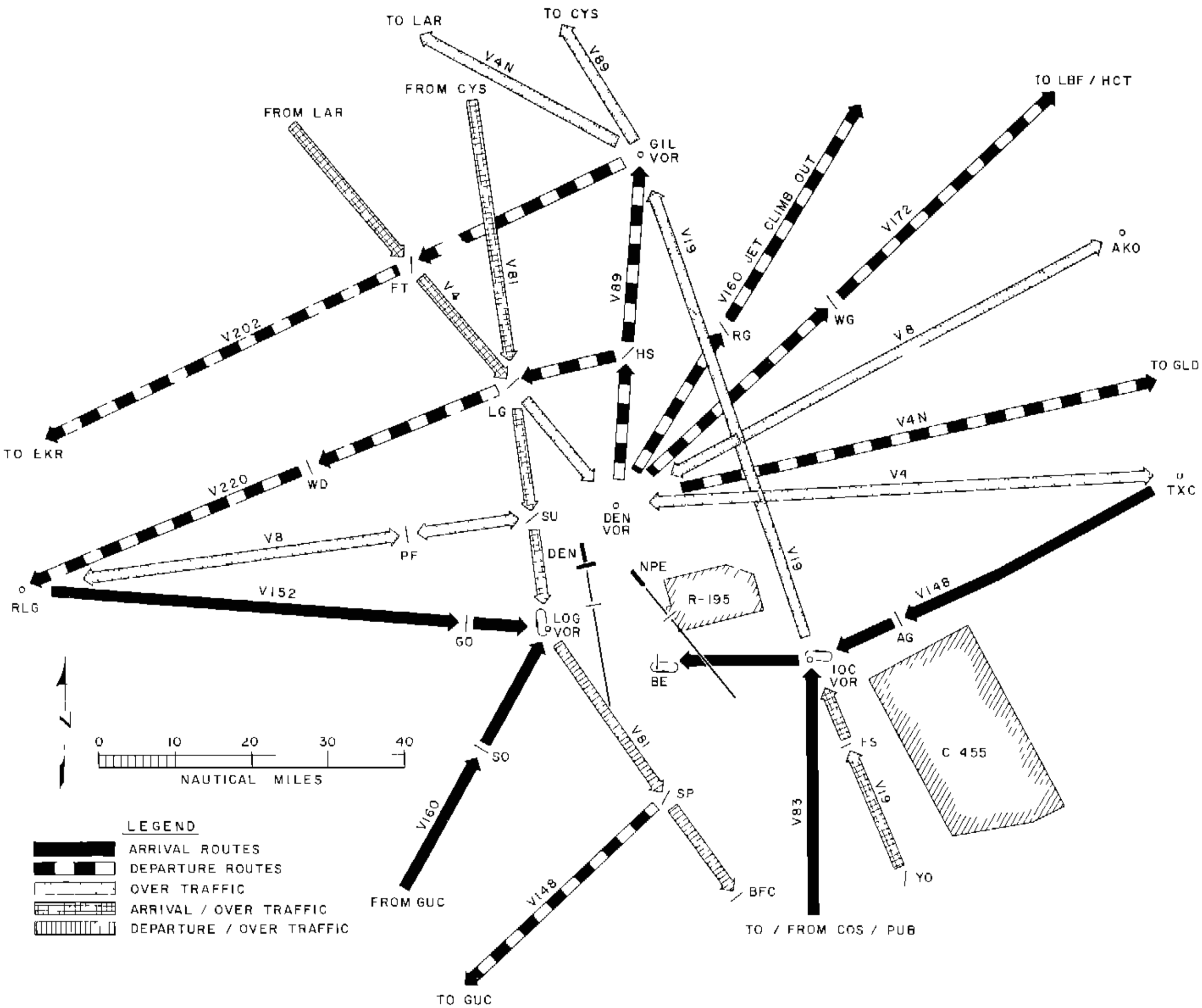


FIG 19 - ROUTE STRUCTURE - PHASE V

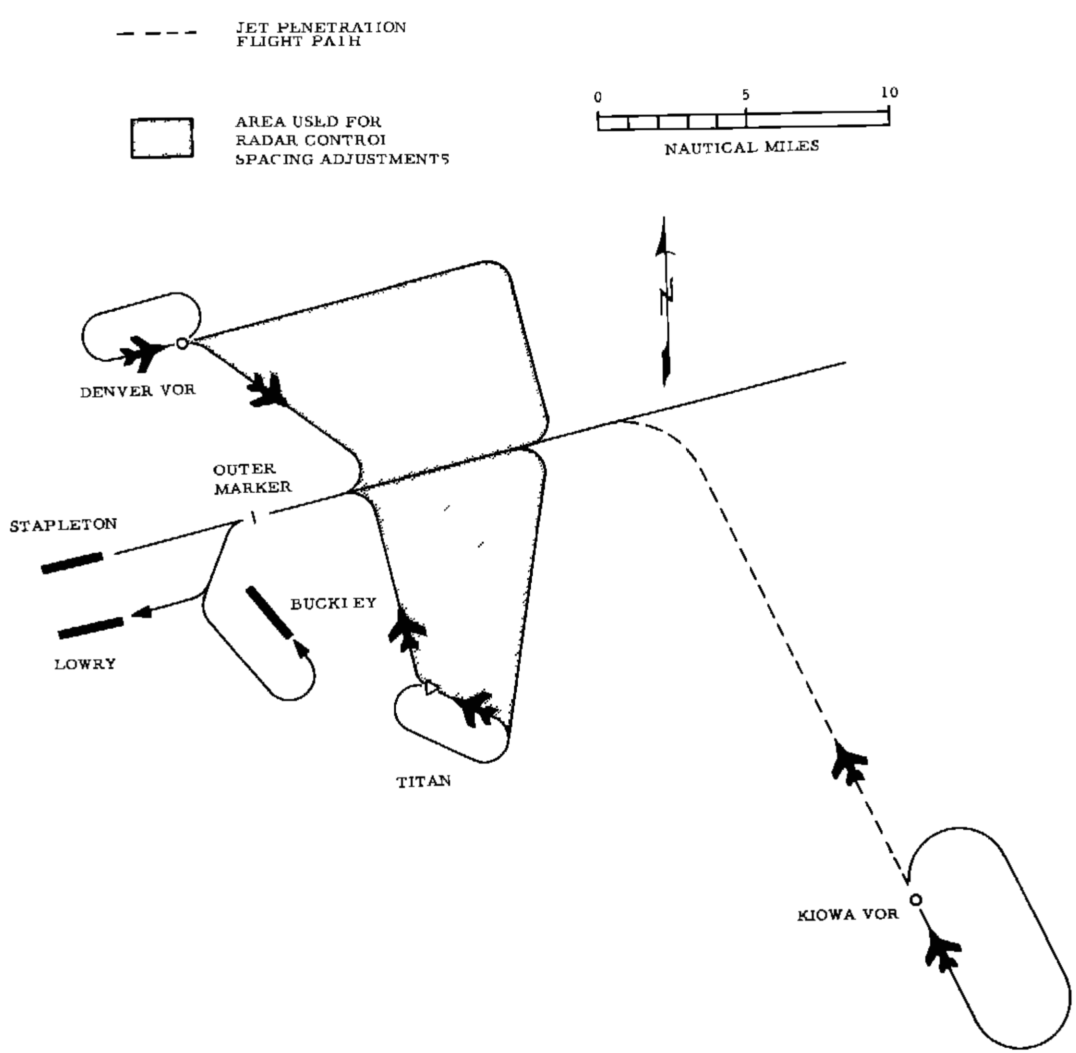


FIG 20 - DENVER TERMINAL AREA PHASE VI APPROACH FIXES AND RADAR VECTOR PATTERNS

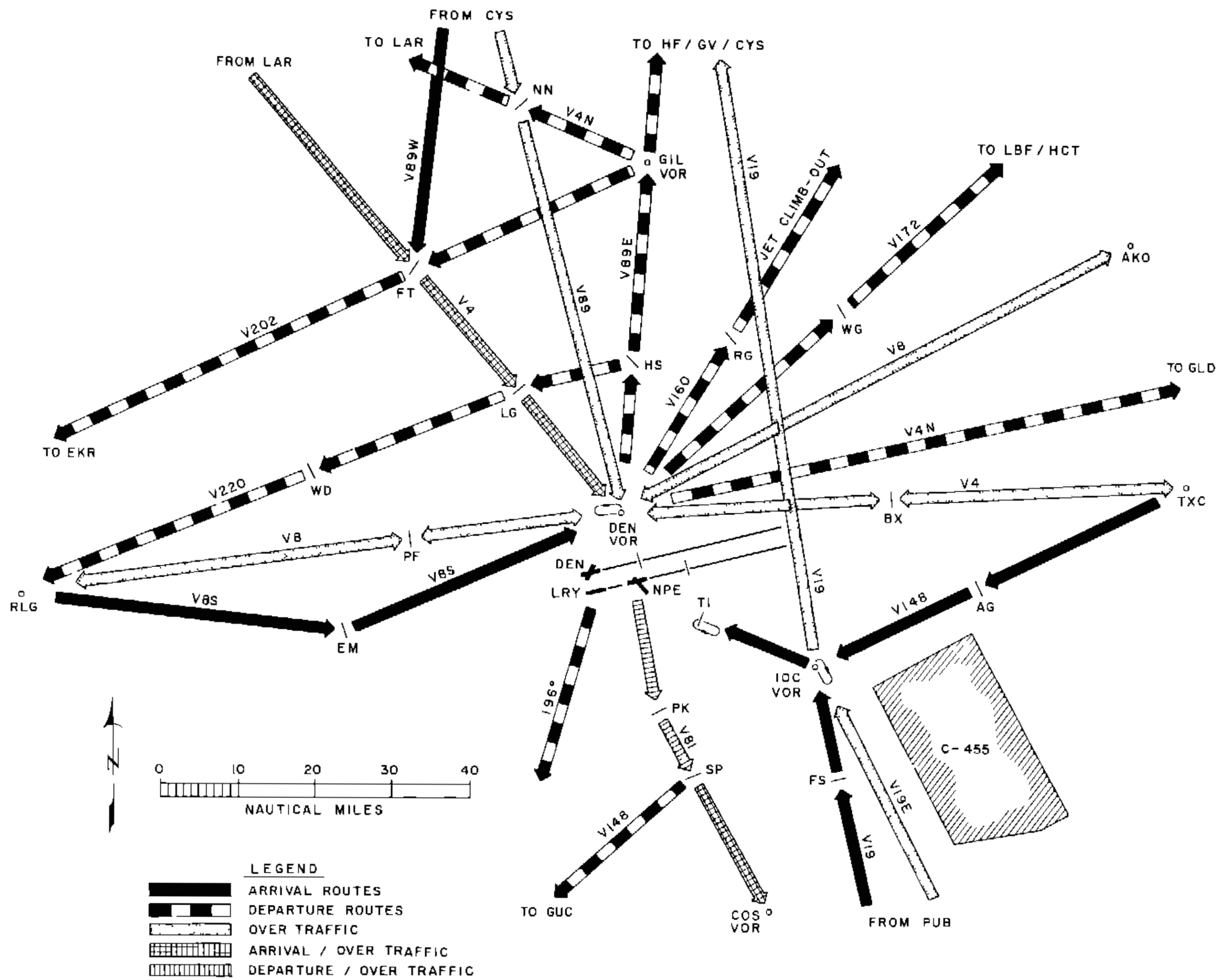


FIG 21 - ROUTE STRUCTURE - PHASES VI AND VIII

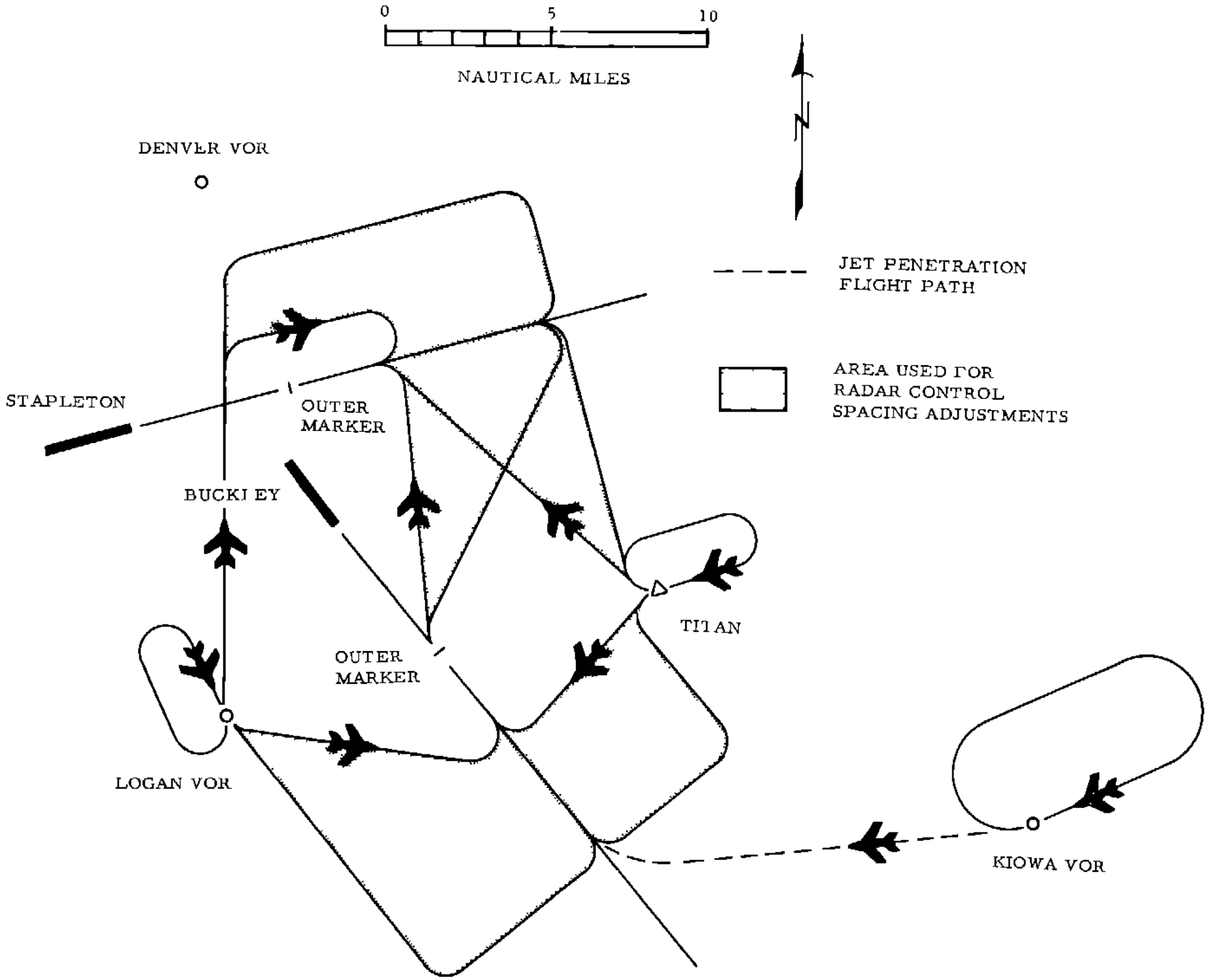


FIG. 22 - DENVER TERMINAL AREA PHASE VII APPROACH FIXES AND RADAR VECTOR PATTERNS

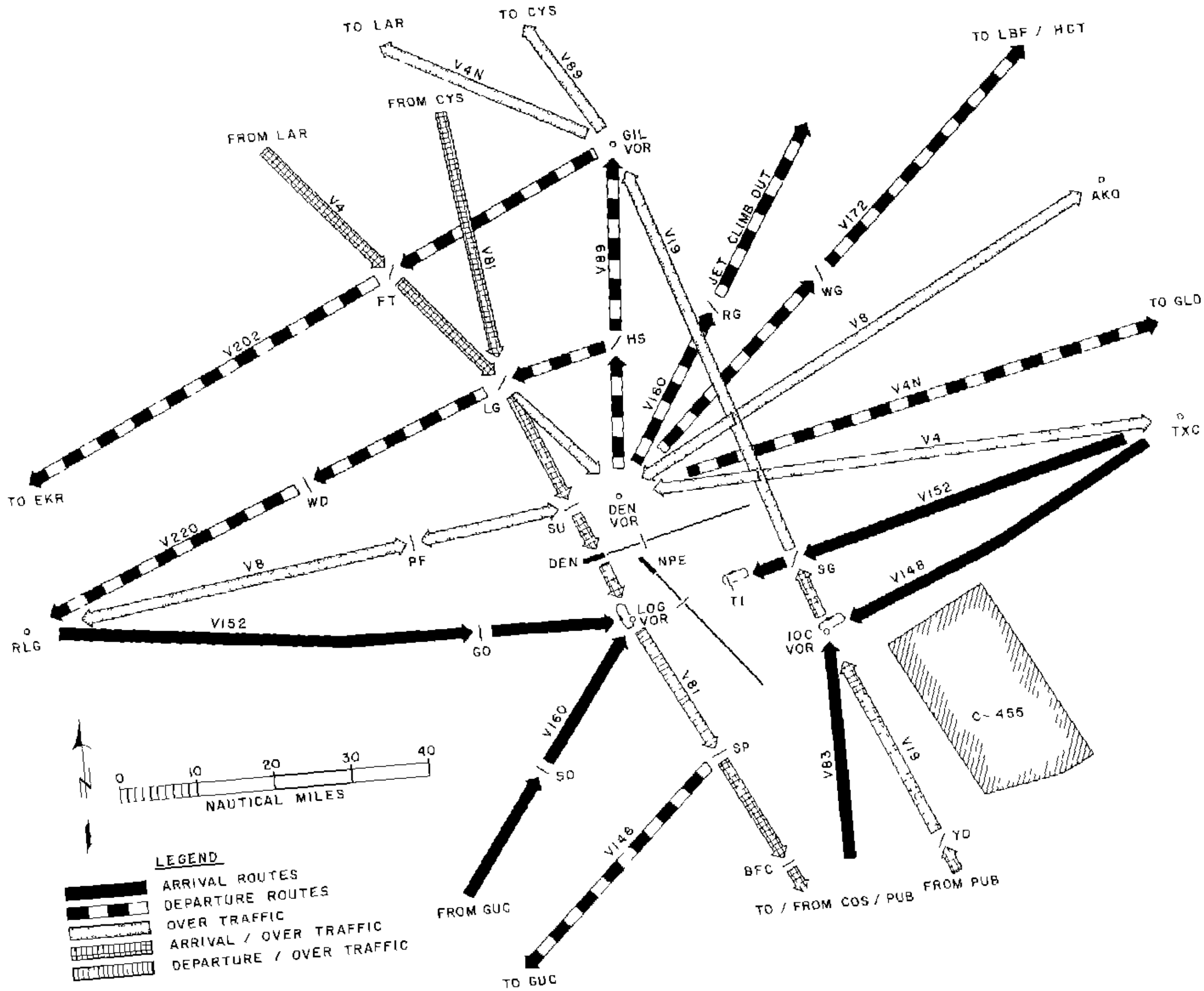


FIG 23 - ROUTE STRUCTURE - PHASE VII

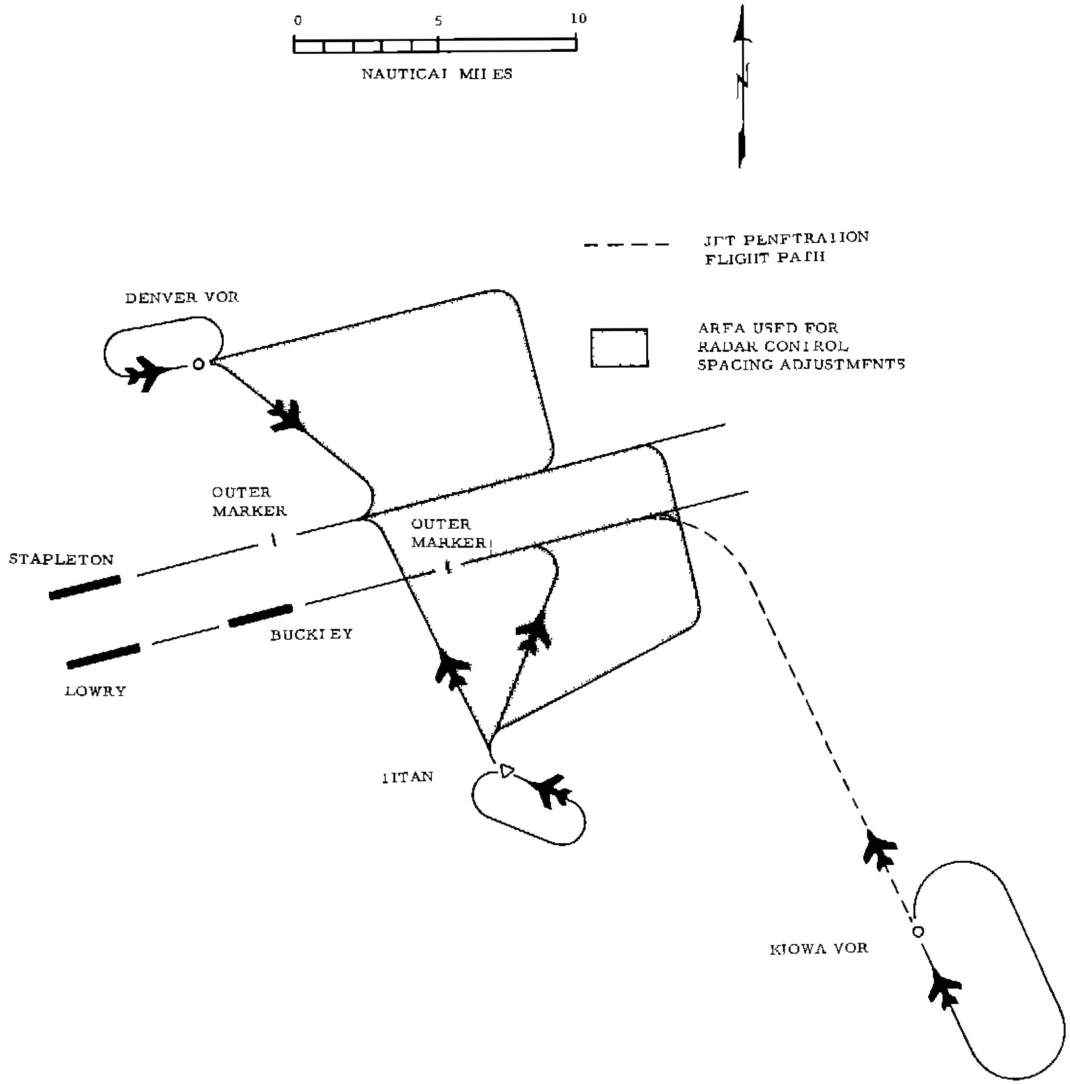


FIG 24 - DENVER TERMINAL AREA - PHASE VIII APPROACH FIXES AND RADAR VECTOR PATTERNS

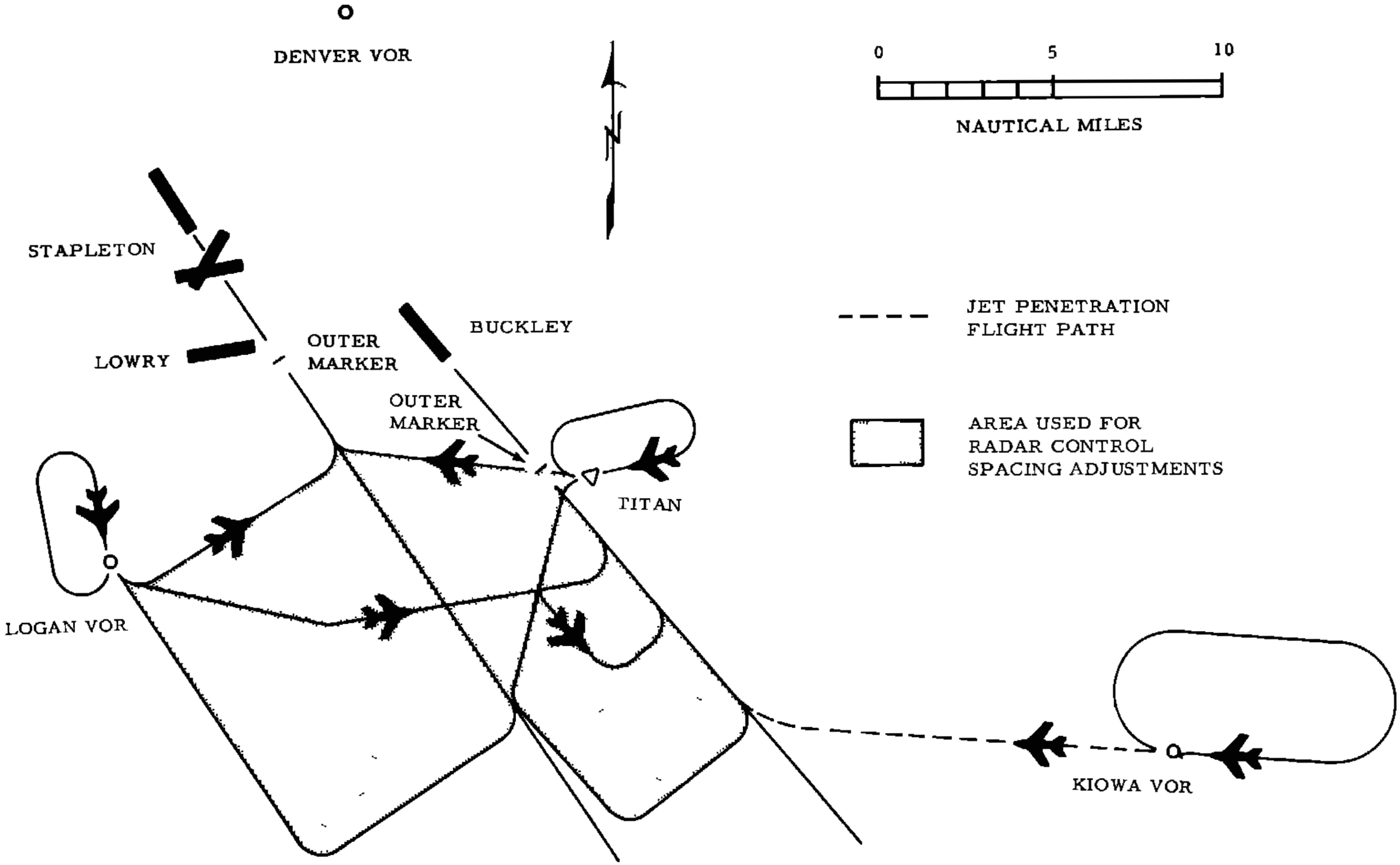


FIG 25 - DENVER TERMINAL AREA - PHASE IX APPROACH FIXES AND RADAR VECTOR PATTERNS

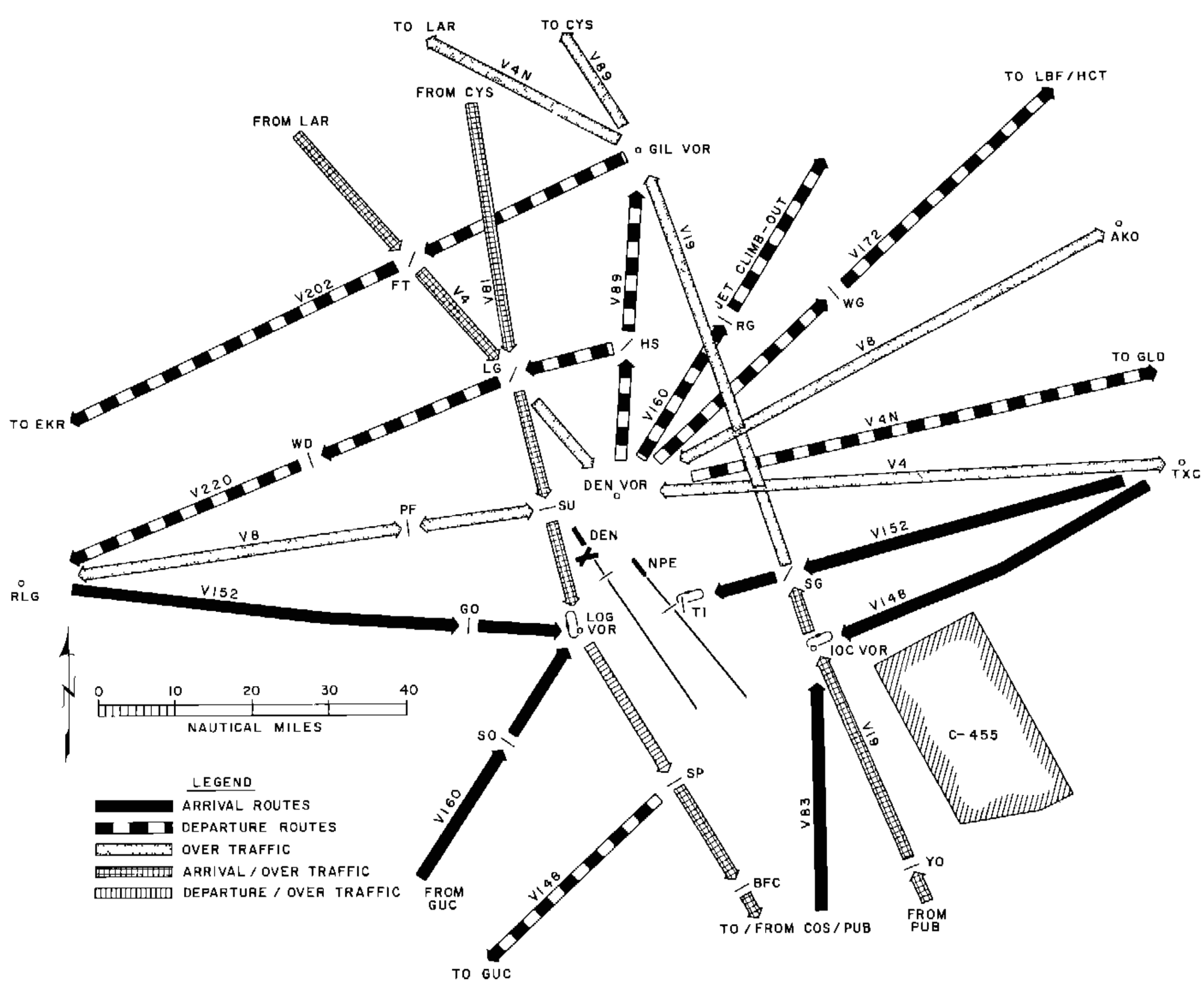


FIG 26 - ROUTE STRUCTURE - PHASE IX

FIG 27 - DENVER APPROACH CONTROL

FIG 28 - COLORADO SPRINGS APPROACH CONTROL

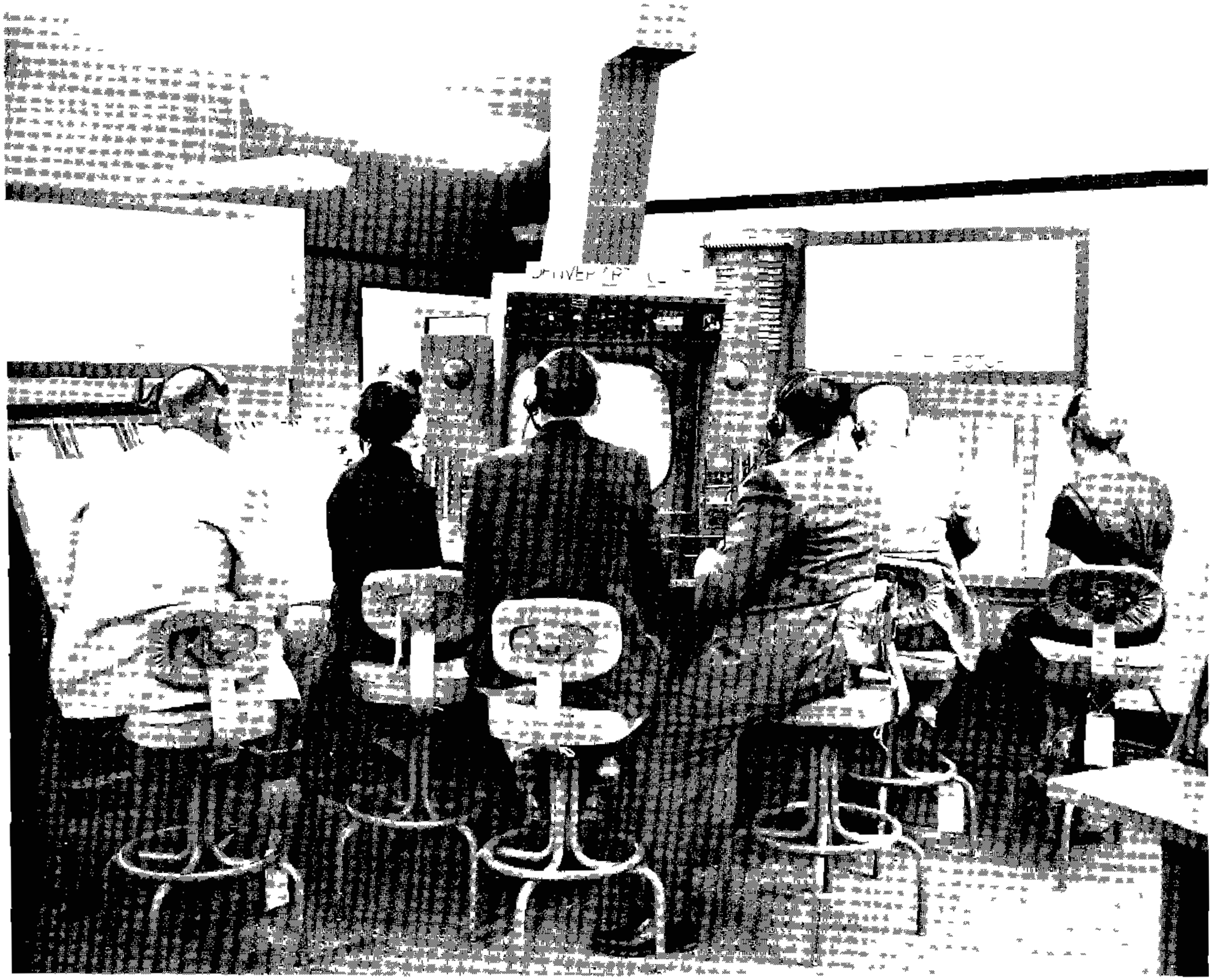


FIG 29 - ARTCC EAST-WEST DENVER SECTORS

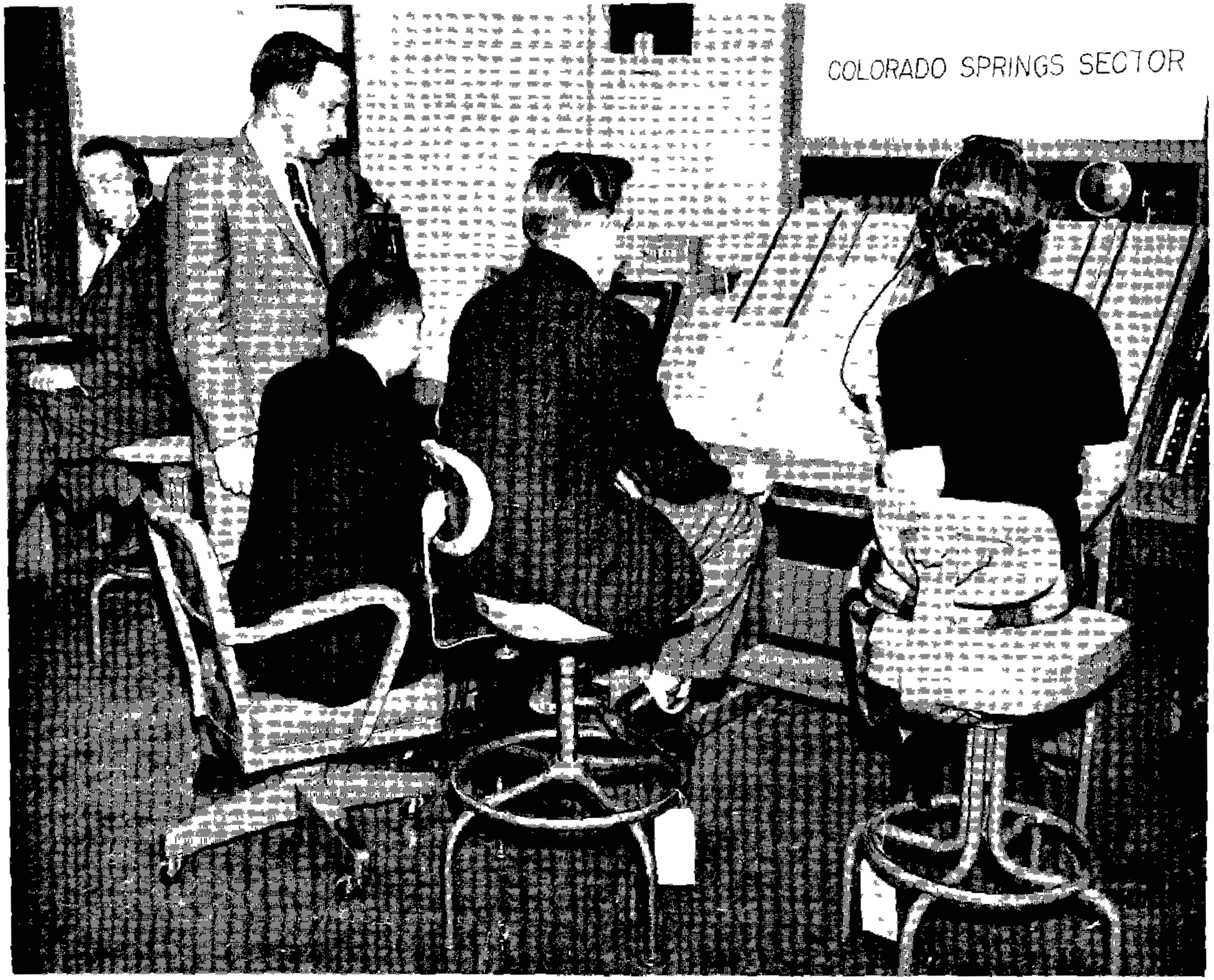


FIG 30 - ARTCC COLORADO SPRINGS SECTOR

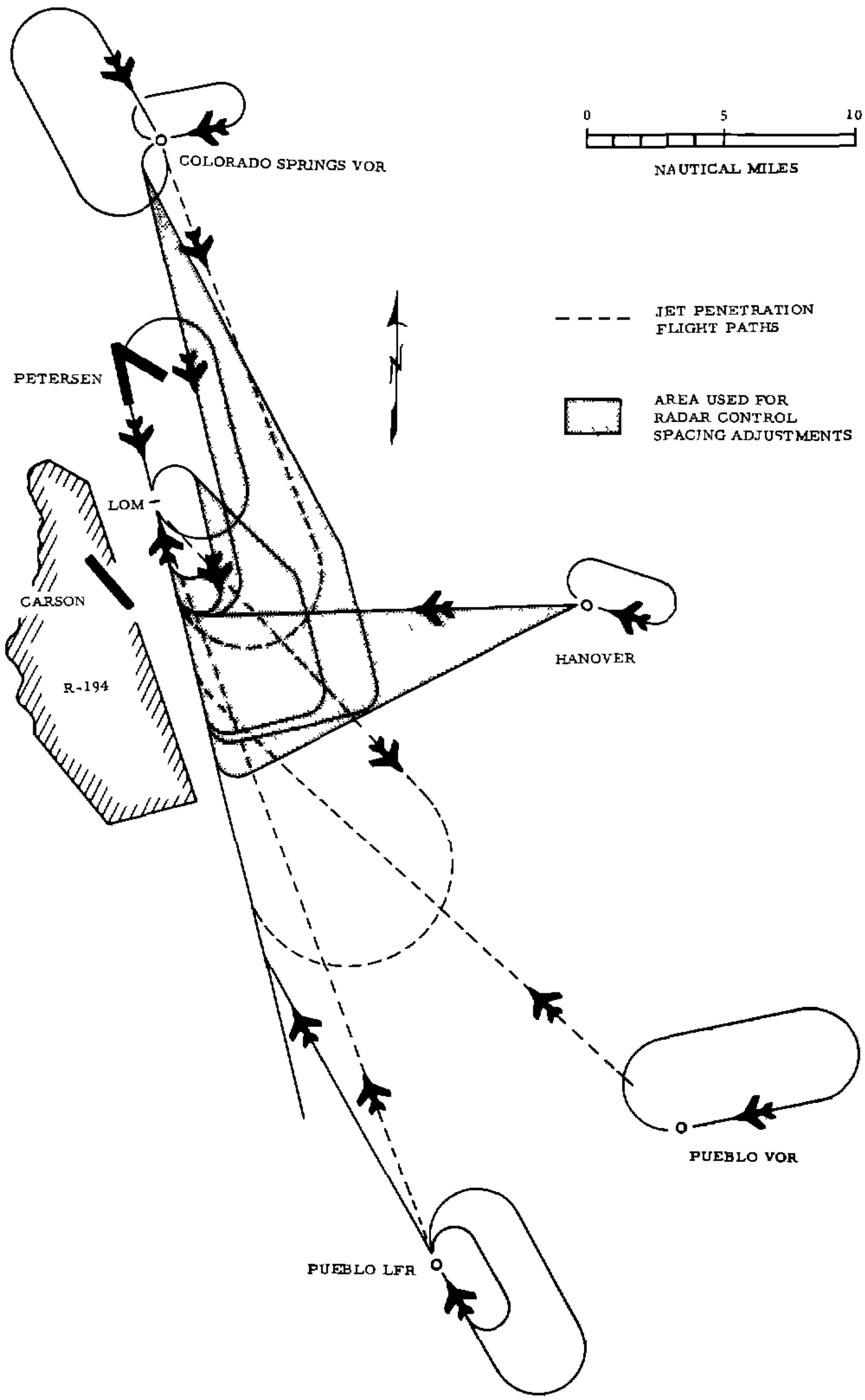


FIG 31 - COLORADO SPRINGS TERMINAL AREA - PHASES I AND II APPROACH FIXES AND RADAR VECTOR PATTERNS

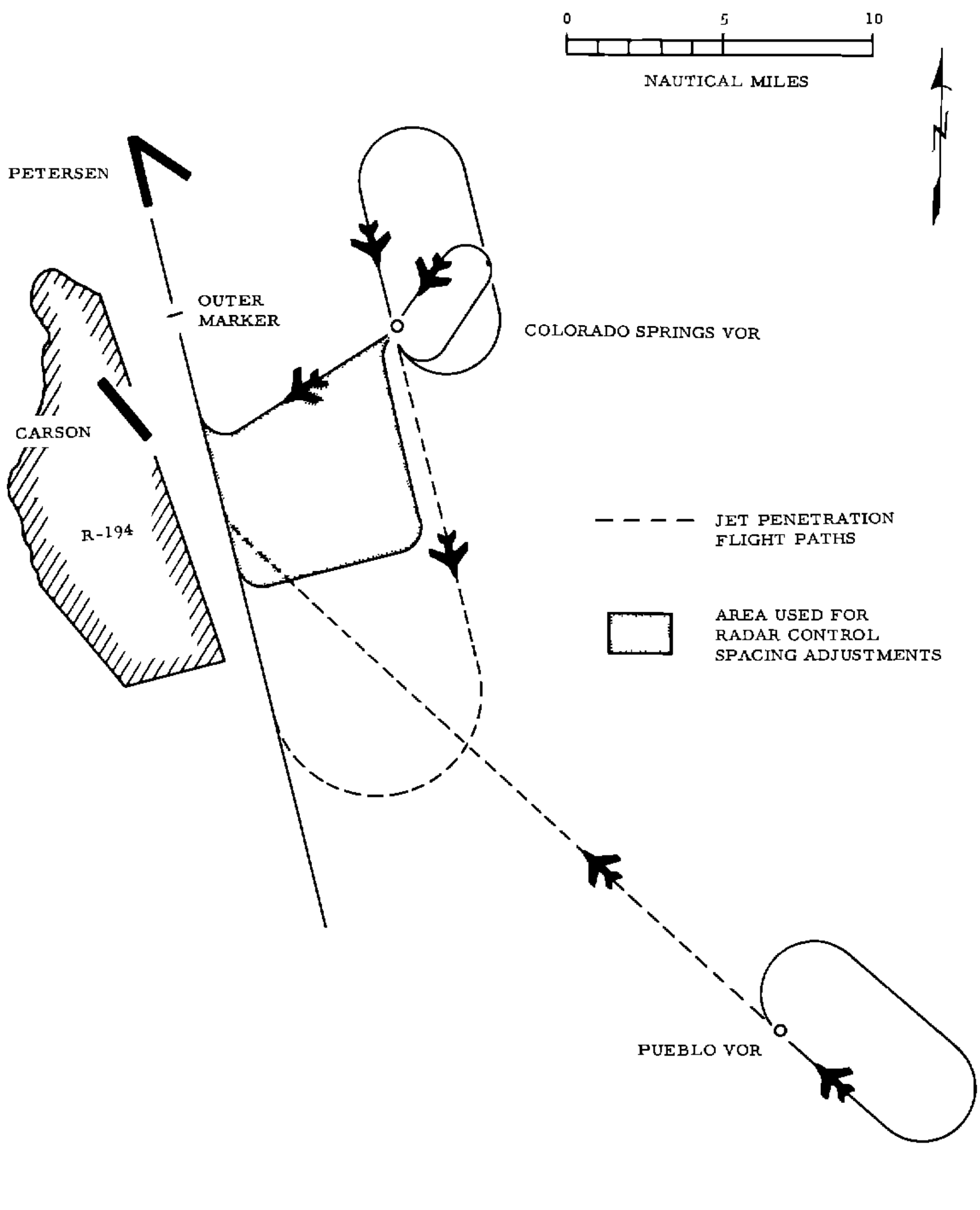


FIG 32 - COLORADO SPRINGS TERMINAL AREA - PHASE III
APPROACH FIXES AND RADAR VECTOR PATTERNS

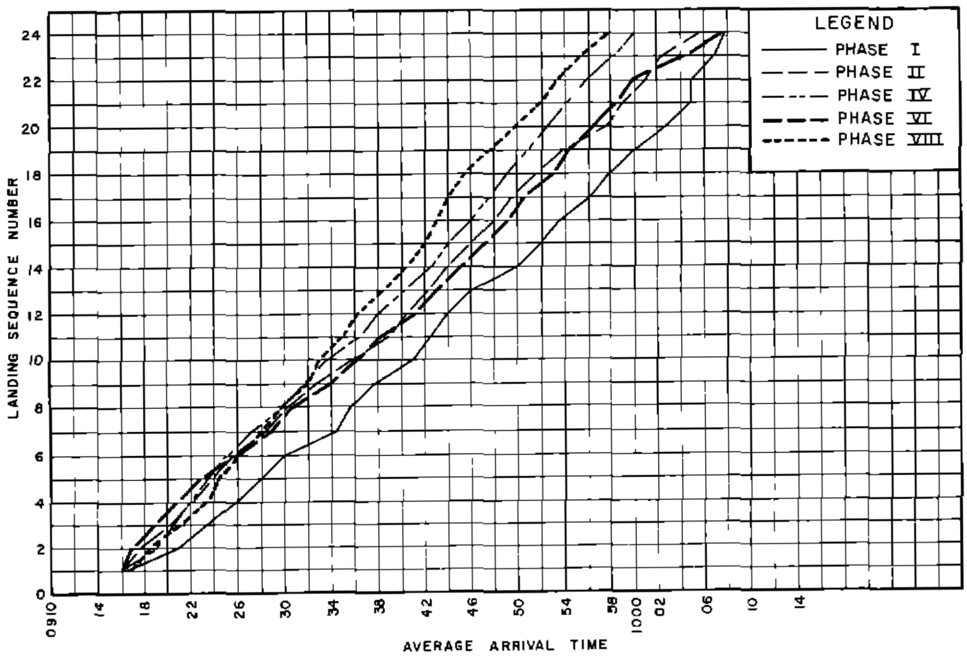


FIG. 33 - AVERAGE ARRIVAL TIMES - TERMINAL RUNS EAST-WEST RUNWAY CONFIGURATION

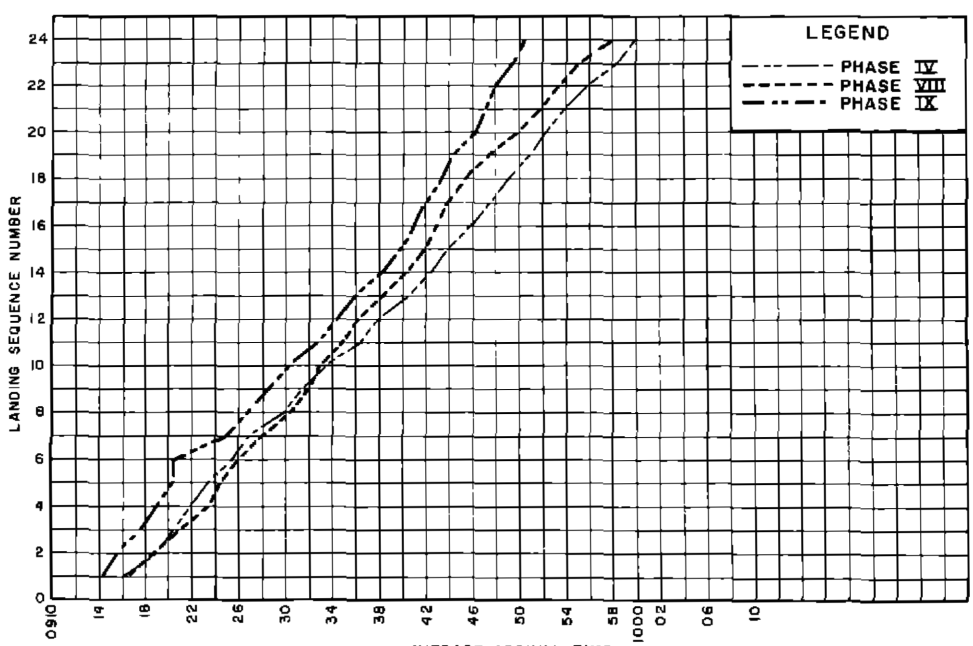


FIG. 34 - AVERAGE ARRIVAL TIMES - TERMINAL RUNS EAST-WEST AND NORTH-SOUTH RUNWAY CONFIGURATIONS

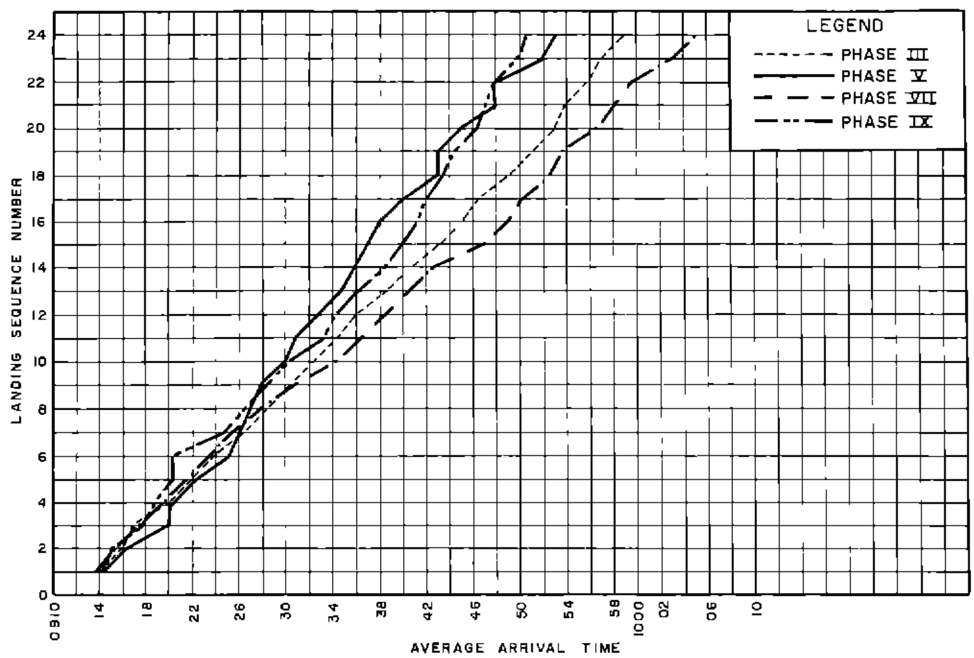


FIG. 35 - AVERAGE ARRIVAL TIMES - TERMINAL RUNS NORTH-SOUTH RUNWAY CONFIGURATION

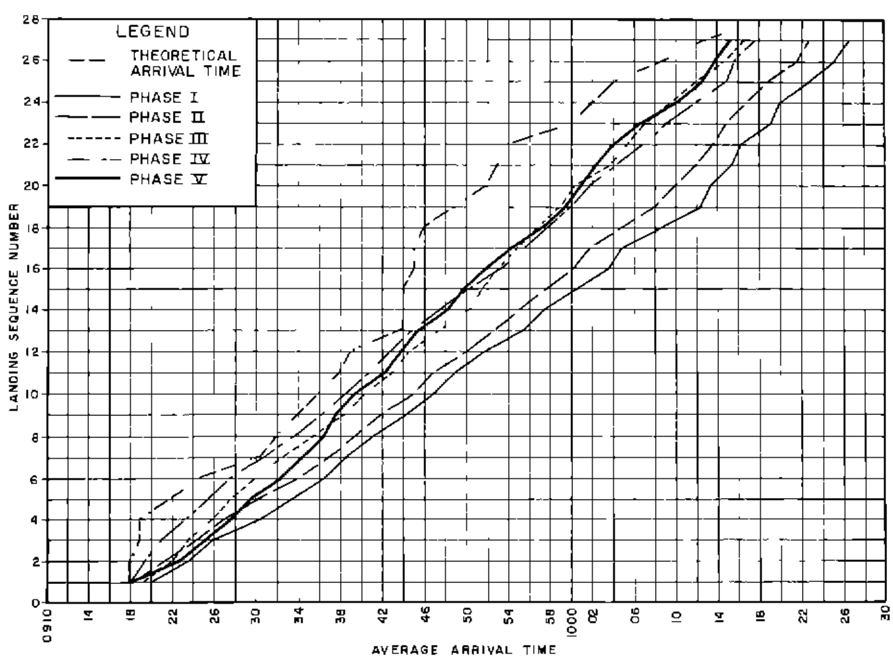


FIG 36 - AVERAGE ARRIVAL TIMES - ENROUTE

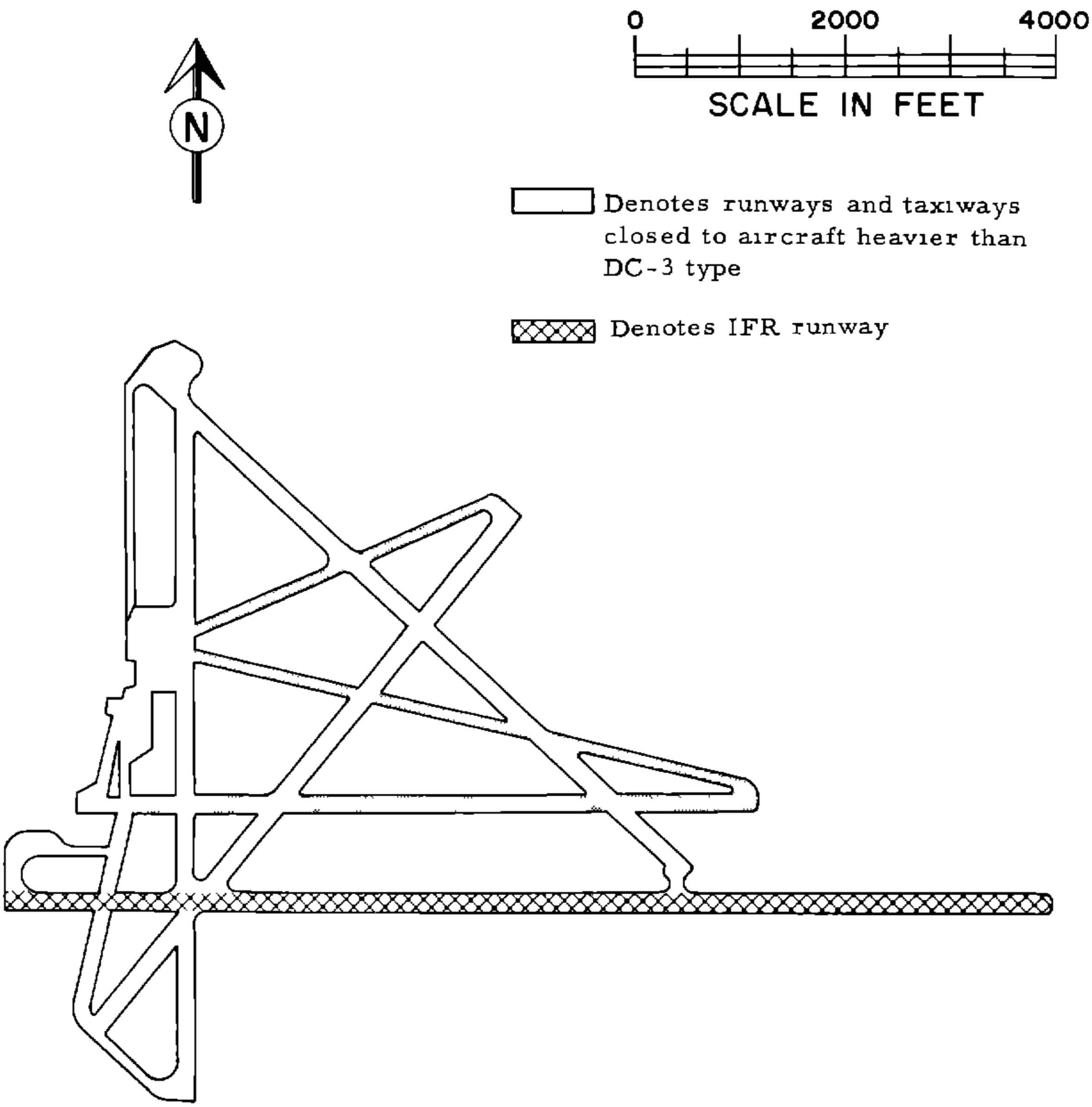


FIG 37 - DENVER STAPLETON AIRPORT RUNWAY LAYOUT