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Expedite Departure Path (EDP) Operational Concept

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19 August 1999

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16. Abstract

This document describes the operational concept for the Expedite Departure Path (EDP) tool. EDP is part of the Center-TRACON Automation System (CTAS) which is being developed under the Advanced Air Transport Technologies program at NASA-Ames Research Center. CTAS provides computer intelligence for planning and controlling arrival and departure traffic within several hundred nautical miles of the adapted airport. It consists of a set of integrated tools. EDP is the tool used by departure controllers in the terminal area.

The high level concept of EDP is that advisories are generated and displayed to controllers in the TRACON and ARTCC. These advisories assist the controllers in dealing with certain departure-related situations. Specifically, EDP is designed to address the complexities of unrestricted climbs into the en route system, and the merging of multiple aircraft over a common fix or through a departure gate. EDP also generates timelines showing sequencing and scheduling information for departure fixes/gates. These timelines will be available in the Traffic Management Units (TMUs) in the TRACON and ARTCC. The operational uses of these timelines have not been fully researched and are not included in this document.

The concept of operation described in this document identifies the specific uses of EDP through operational scenarios. These scenarios are taken from real operational challenges found in the air traffic system. The scenarios illustrate how EDP can safely and optimally expedite the climb of departure aircraft, and merge departures into the en route stream through the use of speed, vector, and altitude advisories. These advisories allow aircraft to be safely climbed and efficiently spaced, while minimizing aircraft maneuvers and controller clearances.

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EXECUTIVE SUMMARY

In response to growth in the amount of air traffic and increased terminal area delays, the National Aeronautics and Space Administration (NASA), in coordination with the Federal Aviation Administration (FAA), began to research and develop air traffic control decision support tools. These tools comprise the Center-TRACON Automation System (CTAS) and are designed to assist Traffic Management Coordinators (TMCs) and Air Traffic Control Specialists (ATCSs) in Air Route Traffic Control Centers (ARTCCs) and Terminal Radar Approach Controls (TRACONs) in the management of terminal area traffic. CTAS is an ongoing effort at NASA-Ames Research Center, under the Advanced Air Transportation Technologies (AATT) Program Office.

CTAS tools provide computer intelligence for planning and controlling arrival traffic within several hundred nautical miles of the arrival airport. The tool used by the TMCs in the ARTCCs and TRACONs is called the Traffic Management Advisor (TMA). The tools used by the ATCSs in the ARTCCs are the TMA-generated meter lists, and the En Route Descent Advisor (EDA). The tools used by the ATCSs in the TRACONs are called the Final Approach Spacing Tool (FAST) and the Expedite Departure Path (EDP). The FAST functionality has been separated into passive advisories (pFAST - runway assignment and sequence number), and active advisories (aFAST - speed, heading, and possibly altitude).

The high level concept of EDP is that CTAS will generate advisories to be displayed to controllers in the TRACON and ARTCC. These advisories will assist the controllers in managing certain departure-related situations. Specifically, EDP is designed to address the complexities of unrestricted climbs into the en route system, and the merging of multiple aircraft over a common fix or through a departure gate. EDP will also generate timelines showing sequencing and scheduling information for departure fixes/gates. These timelines will be available in the Traffic Management Units (TMUs) in the TRACON and ARTCC. The operational uses of these timelines have not been fully researched and are not included in this document.

The operational scenarios included in this document illustrate numerous ways in which EDP may be used in the operational environment. For example, when EDP computes that a departure can safely climb, it displays an advisory to the air traffic controller, eliminating unnecessary altitude restrictions. EDP can also reduce controller workload while optimizing the flow of aircraft into the en route stream. EDP also generates speed, vector, and altitude advisories to sequence and schedule aircraft into the en route stream. These advisories allow aircraft to be spaced efficiently, while minimizing aircraft maneuvers and controller clearances. Both uses are expected to improve overall system efficiency.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1. INTRODUCTION

In response to growth in the amount of air traffic and increased terminal area delays, the National Aeronautics and Space Administration (NASA), in coordination with the Federal Aviation Administration (FAA), began to research and develop air traffic control decision support tools. These tools comprise the Center-TRACON Automation System (CTAS) and are designed to assist Traffic Management Coordinators (TMCs) and Air Traffic Control Specialists (ATCSs) in Air Route Traffic Control Centers (ARTCCs) and Terminal Radar Approach Controls (TRACONs) in the management of terminal area traffic. CTAS is an ongoing effort at NASA-Ames Research Center, under the Advanced Air Transportation Technologies (AATT) Program Office.

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These tools have been developed over the past decade. The initial research on all tools except EDP was conducted at Denver ARTCC (ZDV) and TRACON (DEN), and later refined at Fort Worth ARTCC (ZFW) and DFW TRACON (DFW). While research continues, the refinements developed at ZFW and DFW for TMA and pFAST are now part of a version of CTAS which has been transferred to an FAA-funded contractor for national deployment into the National Airspace System (NAS). The version of CTAS which has been transferred for deployment is called Build 2, and is included as part of the FAA's Free Flight Phase I Program.

The high level concept of EDP is that CTAS will generate advisories to be displayed to controllers in the TRACON and ARTCC. These advisories will assist the controllers in managing certain departure-related situations. Specifically, EDP is designed to address the complexities of unrestricted climbs into the en route system, and the merging of multiple aircraft over a common fix or through a departure gate. EDP will also generate timelines showing sequencing and scheduling information for departure fixes/gates. These timelines will be available in the Traffic Management Units (TMUs) in the TRACON and ARTCC. The operational uses of these timelines have not been fully researched and are not included in this document.

It is anticipated that EDP will be interoperable with surface decision support tools, requiring an interface between surface decision support tools and EDP. The surface decision support tools will share information with EDP regarding the aircraft in the departure queue. EDP will use this information to calculate an aircraft departure time, which is optimized for the airborne constraints. The surface decision support tools will use this time to determine an optimal taxi scheme, and then send information to EDP as a revised departure queue. The two systems will iterate until an optimal solution is negotiated.

1.1 PURPOSE OF DOCUMENT

The work on EDP is still in the concept exploration phase. This document describes the operational concept of the EDP tool, through the use of operational scenarios. EDP capabilities are compared with current operational techniques; thus allowing the readers to see how, and under what operational instances the EDP tool can be used.

1.2 SCOPE OF DOCUMENT

The intended audience for this document are the developers and users of the EDP tool. As research on EDP continues, this document will be updated to reflect progress. In particular, controller simulations and interactions will contribute to the refinement of the Computer Human Interface (CHI) description. The operational uses of EDP will also be expanded based upon the user feedback. This feedback will provide the background and basis for the system requirements and CHI requirements of EDP.

This document is comprised of 7 sections. Section 1 provides an introduction to CTAS and EDP. Section 2 describes the EDP system software, hardware, and Computer Human Interface (CHI). Section 3 describes specific operational scenarios where EDP could be used, including graphical representations of planned advisories. Section 4 provides some EDP implementation considerations such as external interfaces. Section 5 provides a listing of applicable acronyms. Section 6 provides a glossary of relevant terms. Section 7 provides a list of references.

2. EDP OVERVIEW

2.1 SYSTEM OVERVIEW

This section provides a high-level description of the EDP system, its basic operation, and interfaces. As shown in Figure 2.1.1, the EDP network uses aircraft flight plans and position data from FAA computers, inputs from TRACON departure controllers, and current weather predictions, to produce advisories to assist controllers in managing departure traffic. TRACON departure controllers interact with EDP, both receiving advisories and providing inputs, through standard FAA hardware. Center and TRACON TMCs interact with EDP through a dedicated EDP display, although the center TMU provides no inputs to EDP.

2.2 SOFTWARE DESCRIPTION

The EDP system will be divided into nine software modules: Communications Manager (CM), Weather Data Acquisition Daemon (WDAD), and Weather Data Processing Daemon (WDPD), Route Analyzer (RA), Trajectory Synthesizer (TS), EDP Scheduling Process (ESP), Input Source Manager (ISM), Planview Graphical User Interface (PGUI), Timeline Graphical User Interface (TGUI). The CM controls the flow of information between the modules and manages system start-up and shutdown procedures. The WDAD and WDPD retrieve and process weather predictions for both ARTCC and TRACON airspace. The RA generates and analyzes predicted possible routes for each aircraft. The TS computes predicted 4D trajectories given the aircraft routes, weather conditions, and aircraft performance models. The RA, in conjunction with the TS, produces 4D trajectories and Estimated Times of Arrival (ETAs) spanning the range of possible paths for each aircraft. Given the set of likely flight paths for all aircraft in the system, produced by the RA/TS combination, ESP generates an efficient conflict-free schedule and the corresponding advisories required to meet this schedule. The ESP accomplishes this task in coordination with the arrival scheduler, insuring the departure schedule is not in conflict with the arrival schedule.

Figure 2.2.1 depicts the flow of information between these modules. As previously mentioned, the CM coordinates inter-process messaging, distributing necessary data to each software module. Note that the processes that request trajectories (RA and ESP) spawn the TS, thus forming a direct link of communication via shared memory. Furthermore, the number of RA/TS modules is scalable to accommodate the traffic load encountered. This architecture allows all aircraft trajectories to be updated within the radar update cycle.

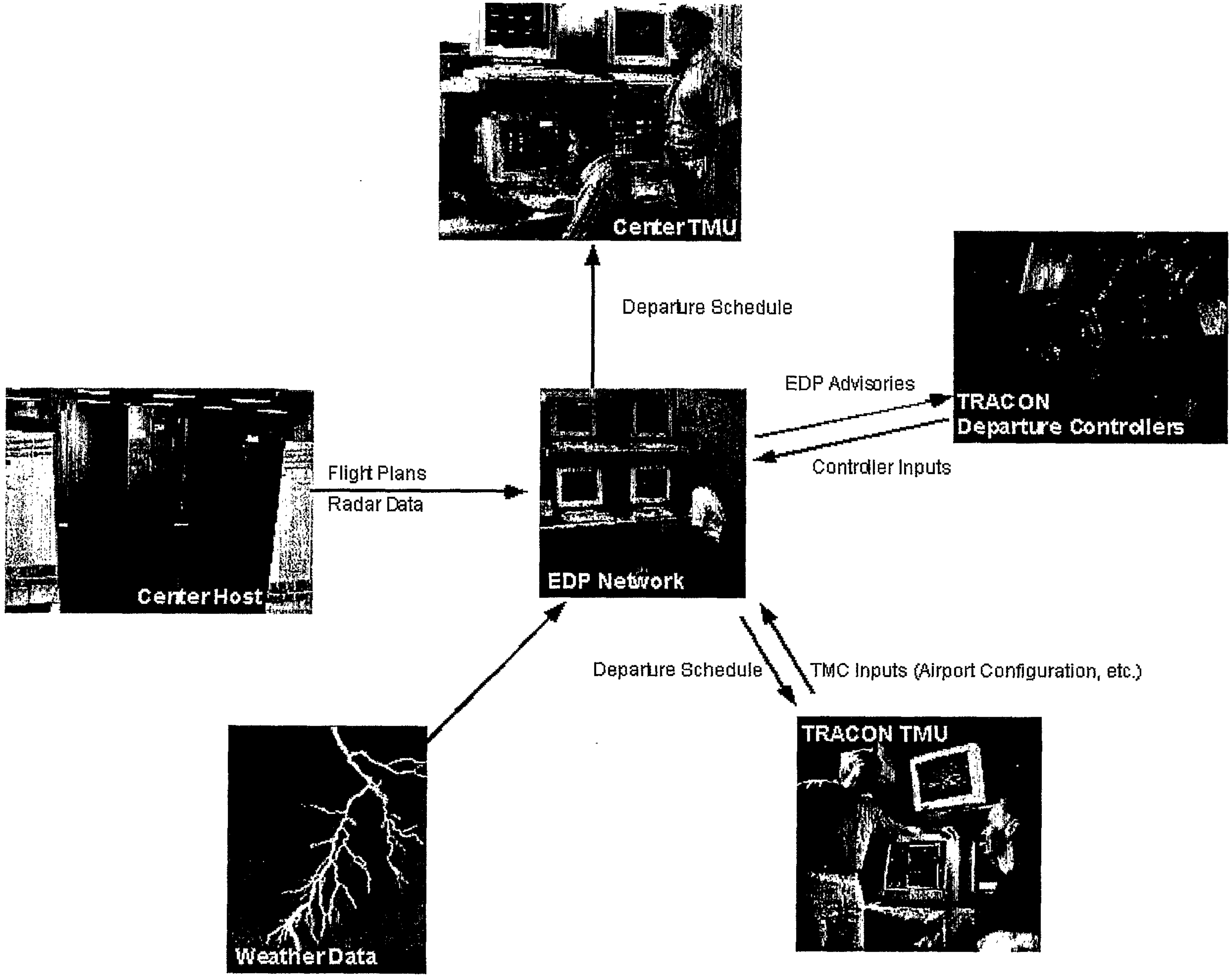

Figure 2.1.1. EDP System Overview.

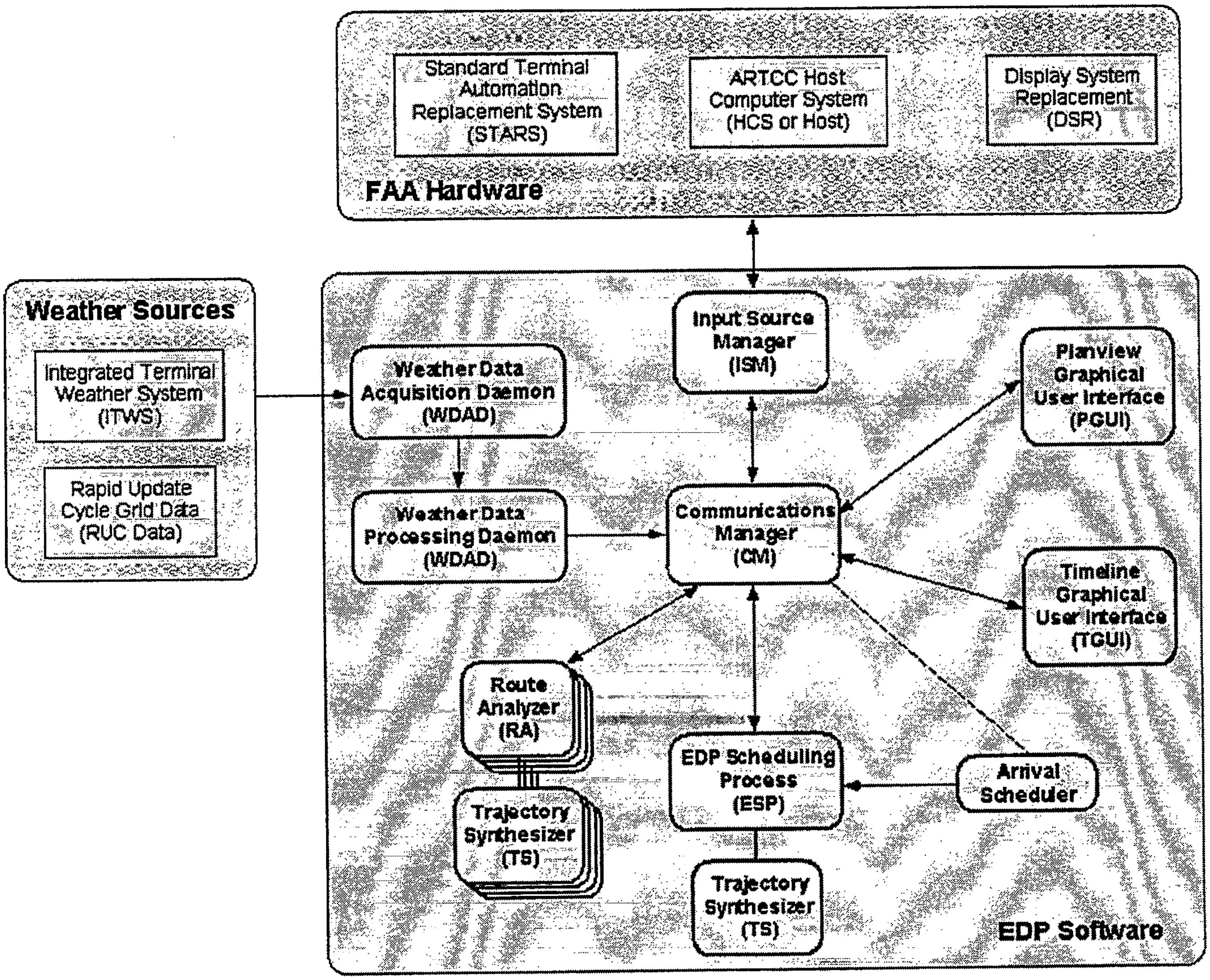

Figure 2.2.1 EDP Software Architecture.

2.3 HARDWARE CONFIGURATION

The EDP system is resident on a network of UNIX workstations. Each software module executes as a separate UNIX process, which may be run on separate workstations, or on a single machine (e.g., WDPD and WDAD). Furthermore, the number of RA/TS processes is scalable to meet the computational requirements of the traffic load although each pair must execute on a dedicated workstation. External interfaces (Section 4.1) are handled by the CM and by the ISM.

2.4 COMPUTER HUMAN INTERFACE (CHI) DESCRIPTION

EDP advisory information for controllers in the TRACON and ARTCC will be displayed on the Standard Terminal Automation Replacement System (STARS) and Display System Replacement (DSR) displays, respectively. An example of the display is shown in Figure 2.4.1. Controller inputs will be made through the STARS/DSR message entry devices. Although much of the CHI requirement discovery has yet to take place, the notion is that the EDP advisories will be displayed in the full data blocks with associated symbology to indicate where the advisory should either be issued or implemented. It is likely that color will be used either for the advisory, for an indicator of when to issue the advisory, or both. During the CTAS Build 2 requirement definition process, the TGUI CHI requirements were extensively documented. The Build 2 CHI Requirements Document (1) provides an excellent starting point for the display of EDP advisories in the TMU. CHI issues surrounding the display of controller advisories in the STARS and DSR environment still need to be explored.

The evaluation of EDP functionality will be affected by the usability of EDP advisories. Consequently, the basic CHI requirements of the proposed EDP advisories must be defined first. A series of simulations involving air traffic controllers will be used to determine these requirements. The simulations are designed to evaluate aspects of the EDP advisories in an incremental manner. Three phases of simulations will study advisory characteristics, advisory implementation, and advisory presentation.

The first phase will focus on the physical characteristics of the advisories. The preliminary color and advisory formats will be presented to air traffic controllers, assessed and modified, until they meet controller acceptance. This phase will be conducted using static presentations and Visual Basic mock-ups of simple moving data tags.

The second phase will focus on the implementation of the advisories. The placement of the advisory, the timing of the display, the timesharing features, and the priority of the advisories will be varied, assessed, and modified until they meet controller acceptance. This phase will consist of scripted scenarios in a "shadowing" mode. The scripted scenarios will be generated from live traffic or PAS (Pseudo Aircraft Systems) generated simulations, so that the traffic will appear realistic. Actual data will be used to script the degree of turn, speed, or altitude clearance for the advisories. These advisories will then be displayed to controllers on the Planview Graphical User Interface (PGUI), a given distance/time prior to the point at which the aircraft changes speed, heading, or altitude. Therefore, the controller will not be actively controlling aircraft, but will perform handoffs for aircraft entering and exiting the sector. The controller will be asked to acknowledge the onset of an advisory, and specify the point at which the advisory would be issued to the aircraft. Reaction-time will be measured for both of these events. This will allow data collection and feedback on the format and timing of advisories under varying traffic conditions, as well as to determine initial limits on traffic complexity and clutter. The color and format of the advisories will also be re-visited in this phase, evaluating these issues under traffic control conditions.

The third phase will incorporate the EDP algorithms to investigate the simultaneous presentation of multiple advisories, to evaluate limits on the number and types of advisories that can be presented. Issues of advisory adherence, the effects of early, late, or missed advisories, as well as acceptance of the system as defined in the first two phases will be investigated.

Once the physical characteristics of the EDP advisories are determined, the procedural implications must be addressed. Since the advisories may be displayed to controllers in several facilities, communication and coordination issues are significant. Controllers, traffic managers, and human factors engineers must work together to solve these issues. The EDP information displayed on a TGUI to TMCs may also be evaluated at this stage.

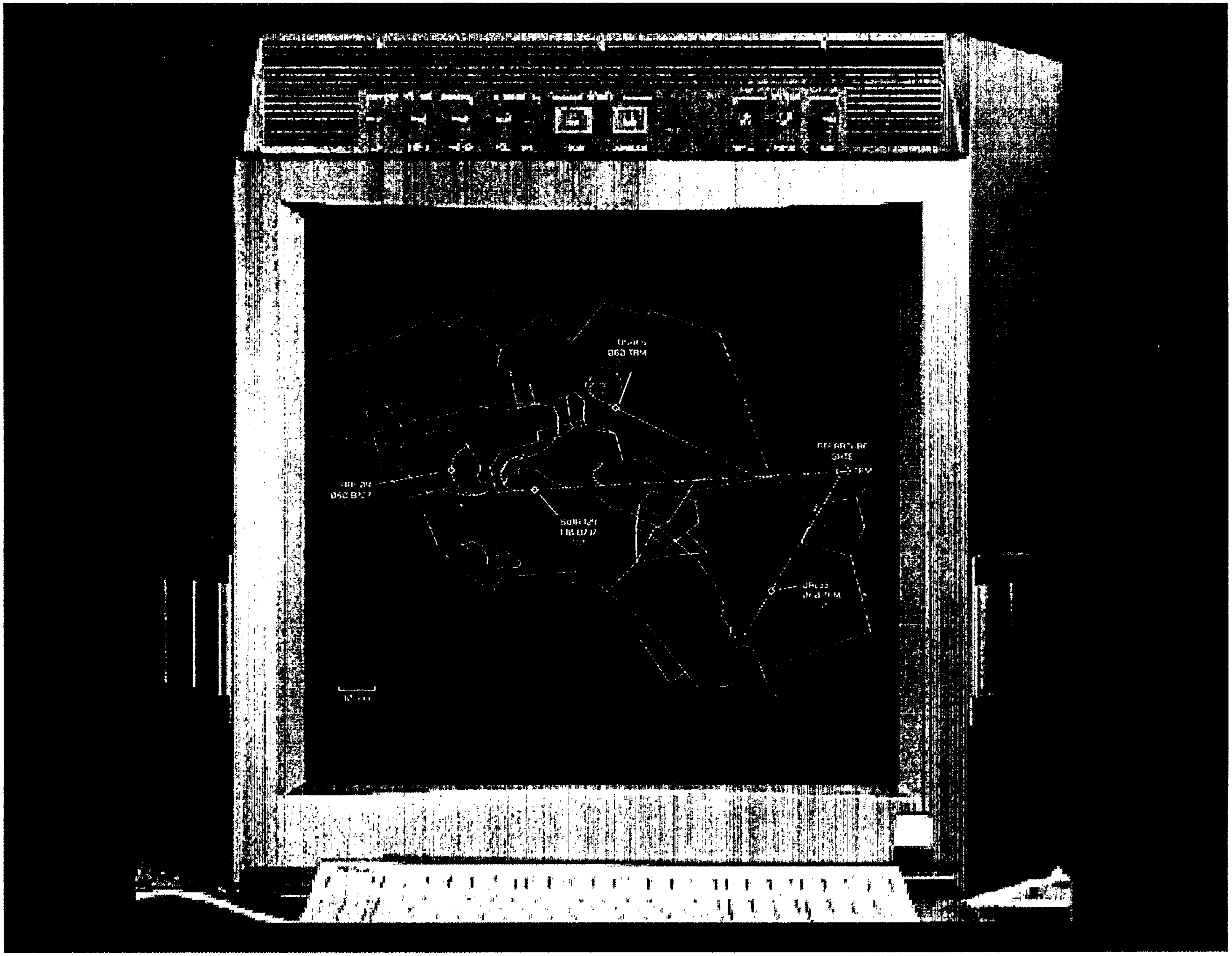

Figure 2.4.1. EDP Controller Display.

3. OPERATIONAL SCENARIOS

In the current operational environment, there is only a minimal set of automation tools to assist air traffic controllers. The most advanced automation for controllers includes PlanView Displays (PVDs) in the ARTCCs and Full Digital ARTS Displays (FDADs) in the TRACONs (though the majority of TRACONs have even earlier generation displays). These displays are monochrome, and have very limited capabilities. As a result, controllers are forced to rely primarily on their mental skills to solve the complex problems presented to them. While controllers have always done an excellent job with these complexities, some situations are beyond the scope of their informational awareness. Incomplete information creates a setting where controllers tend to be conservative. This conservatism includes restricting aircraft from airspace boundaries and perceived traffic, even where there is no actual conflicting traffic. The lack of information creates situations where controllers do not know what is happening in adjacent facilities. In these cases, lack of information leads to inefficiencies.

Once an aircraft is airborne, a radar tracking system acquires the target and a transponder is interrogated. This information is processed by the ARTS computer system, and information associated with the aircraft (aircraft identification, aircraft type, position, altitude, speed, etc.) is displayed to the controller in the form of a Full Data Block (FDB) on an FDAD or PVD. This information is the basis for the controller's decisions. When a controller sees a departure aircraft's FDB, decisions are made based on current procedures. The decisions are also based upon any FDBs associated with potentially conflicting traffic. If, for example, the procedural route of a departure will intersect the procedural route of arrival aircraft, the controller will scan the arrival route backward from the intersection point to assess potential conflicts. In this manner, the controller mentally calculates when attention will need to be devoted to resolve this potential conflict. As the departure aircraft progresses toward the intersection point, the controller attention becomes more focused on the potential conflict. Generally, these aircraft are procedurally separated by altitude, restricting departures below arrivals until there is no risk of conflict.

Another operational situation involves merging departures. This occurs most frequently in the form of merging over a fix, but occasionally takes the form of sequencing through a gate. When aircraft are sequenced in this manner there is often a lack of shared information between controllers. For example, when aircraft are merging over a fix, there may be several controllers working numerous departures, all bound for the same fix. In this case, there is little or no information shared between the controllers. The aircraft are procedurally separated by altitude and must eventually be merged into a single stream at the same altitude by the controller who works the airspace beyond the departure fix. To help achieve this goal, while reducing controller workload, a miles-in-trail constraint for aircraft bound for the departure fix is often levied on the departure controllers. In the case of sequencing departures through a gate, miles-in-trail restrictions are also the norm.

EDP is designed to provide advisory information to minimize the inefficiencies as aircraft transition into the en route system. Controllers are presented with advisories based upon a more complete picture of the air traffic control system. These advisories will likely be presented in the FDB. Operational fielding of EDP assumes that STARS will be available; thus allowing color to be used in the FDB.

Once an aircraft is airborne, EDP advisories will be generated and displayed to controllers. Altitude advisories will indicate the highest useable altitude for each departure, based upon procedural constraints and conflicting traffic. The calculation of traffic conflicts will be based upon EDP trajectory predictions for the departures and potentially conflicting arrivals. Speed and heading advisories will indicate the optimal path and speed for sequencing departures over a fix or through a gate. The calculations will be based upon trajectory predictions for each of the departures relevant to the sequence. EDP information will also be displayed in the TRACON and ARTCC TMUs. In addition to advisory information displayed on the PGUIs, TMCs can view timelines indicating when the departures will cross various fixes.

There are three categories of operational uses for EDP. The first category is Climb Advisories. Climb advisories are presented to controllers only when altitude restrictions are required. The second category is Merging Over a Fix. Advisories are presented to controllers in order to optimize en route spacing over a fix. The third category is Merging Into the En Route Stream. The primary difference between the second and third category is that these advisories are associated with vectoring aircraft through a gate, instead of over a fix.

3.1 CLIMB ADVISORIES

There are numerous cases where EDP climb advisories can provide benefits in the operational environment. Many major TRACONs have operational procedures where departures are restricted below arrivals. Often this occurs because there is an intersection between an arrival route and a departure route close to the airport. In these cases, the departure is often restricted below the arrival path until there is an assurance that no conflict exists. Figures 3.1.1.1, 3.1.1.2, 3.1.1.3, 3.1.1.4, 3.1.2.1, 3.1.2.2, 3.1.2.3, and 3.1.2.4 show scenarios describing current operational practices contrasted with situations where EDP climb advisories will improve efficiency.

3.1.1 Restricted Climbs Due to Traffic

The first operational scenario shows a departure from Los Angeles International Airport (LAX) and an arrival to LAX. Figure 3.1.1.1 shows the departure (AAL123) climbing westbound out of 2,000 Mean Sea Level (MSL). The FDB associated with AAL123 shows that the aircraft is climbing out of 2,000 MSL at a speed of 210 knots (the "T" denotes collision avoidance equipage). The second visible line of the FDB timeshares showing that AAL123 is a B757 on a Gorman (GMN) departure. The nominal route of this aircraft is to fly westbound until abeam of BAYST intersection and then turn northbound on course so as to fly approximately 3 miles west of BAYST. Arrivals to LAX from Fillmore VORTAC (FIM) fly a route that intersects a radial from Santa Monica VORTAC (SMO) and proceed eastbound through BAYST. These aircraft must stay at or above 10,000 MSL until passing BAYST, then begin a descent for LAX. The aircraft inbound to LAX (UAL1708) is assigned an altitude of 10,000 MSL. The FDB associated with UAL1708 shows that the aircraft is descending out of 13,200 MSL at a speed of 230 knots. UAL1708 is a B737 assigned to Runway 25L. These 2 routes intersect just west of BAYST, and in today's environment, the controller restricts AAL123 to 9,000 MSL until there is clearly no conflict between the two aircraft. Often altitude restrictions are warranted, as the aircraft trajectories would otherwise be in conflict. When aircraft are far apart, controllers do not generally anticipate that the departure will cross behind or out climb the arrival. The consequences of an error are too great.

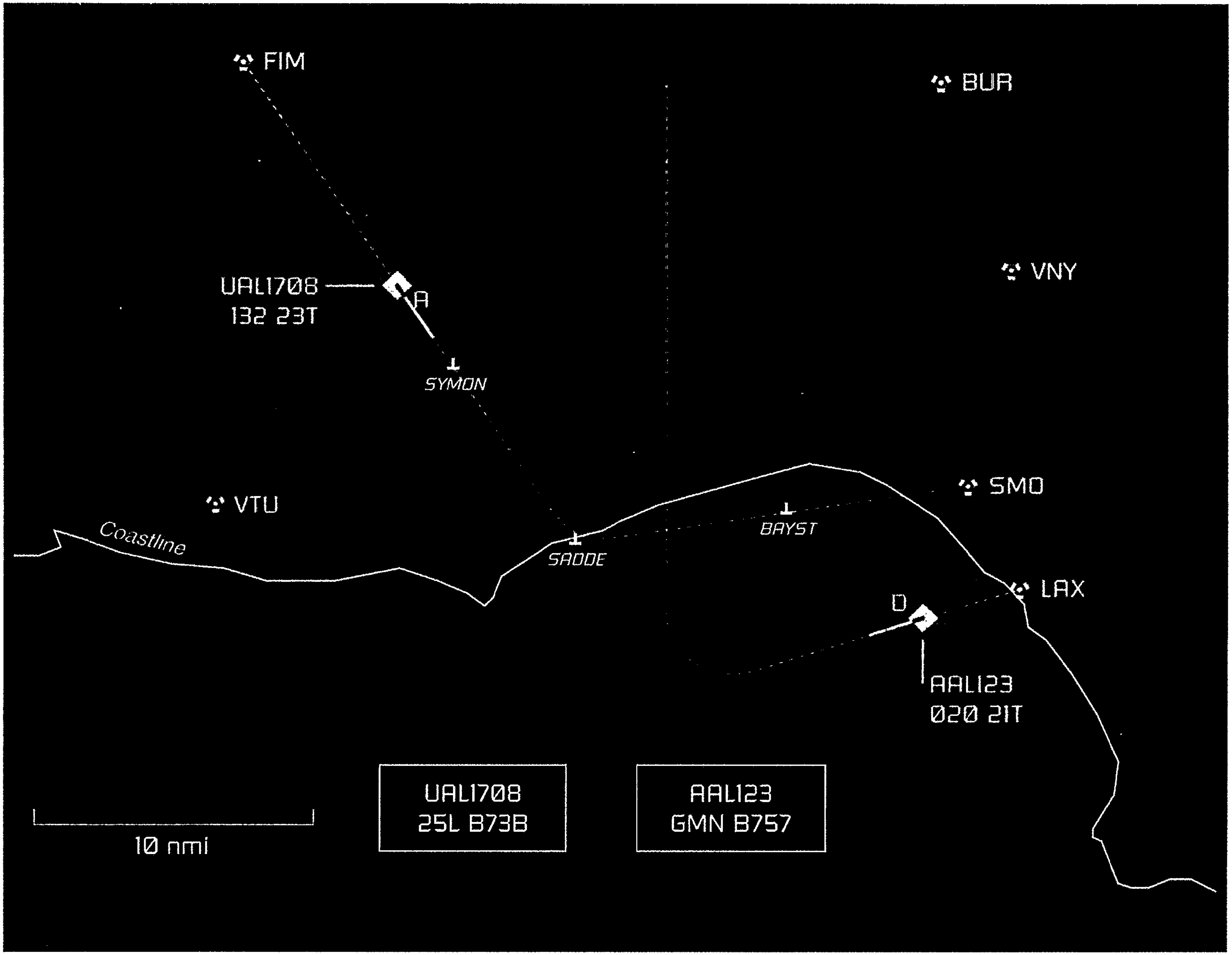

Figure 3.1.1.1. Restricted Climbs Due to Traffic #1.

Figure 3.1.1.2 shows how the aircraft converge in the vicinity of BAYST. AAL123 has leveled of at 9,000 MSL and UAL1708 has leveled off at 10,000 MSL. After the courses of the two aircraft begin to diverge, AAL123 can be safely climbed, and UAL1708 can be safely descended. In this case, the aircraft pass within 3 miles laterally, requiring the use of altitude separation. In today's environment, controllers generally choose to restrict the departure below the arrival. This is primarily due to a lack of information regarding the ascent trajectory associated with the specific departure aircraft. Even if the controller thinks that the departure might out climb the arrival, there is a tendency to be conservative and restrict the departure in order to ensure separation. This is even more pronounced when the arrival is descending from a higher altitude to level off at the restricted altitude.

Figure 3.1.1.3 shows the departure from LAX (AAL544) climbing westbound out of 2,000 MSL. The first visible line of the FDB associated with AAL544 shows that the aircraft is climbing out of 2,000 MSL at a speed of 210 knots. The second line of the FDB timeshares showing that AAL544 is a B737 on a GMN departure. The two inbound aircraft inbound to LAX (UAL1708 and SWA210) are descending to an altitude of 10,000 MSL. The FDB associated with UAL1708 shows the aircraft descending out of 11,700 MSL at a speed of 230 knots. The FDB associated with SWA210 shows that the aircraft is descending out of 13,700 MSL at a speed of 230 knots. UAL1708 is a B737 assigned to Runway 25L, and SWA210 is a B737 assigned to 24R.

Figure 3.1.1.4 shows how the aircraft converge in the vicinity of BAYST. AAL544 has leveled of at 9,000 MSL, UAL1708 has leveled off at 10,000 MSL, and SWA210 is descending out of 11,700 MSL. In this case, AAL544 is not within 3 miles of either UAL1708 or SWA210. In fact, AAL544 is separated from the arrivals by more than 5 miles. When the departure controller first observed AAL544, it was not visibly clear that AAL544, UAL1708, and SWA210 were not potential conflicts. As a result, altitude separation was maintained.

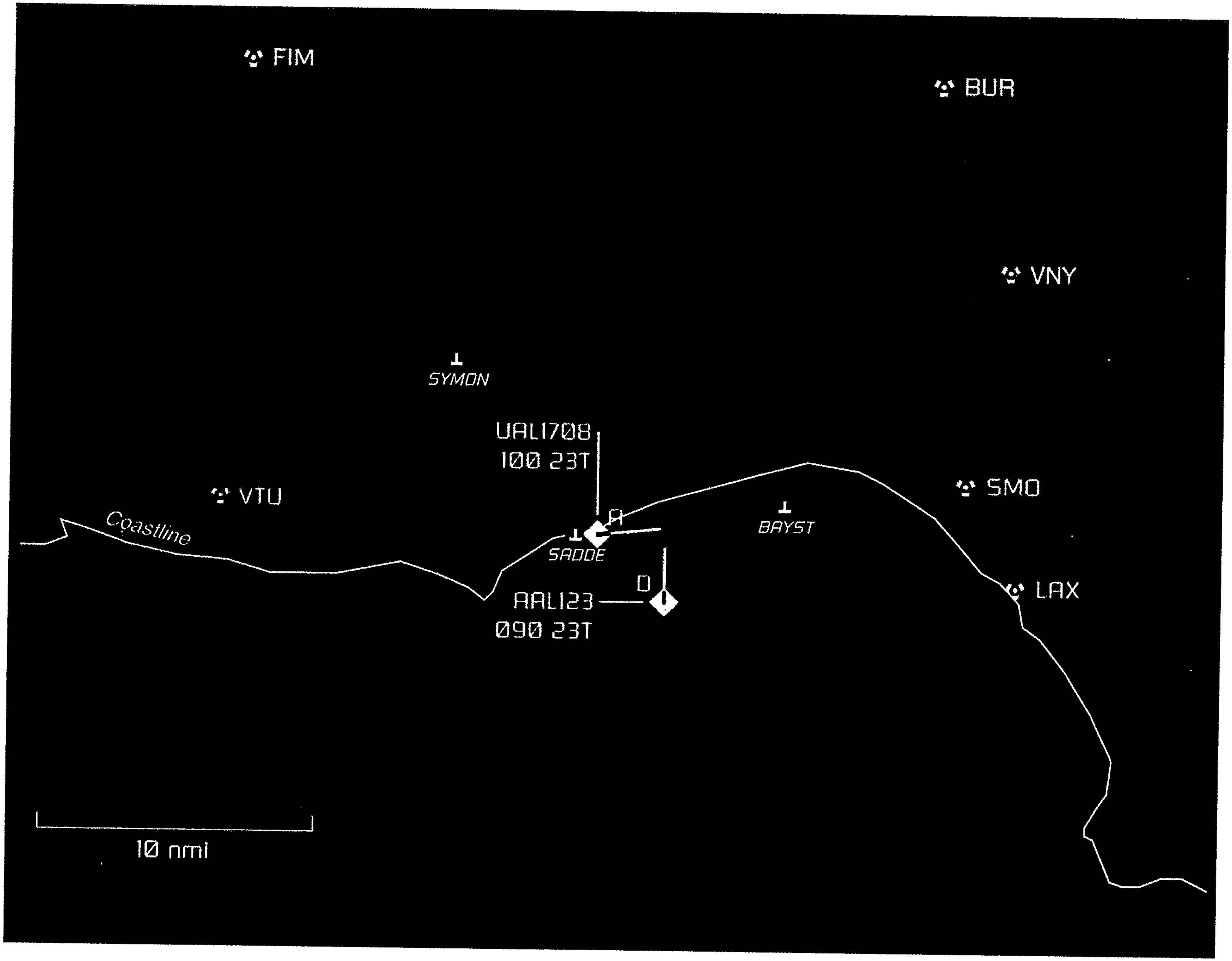

Figure 3.1.1.2. Restricted Climbs Due to Traffic #2.

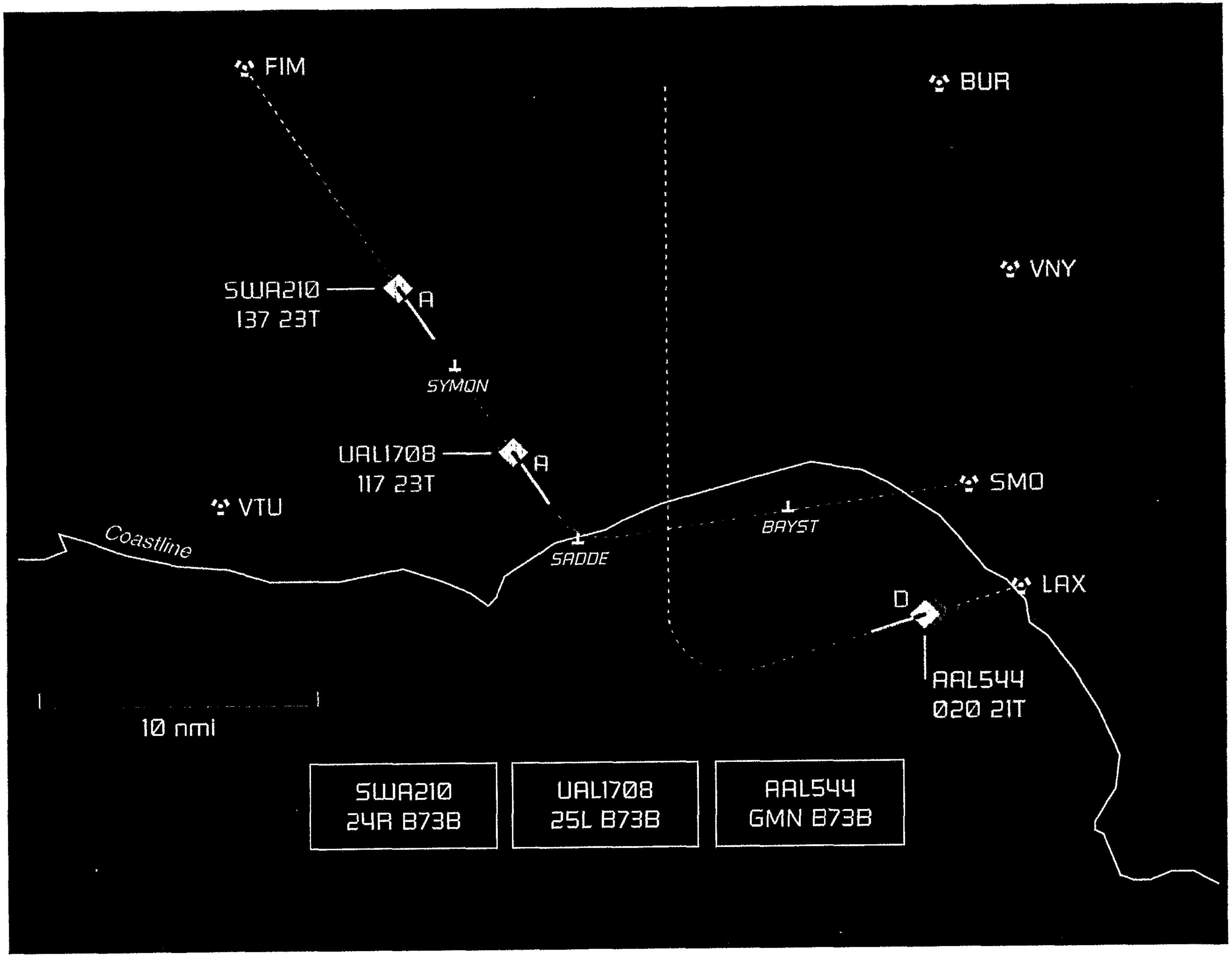

Figure 3.1.1.3. Restricted Climbs Due to Traffic #3.

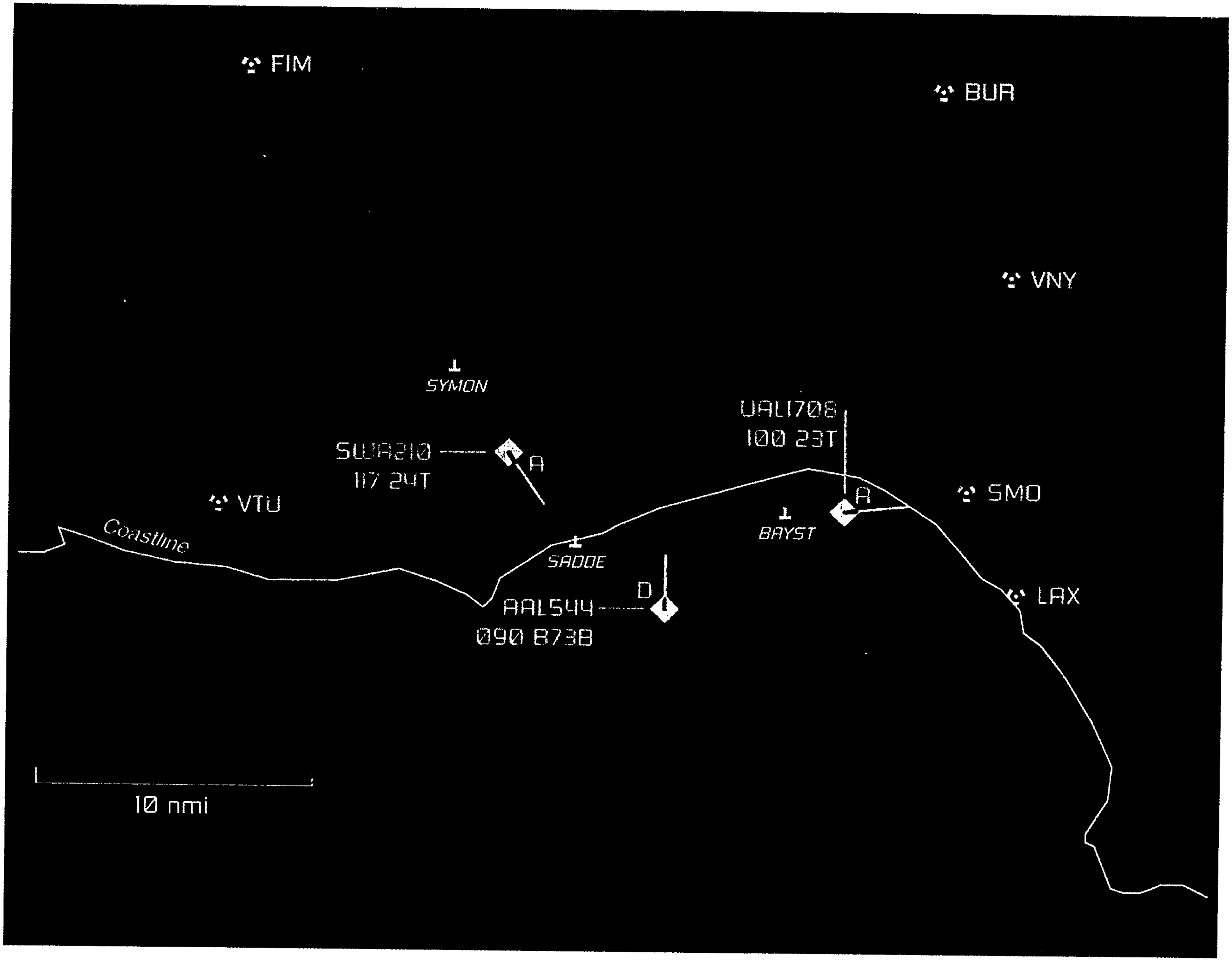

Figure 3.1.1.4. Restricted Climbs Due to Traffic #4.

3.1.2 Unrestricted Climbs

Figure 3.1.2.1 shows an aircraft (AAL123) departing from LAX, climbing westbound out of 2,000 MSL. The FDB associated with AAL123 shows that the aircraft is climbing out of 2,000 MSL at a speed of 210 knots. The second visible line of the FDB timeshares showing that AAL123 is a B757 on a GMN departure. The third visible line of the FDB shows an EDP advisory recommending a climb to FL230. The aircraft inbound to LAX (UAL1708) is level at 10,000 MSL. The FDB associated with UAL1708 shows that the aircraft is level at 10,000 MSL, flying at a speed of 230 knots. UAL1708 is a B737 assigned to Runway 25L.

Figure 3.1.2.2 shows the aircraft at a later time, in the vicinity of BAYST. AAL123 is climbing through 13,000 bound for FL230, and UAL1708 has leveled off at 10,000 MSL. UAL1708 is no longer a factor for AAL123. To generate the climb advisory, EDP calculated that, based on the ascent and descent profiles of the two aircraft, AAL123 would be able to "top" UAL1708 prior to the merge point. As a result, the controller has "expedited" the climb of AAL123 into the en route system.

Figure 3.1.2.3 shows the departure off LAX (AAL544) climbing westbound out of 2,000 MSL. The FDB associated with AAL544 shows that the aircraft is climbing out of 2,000 MSL at a speed of 210 knots. The second visible line of the FDB timeshares showing that AAL544 is a B737 on a GMN departure. The third visible line of the FDB shows an EDP advisory recommending a climb to FL230. The two aircraft inbound to LAX (UAL1708 and SWA210) are descending to 10,000 MSL. The FDB associated with UAL1708 shows that this aircraft is descending out of 11,700. The FDB associated with SWA210 shows that this aircraft is descending out of 13,700 MSL. Both are at a speed of 230 knots. UAL1708 is a B737 assigned to Runway 25L, and SWA210 is a B737 assigned to 24R.

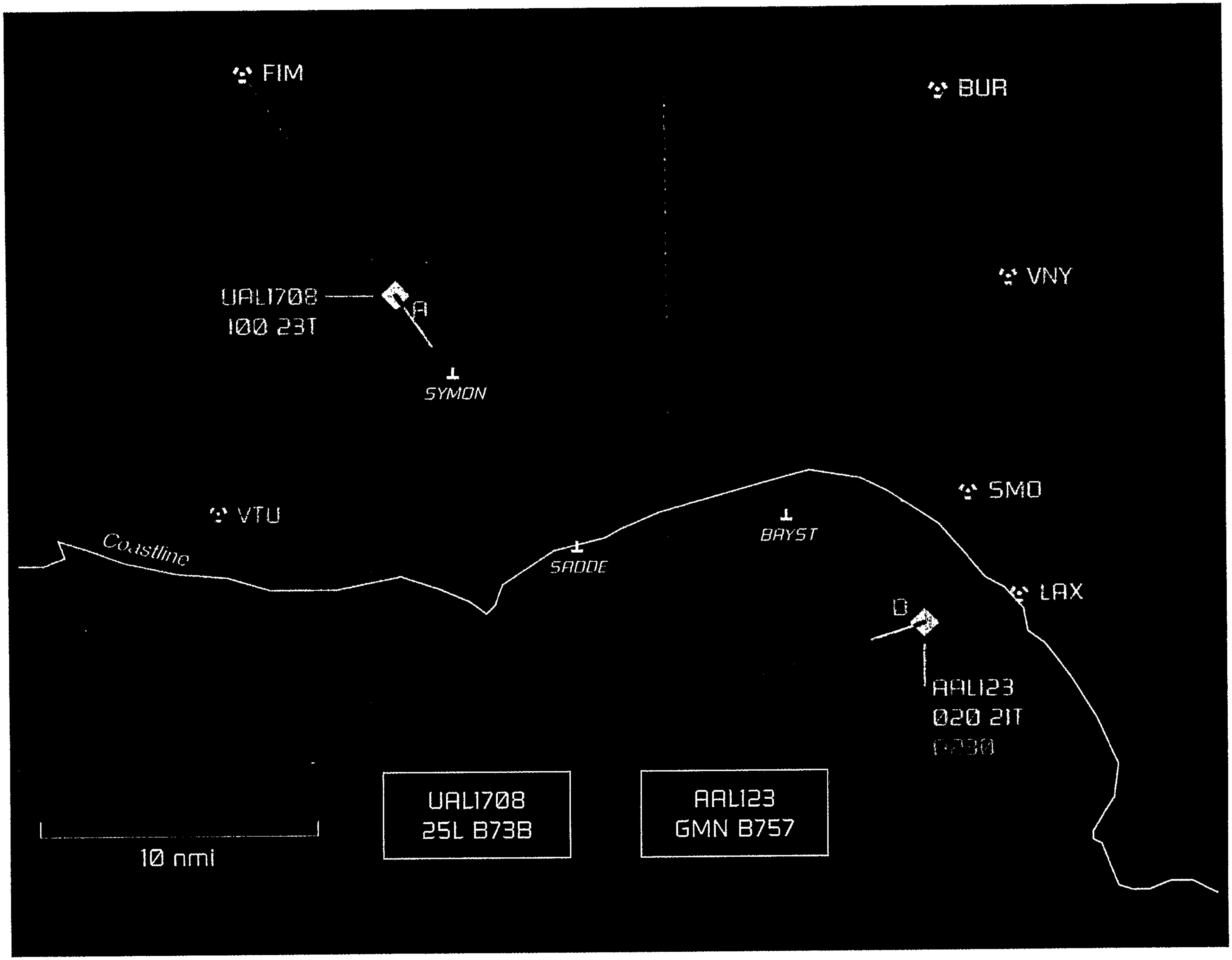

Figure 3.1.2.1. Unrestricted Climbs #1.

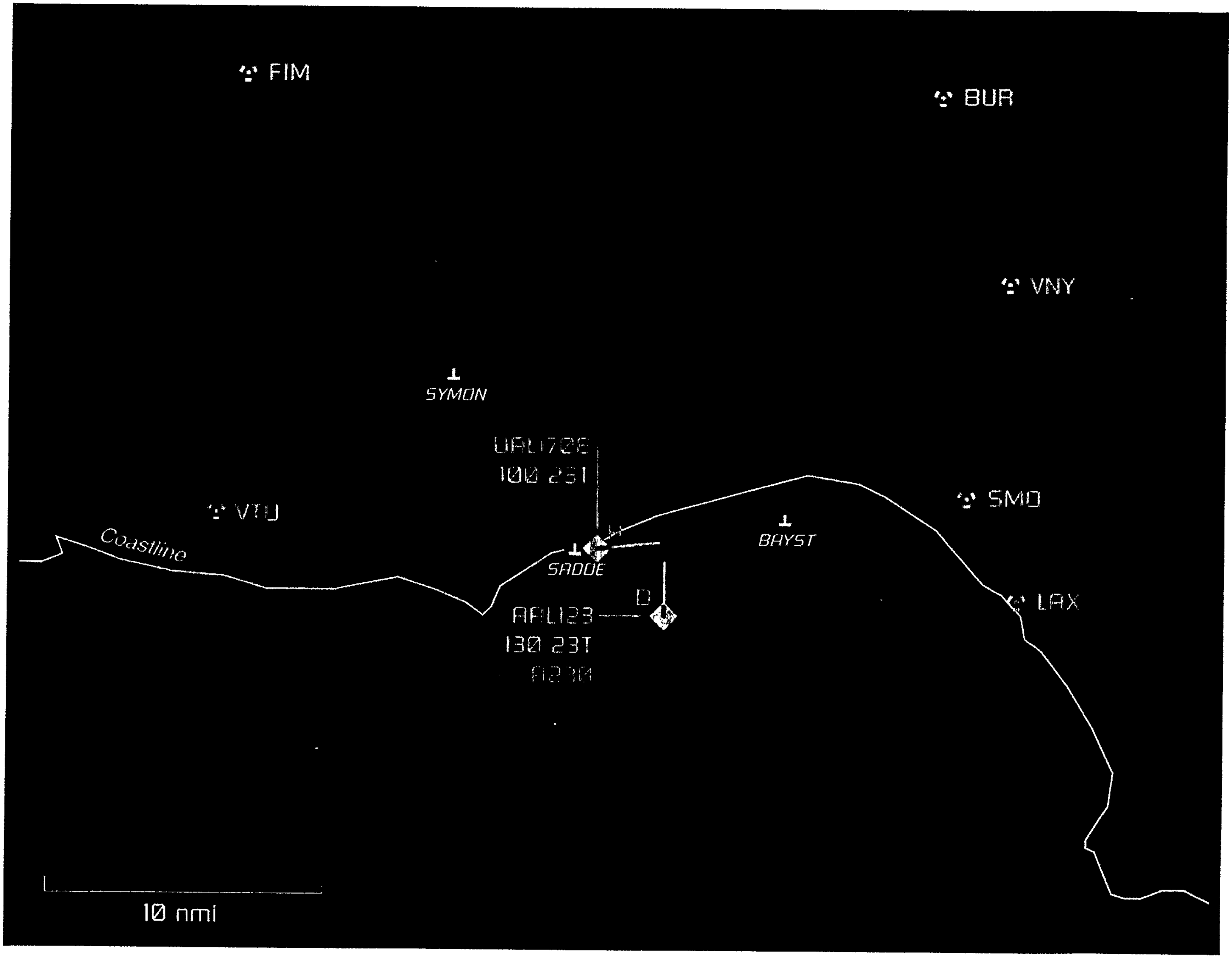

Figure 3.1.2.2. Unrestricted Climbs #2.

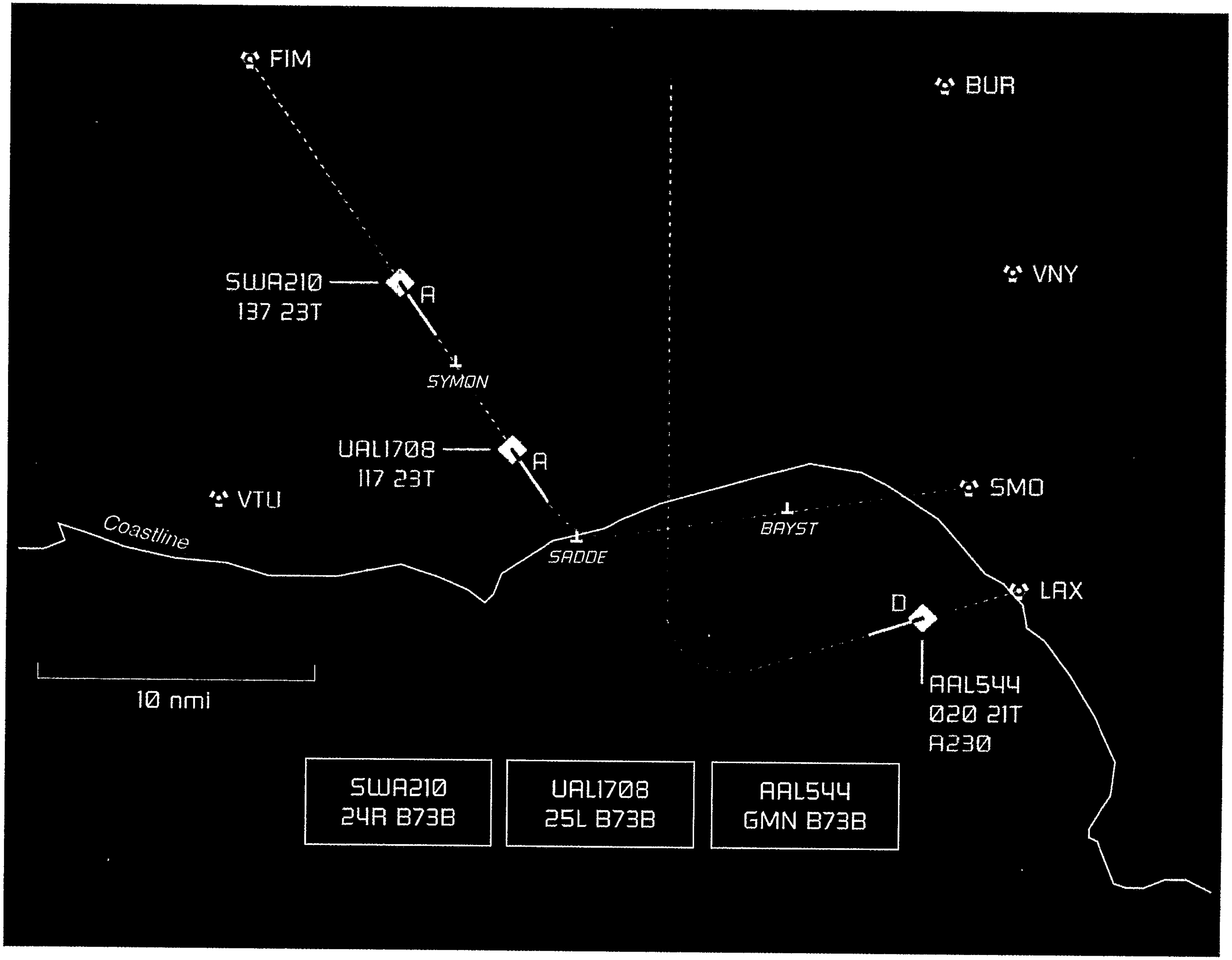

Figure 3.1.2.3. Unrestricted Climbs #3.

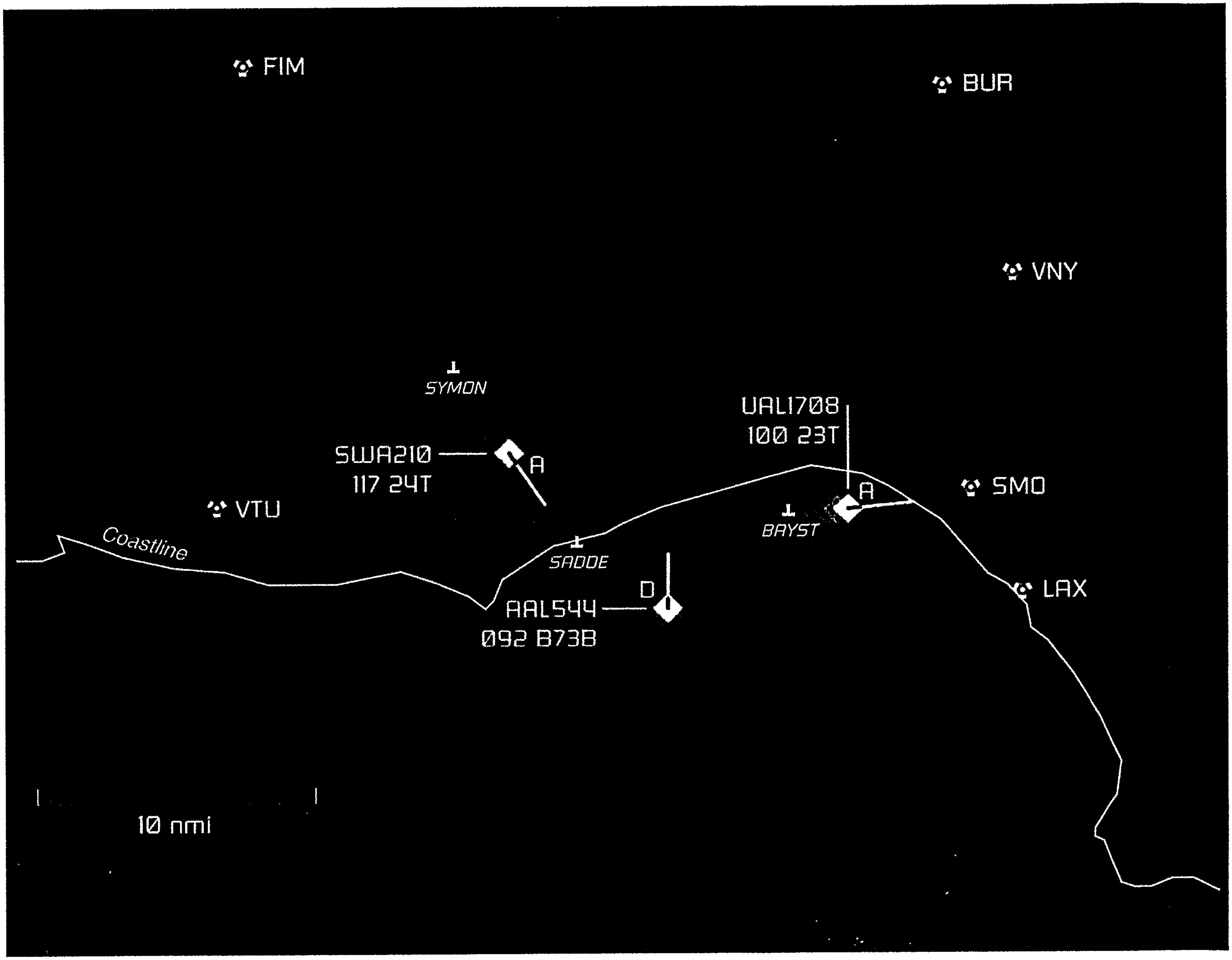

Figure 3.1.2.4. Unrestricted Climbs #4.

3.2 MERGING OVER A FIX

It is common in the existing operational environment for numerous controllers to be working different aircraft bound for the same fix. Today, these aircraft are restricted by altitude, to ensure separation at the airspace boundary. Moreover, departure controllers are often required to space their departures using miles-in-trail constraints. This is done to provide gaps in the stream, allowing for potential merges. For example, if there are two departure routes being merged into one en route stream, 20 miles in trail from the two departure routes should allow for 10 miles in trail along the en route stream. No attempt is made to sequence or space the traffic on an aircraft by aircraft basis. This creates situations where one departure route may be empty, while the other is unnecessarily constrained. Even with these potential inefficiencies there are still cases where aircraft from multiple departure controllers arrive over the en route at the same time. For example, two aircraft may arrive from the departure routes (separated by altitude) followed by a 20 mile gap and then two more aircraft. This causes additional workload on the controller trying to sequence and space the aircraft beyond the fix, which often leads to additional miles-in-trail constraints.

EDP advisories are designed to reduce these inefficiencies. Speed and vector advisories allow for departure aircraft to be sequenced and spaced laterally allowing for a smooth transition into the en route system. EDP calculates and compares the trajectories for each departure aircraft bound for the fix. The EDP algorithm then generates a solution whereby speed and vector changes enacted prior to crossing the fix sequences and spaces the traffic as close to the desired result as feasible. Speed and vector commands are generally sufficient degrees of control to ensure minimum separation. Where additional controllability is required, EDP also generates an altitude advisory to ensure safety.

Figures 3.2.1.1, 3.2.1.2, 3.2.2.1, 3.2.2.2, 3.2.3.1, and 3.2.3.2 contrast scenarios describing current operational practices with situations in which EDP speed and vector advisories would improve efficiency.

3.2.1 Merging Over a Fix without EDP

Figure 3.2.1.1 shows 4 aircraft bound for the Thermal (TRM) departure fix. UAL33 is a departure from San Diego (SAN) climbing out of 2,000 MSL at a speed of 220 knots. UAL33 is being climbed to 17,000 MSL. USA66 is a departure from Ontario (ONT) climbing out of 3,000 MSL. USA66 is being climbed to 17,000 MSL. SWA424 is a departure from LAX climbing out of 10,000 MSL. SWA424 is being climbed to 17,000 MSL. AAL104 is a departure from LAX climbing out of 2,000 MSL. AAL104 is being climbed to 17,000 MSL. The departure controller working SWA424 and AAL104 is required to provide 20 miles-in-trail on the aircraft bound for TRM. These aircraft are procedurally separated by altitude, and the miles-in-trail restrictions are the only lateral constraints.

Figure 3.2.1.2 shows these aircraft at a later time, merging at TRM. UAL33, USA66, and SWA424 are all within 5 miles of each other, and AAL104 is 20 miles behind SWA424. Since altitude separation was applied, the aircraft are safely separated. The inefficiencies of this realistic scenario are obvious. SWA424 has been trapped below UAL33, and forced to level at 16,000 MSL. SWA424 will not be able to climb until UAL33 has pulled at least 5 miles ahead, which will be accomplished by restricting the speed of SWA424. Furthermore, USA66 is trapped below SWA424 at 15,000 MSL. USA66 will not be allowed to climb until SWA424 has slowed sufficiently to climb behind UAL33. USA66 must also be slowed so that it will be safely behind SWA424 when it is allowed to climb. Finally, AAL104 is 20 miles behind SWA424. This gap is excessive. EDP is designed to remedy some of these inefficiencies.

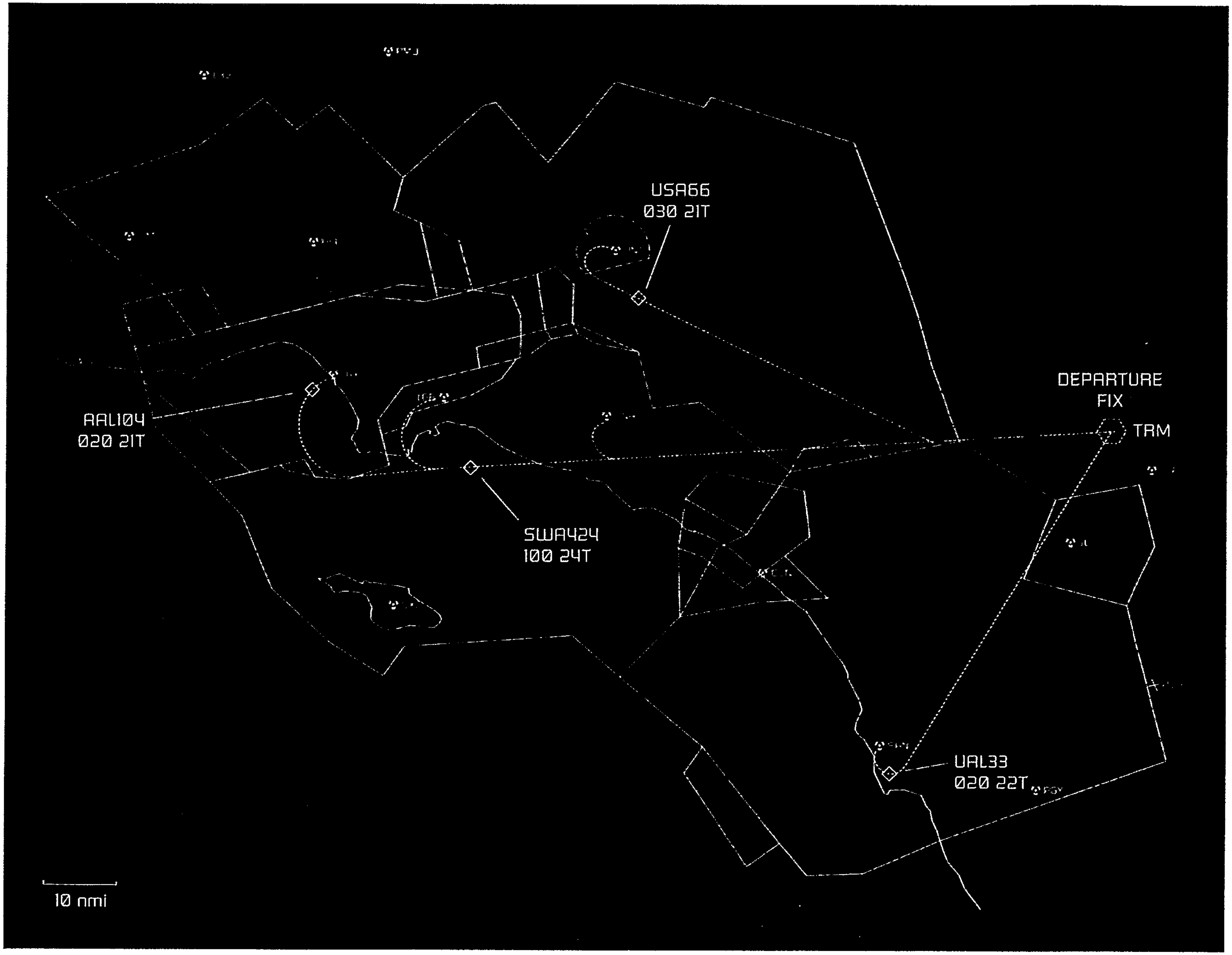

Figure 3.2.1.1. Merging Over a Fix without EDP #1.

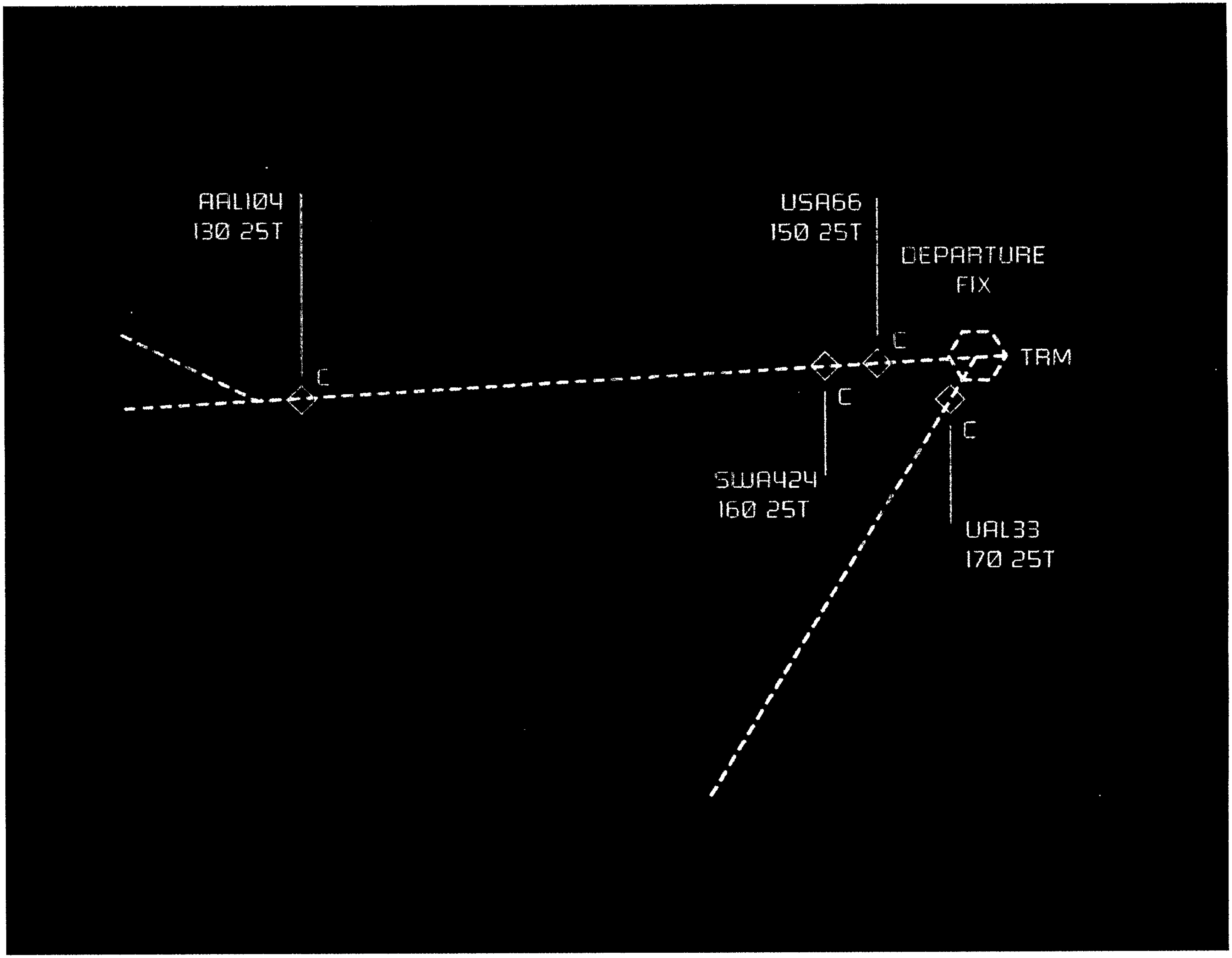

Figure 3.2.1.2. Merging Over a Fix without EDP #2.

3.2.2 Merging Over a Fix When Speed and Vector Advisories are Sufficient

Speed and heading advisories can assist controllers in sequencing aircraft over a fix. Figure 3.2.2.1 shows the same 4 aircraft (Figure 3.2.1.1) bound for the Thermal (TRM) departure fix. UAL33 is a departure from San Diego (SAN) climbing out of 2,000 MSL at a speed of 220 knots. In the third visible line of the FDB an EDP advisory has been displayed indicating that UAL33 should be issued a faster speed (280 knots), and climbed to 17,000 MSL. Since UAL33 is the first aircraft projected to cross TRM, this speed increase will alleviate some of the burden on the following aircraft. USA66 is a departure from Ontario (ONT) climbing out of 3,000 MSL. The EDP advisory in the third visible line of the FDB indicates a recommended climb speed of 230 knots and a recommended altitude of 17,000 MSL. The recommended speed will space USA66 at least 5 miles behind SWA424 allowing for an unrestricted climb.

SWA424 is a departure from LAX climbing out of 10,000 MSL. The EDP advisory in the third visible line of the FDB recommends a climb speed of 250 knots and a recommended altitude of 17,000 MSL. The recommended speed will sequence SWA424 between UAL33 and USA66. This lateral spacing also allows SWA424 to be climbed without restriction. AAL104 is a departure off LAX climbing out of 6,000 MSL. Since EDP provides a smoother flow into the en route system, it is anticipated that miles-in-trail restrictions will be minimized or eliminated. In this case, AAL104 is 5 miles behind SWA424. The third visible line of the FDB recommends a climb speed of 230 knots, and a heading of 140 degrees. This allows SWA424 to pull away slightly creating a gap for USA66 to fit in at 230 knots. When sufficient spacing has been established, EDP will generate an advisory for AAL104 to climb to 17,000 MSL and turn back on course.

Figure 3.2.2.2 shows how these aircraft would merge at TRM if EDP advisories were issued. All four aircraft are now spaced safely in trail at an appropriate altitude. When compared with Figure 3.2.1.2, this shows a clear improvement in terms of efficiency and workload.

3.2.3 Merging Over a Fix When Speed and Vector Advisories are Not Sufficient

There are operational instances in which (due to airspace constraints, traffic conflicts, and aircraft performance characteristics) speed and heading controls are not sufficient to safely space aircraft over a fix. In these instances, EDP will improve system performance by reducing controller workload and enhancing departure efficiency through the use of speed, heading, and altitude advisories. Altitude controls are generally considered to be a short-term solution, since the aircraft will ultimately need to be spaced in-trail along the route.

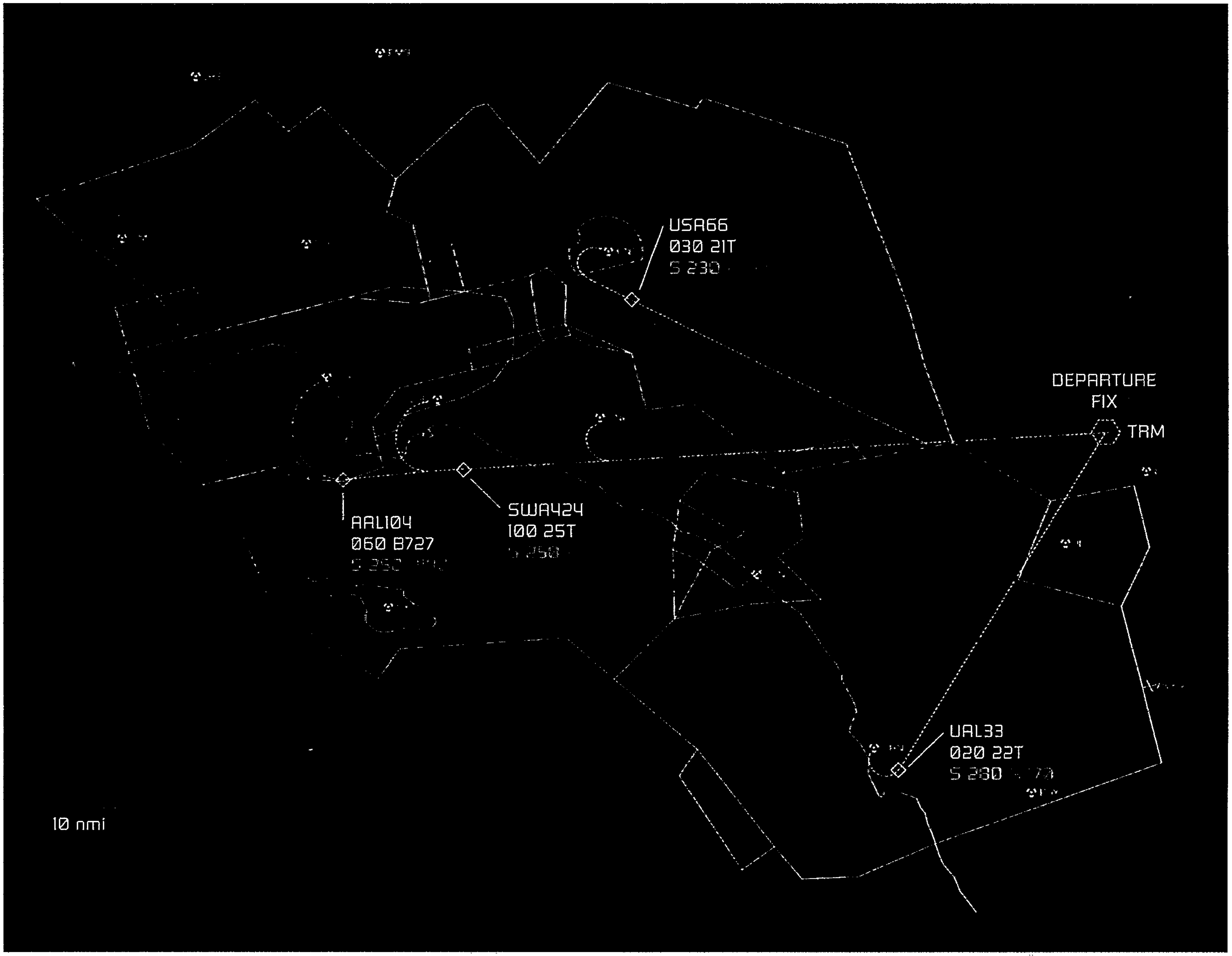

Figure 3.2.2.1. Merging Over a Fix When Speed and Vector Advisories are Sufficient #1.

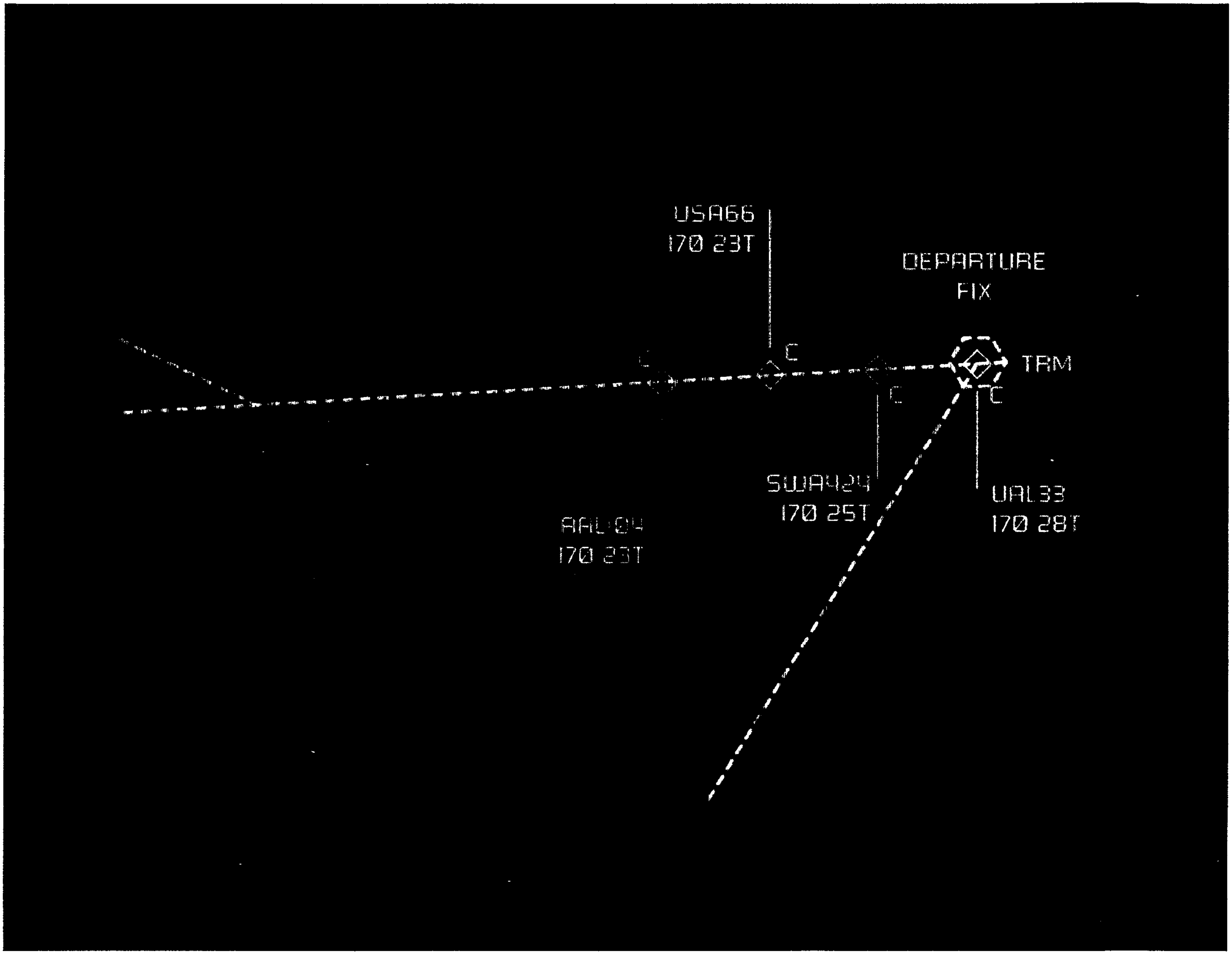

Figure 3.2.2.2. Merging Over a Fix When Speed and Vector Advisories are Sufficient #2.

Figure 3.2.3.1 shows the same 4 aircraft (Figure 3.2.2.1) bound for the Thermal (TRM) departure fix. UAL33 is a departure from San Diego (SAN) climbing out of 2,000 MSL at a speed of 220 knots. UAL33 is being climbed to 17,000 MSL. In the third visible line of the FDB an EDP advisory has been displayed indicating that UAL33 should be issued a speed of 250 knots. In this case, UAL33 is following another aircraft bound for TRM (not pictured), and 250 knots is the recommended speed to follow that aircraft. USA66 is a departure from Ontario (ONT) climbing out of 3,000 MSL. The EDP advisory in the third visible line of the FDB indicates a recommended climb speed of 230 knots, and an altitude restriction of 16,000 MSL. Since the recommended speed will not provide at least 5 miles behind SWA424, USA66 must be temporarily restricted below SWA424. SWA424 is a departure from LAX climbing out of 10,000 MSL. The EDP advisory in the third visible line of the FDB recommends a speed of 230 knots, and an altitude of 17,000 MSL. This speed will sequence SWA424 behind UAL33 and allow for an unrestricted climb. AAL104 is a departure from LAX climbing out of 6,000 MSL. The third visible line of the FDB recommends a climb speed of 230 knots, and a heading of 140 degrees. When sufficient spacing has been established, EDP will generate an advisory for AAL104 to climb to 15,000 MSL and turn back on course. Even though AAL104 will be at least 5 miles behind USA66, the altitude restriction is necessary to provide for flexibility when sequencing USA66 behind SWA424.

Figure 3.2.3.2 shows these aircraft at a later time, merging at TRM. The speeds of SWA424, USA66, and AAL104 have created sufficient separations along the route, so that all of the aircraft may safely climb at this time. Compared with Figure 3.2.1.2, the scenario that results from the EDP advisories is clearly an improvement in terms of efficiency and workload.

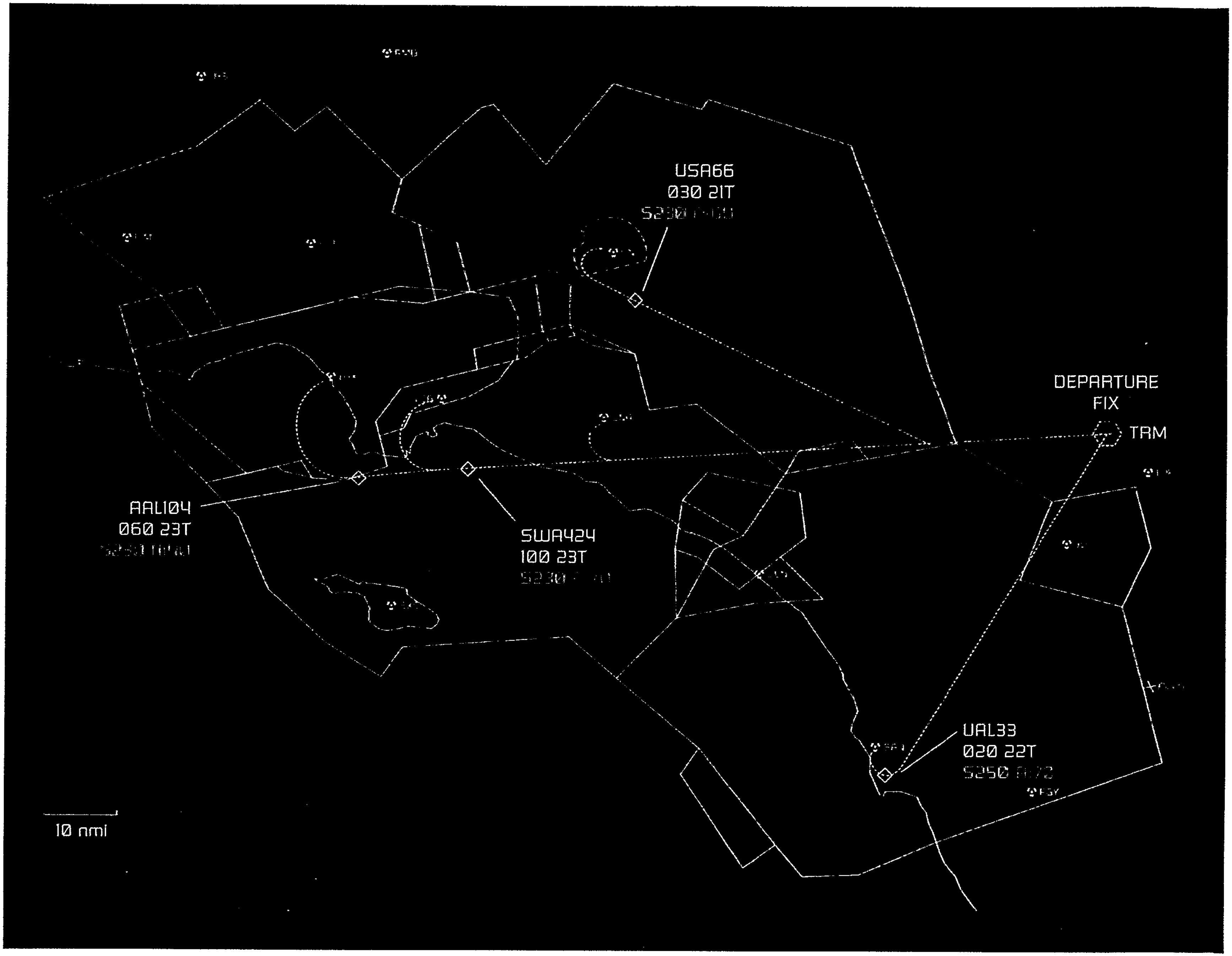

Figure 3.2.3.1. Merging Over a Fix When Speed and Vector Advisories are Not Sufficient #1.

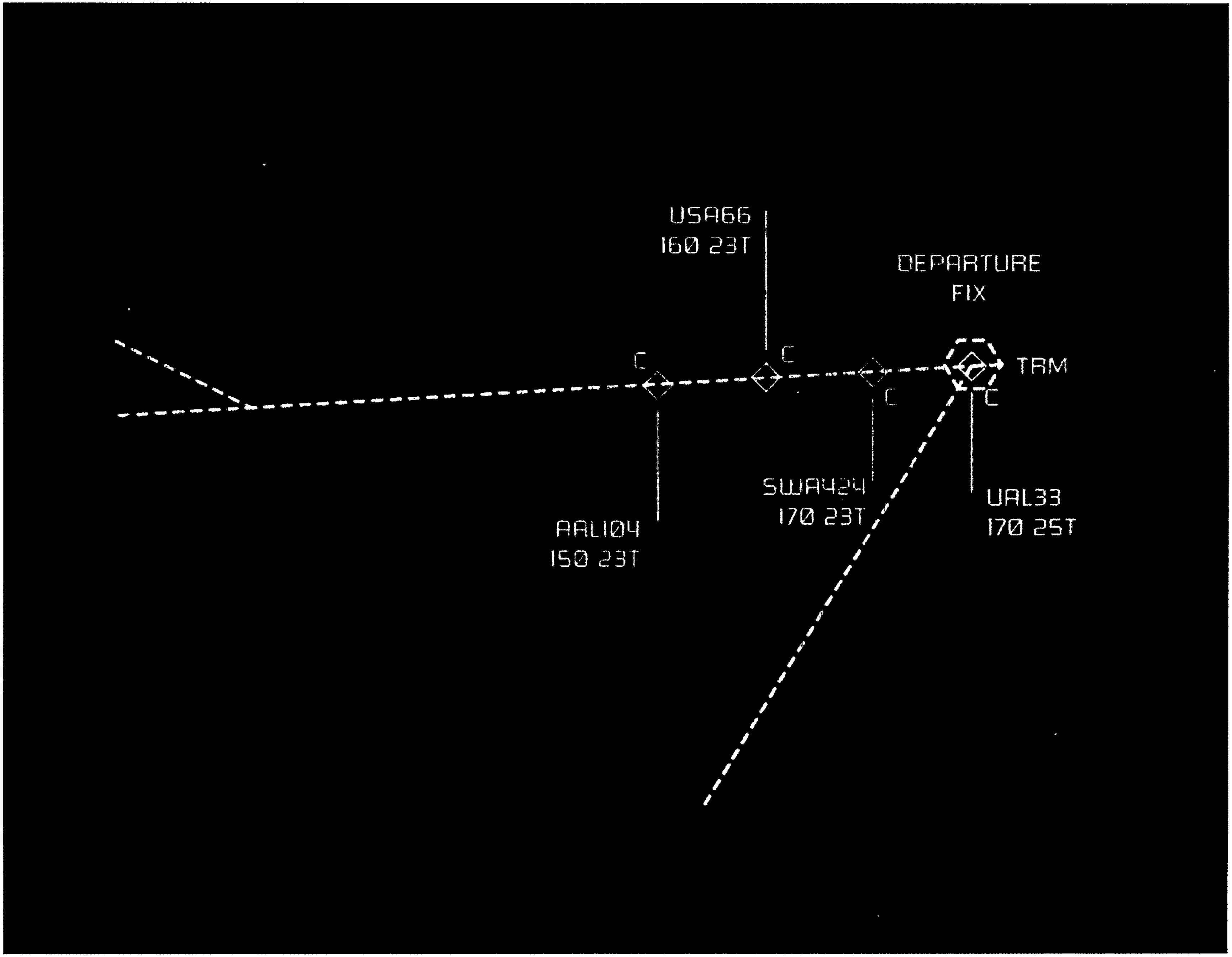

Figure 3.2.3.2. Merging Over a Fix When Speed and Vector Advisories are Not Sufficient #2.

3.3 MERGING INTO AN EN ROUTE STREAM

In the existing operational environment, there are situations where controllers vector departures through a departure gate. Since the departure gate is generally a 10-mile arc, controllers have more flexibility than routing aircraft over a departure fix. However, the aircraft must still be sequenced in-trail of one another, and the additional flexibility may actually create inefficiencies. When controllers are attempting to space aircraft out a departure gate, they typically provide miles-in-trail spacing based upon the arc that defines the gate. This creates situations where, for example, even though the second aircraft is spaced 10 miles away from the arc when the first aircraft passes it, the second aircraft may actually be more than 10 miles-in-trail of the first aircraft based on the angular distance. This distance is based upon the Cosine of the angle of displacement. Thus, the farther away from the en route stream, the greater the distance.

EDP advisories are designed to reduce this inefficiency. Speed and vector advisories allow for departure aircraft to be sequenced and spaced in trail of the aircraft that they will be following after merging, instead of the arc that defines the gate. Moreover, if the controller needs to issue numerous speeds and headings to achieve the prescribed spacing, EDP can also provide benefit by reducing controller workload. The precise calculations of the EDP advisories can reduce the number of clearances required to achieve the desired spacing or sequencing.

Another example of how EDP can enhance the current operational environment is when a departure must cross a fix at or above a specified altitude. The Loop Departure procedure at LAX and San Jose, for example, require aircraft to depart in one direction (westbound) and then turn back toward the airport and cross the VOR at the airport at or above a specified altitude. Although controllers have a general idea of the climb characteristics of each aircraft type, they can not accurately know the climb performance of individual aircraft. Consequently, controllers often turn the aircraft later than necessary, to be sure the aircraft can achieve the proper crossing altitude. This creates inefficiencies.

Figures 3.3.1.1, 3.3.1.2, 3.3.2.1, 3.3.2.2 contrast scenarios describing current operational practices contrasted with situations in which EDP speed and vector advisories will improve efficiency.

3.3.1 Merging Into an En Route Stream without EDP

Figure 3.3.1.1 shows 3 aircraft on the Loop departure from LAX. The nominal route for these aircraft is to depart LAX on a westbound heading, and then turn left and proceed back across LAX. These departures are required to cross LAX at or above 10,000 MSL. AWE100 is a B737 climbing out of 8,200 MSL, and is projected to cross LAX at approximately 12,300 MSL. NWA1204 is a B747 climbing out of 5,200 MSL, and is projected to cross LAX at approximately 11,200 MSL. UAL342 is a B757 climbing out of 2,000 MSL. Since this aircraft is still west bound, there is no projected crossing altitude.

Figure 3.3.1.2 shows the separation between these aircraft after they are established on a northeast bound heading. AWE100 crossed LAX at 12,300 MSL, and is now climbing out of 15,200 MSL. NWA1204 is 15 miles behind AWE100, and is crossing LAX at 11,200 MSL. UAL342 is 12 miles behind NWA1204, is climbing out of 5,800 MSL, and is projected to cross LAX at 11,800MSL.

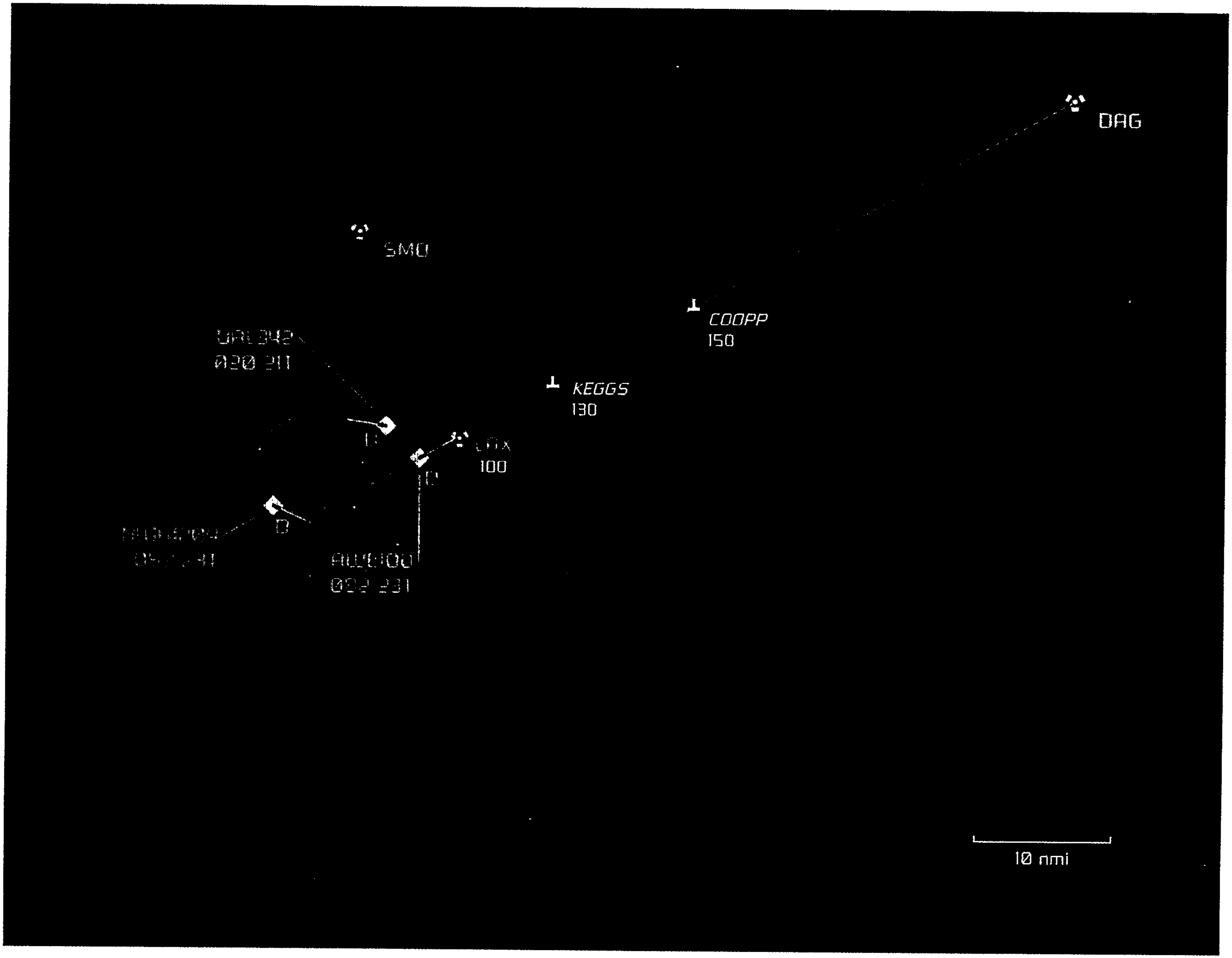

Figure 3.3.1.1. Merging into an En Route Stream without EDP #1.

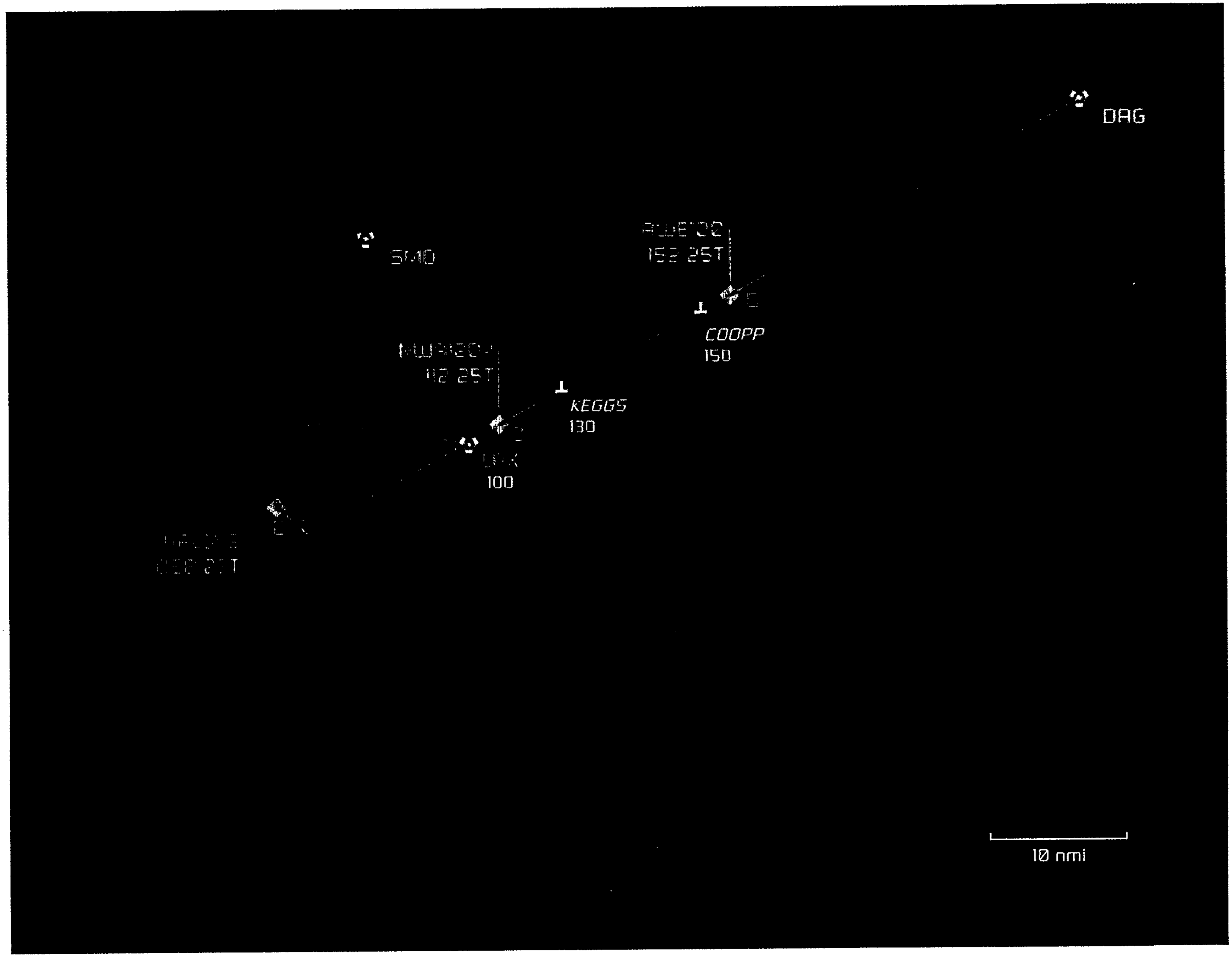

Figure 3.3.1.2. Merging into an En Route Stream without EDP #2.

3.3.2 Merging Into an En Route Stream with EDP

Figure 3.3.2.1 shows the same 3 aircraft (Figure 3.3.1.1) on the Loop departure from LAX. AWE100 is a B737 climbing out of 8,200 MSL. An EDP advisory was issued to AWE100 to turn the aircraft on a heading of 040 approximately 3.5 miles west of LAX. This aircraft is heading back northeast bound and will cross LAX at approximately 10,500 MSL. NWA 1204 is a B747 climbing out of 5,200 MSL. In the third visible line of the FDB an EDP advisory was displayed indicating that NWA1204 should be issued a turn back to LAX on a heading of 040. The advisory was issued, and now NWA1204 is in the turn back toward LAX. This aircraft is projected to cross LAX at approximately 10,500 MSL. UAL 342 is a B757 climbing out of 3,000 MSL. In the third visible line of the FDB an EDP advisory was displayed indicating that UAL342 should be issued a turn back to LAX on a heading of 030. This aircraft is just beginning to turn back toward LAX, and is also projected to cross LAX at approximately 10,500 MSL.

Figure 3.3.2.2 shows the separation between these aircraft after they are established on a northeast bound heading. AWE100 crossed LAX at 10,500 MSL, and is climbing out of 15,000 MSL. NWA1204 is 10 miles behind AWE100, crossed LAX at 10,500 MSL, and is climbing out of 12,600 MSL. UAL342 is 10 miles behind NWA1204, is climbing out of 8,300 MSL, and will cross LAX at 10,500MSL. Compared with Figure 3.3.1.2, this scenario is a clear improvement in terms of efficiency: AWE100 was able to reduce its flight distance by 5 miles due to an earlier turn, NWA1204 was able to save 5 miles, and UAL342 was able to save 2 miles.

3.4 CONCLUSIONS

Figures 3.3.2.1 and 3.3.2.2 illustrate numerous ways in which EDP may be used in the operational environment. EDP can expedite the climb of departure aircraft. When EDP computes that a departure can safely climb, it displays an advisory to the air traffic controller, eliminating unnecessary altitude restrictions. EDP can also reduce controller workload while optimizing the flow of aircraft into the en route stream. EDP generates speed, vector, and altitude advisories to sequence and schedule aircraft into the en route stream. These advisories allow aircraft to be spaced efficiently, while minimizing aircraft maneuvers and controller clearances. Both uses will improve overall system efficiency.

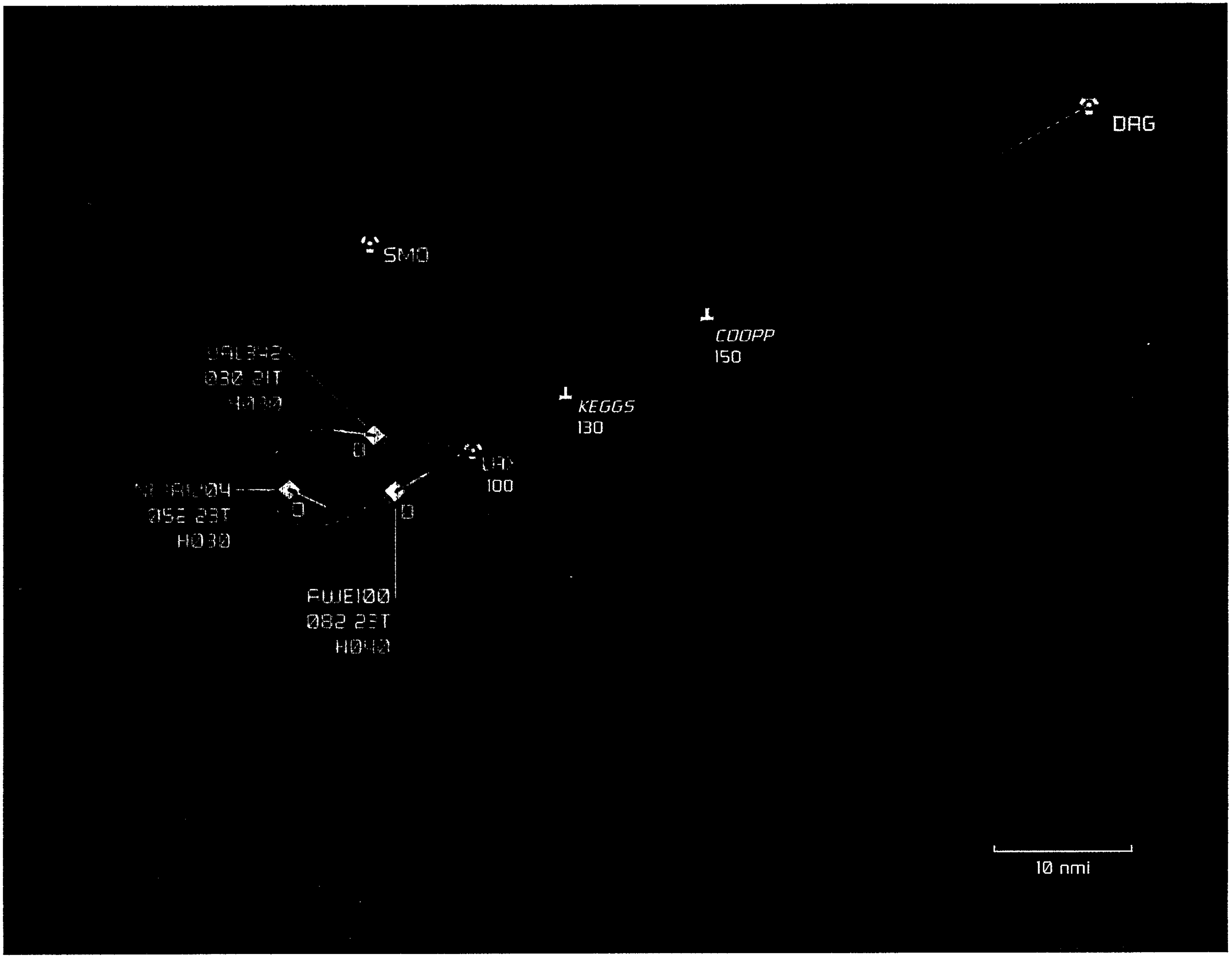

Figure 3.3.2.1. Merging into an En Route Stream with EDP #1.

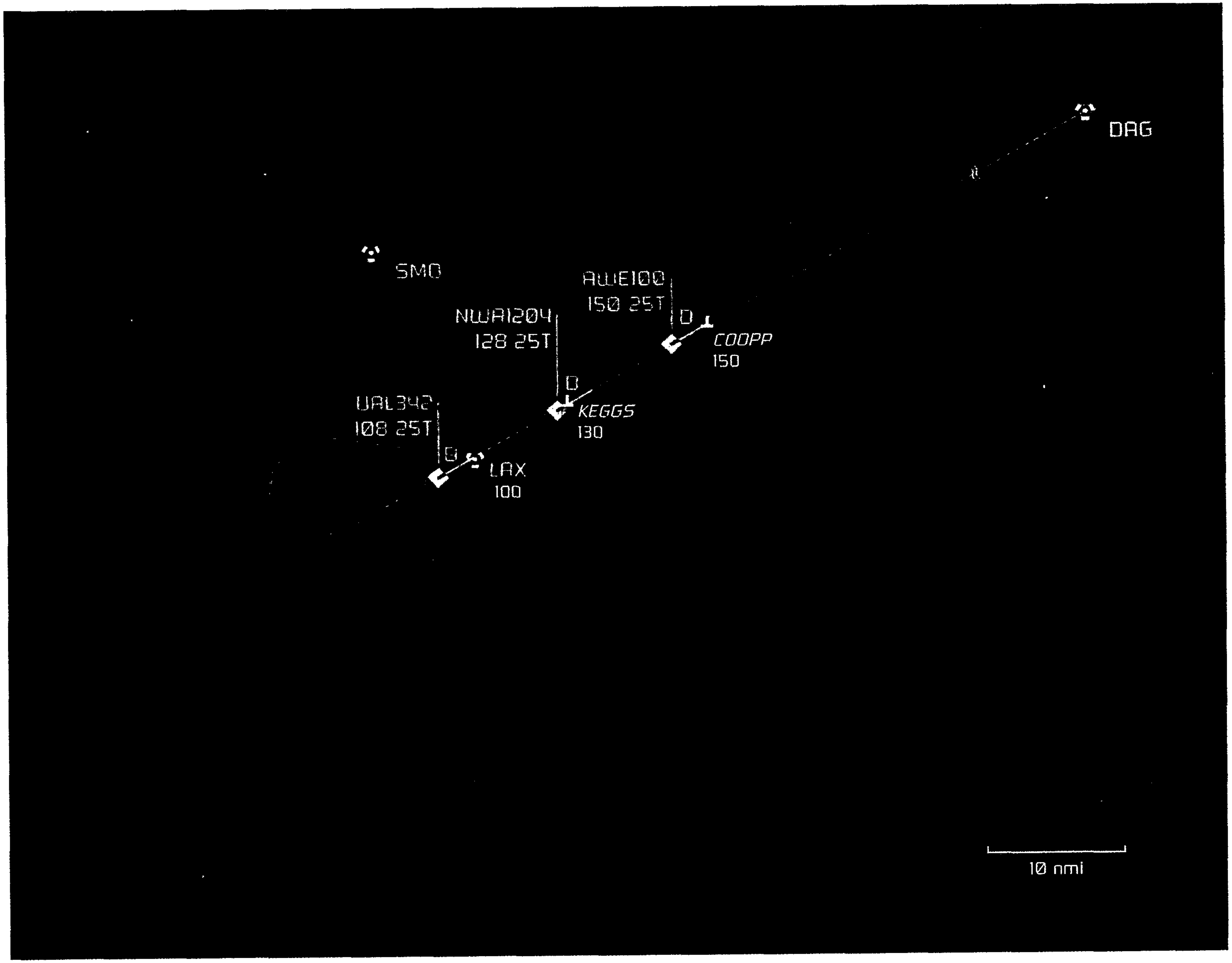

Figure 3.3.2.2. Merging into an En Route Stream with EDP #2.

4. EDP IMPLEMENTATION CONSIDERATIONS

4.1 EXTERNAL INTERFACES

The following are the external interfaces required for EDP:

Host Computer System (HCS) - EDP will receive flight data and radar tracks from the ARTCC's HCS via an interface device.

Display System Replacement (DSR) - EDP will receive controller entries from DSR via an interface device.

Standard Terminal Automation Replacement System (STARS) - EDP will receive flight data, radar tracks, and controller entries from the STARS via an interface device.

Surface Decision Support Tools – EDP will exchange information with surface decision support tools in order to optimize the queuing of departures.

Integrated Terminal Weather System (ITWS) - EDP will receive low altitude wind and storm motion data from ITWS via an interface device.

Other atmospheric data - EDP will receive high altitude wind, temperature, and air pressure data as a function of position and altitude.

4.2 INTEGRATION WITHIN AIR TRAFFIC MANAGEMENT (ATM)

EDP is interoperable with other ATM products. This includes using consistent Computer Human Interfaces (CHI), common interfaces and databases, and adherence to common standards.

5. ACRONYMS AND ABBREVIATIONS

AATT	Advanced Air Transportation Technologies
aFAST	Active Final Approach Spacing Tool
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System (IIIA or IIIE)
ATCS	Air Traffic Control Specialist
CHI	Computer Human Interface
CM	Communications Manager
CTAS	Center-TRACON Automation System
DEN	Denver Terminal Radar Approach Control
DFW	Dallas-Fort Worth Terminal Radar Approach Control
DSR	Display System Replacement
EDA	En Route Descent Advisor
EDP	Expedite Departure Path
ESP	EDP Scheduling Process
ETA	Estimated Time of Arrival
FAA	Federal Aviation Administration
FAST	Final Approach Spacing Tool
FDAD	Full Digital ARTS Display
HCS	Host Computer System
ISM	Input Source Manager
ITWS	Integrated Terminal Weather System
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
PAS	Pseudo Aircraft Systems

pFAST	Passive Final Approach Spacing Tool
PGUI	Plan View Graphical User Interface
PVD	Plan View Display
RA	Route Analyzer
STARS	Standard Terminal Automation Replacement System
TGUI	Timeline Graphical User Interface
TMA	Traffic Management Advisor
TMC	Traffic Management Coordinator
TMU	Traffic Management Unit
TRACON	Terminal Radar Approach Control
TS	Trajectory Synthesizer
ZDV	Denver Air Route Traffic Control Center
ZFW	Dallas-Fort Worth Air Route Traffic Control Center

6. GLOSSARY

Air Route Traffic Control Center (ARTCC) (also called "Center")

The facility responsibility for the en route portion of Instrument Flight Rules (IFR) flights.

Center

Air Route Traffic Control Center (also called "ARTCC").

Center-TRACON Automation System (CTAS)

The collection of decision support ATC tools, consisting of integrated software and hardware, that calculate automated schedules for efficient arrival and departure of air traffic at TRACONs and ARTCCs.

Communication Manager (CM)

A centralized communication hub between all CTAS processes.

EDP Scheduling Process (ESP)

Given the set of likely flight paths for all departure aircraft in the system, produced by the RA/TS combination, ESP generates an efficient conflict-free schedule and the corresponding advisories required to meet this schedule.

En Route Descent Advisor (EDA)

EDA generates advisories that enable ARTCC controllers to optimally sequence and schedule aircraft over meter fixes. The advisories are fuel efficient and conflict free.

Estimated Time of Arrival (ETA)

The time at which the aircraft is estimated to cross the runway threshold (or meter fix, FAF). The ETA is determined without any restrictions imposed by other aircraft. Before the aircraft is tracked by radar, a non-radar based ETA is derived from an aircraft's flight plan. Radar-based ETAs are computed based on the aircraft's current position and velocity estimates given by the surveillance processor, the expected route, speed, altitude profile to the threshold, aircraft performance model, and the projected wind.

The ETA is the earliest time an aircraft would cross a fix or runway threshold if allowed to follow its assigned flight path without being impeded by separation constraints to other aircraft and with no weather or air traffic control restrictions are placed on the aircraft flight.

Final Approach Spacing Tool (FAST)

FAST generates advisories that enable TRACON controllers to optimally sequence and schedule aircraft to a runway threshold. The initial version of FAST is Passive FAST (pFAST) which provides only runway assignment and sequence number advisories. The second version is Active FAST (aFAST), which adds speed, vector, and possibly altitude advisories.

Input Source Manager (ISM)

Merges, filters, and transforms aircraft data into a single CTAS format.

Integrated Terminal Weather System (ITWS)

Receives and processes weather inputs from a variety of sources and provides a fully automated display of current and predicted weather. Used by controllers and TMCs to improve safety and capacity within the terminal area.

Miles-in-Trail

A method of restricting aircraft flow based on defining a minimum separation distance between subsequent aircraft.

Planview Graphical User Interface (PGUI)

A map-based display showing aircraft position and other information. Similar to the PVDs and FDADs used by controllers, but with additional functionality.

Route Analyzer (RA)

Computes the horizontal route for each aircraft and sends the prediction to TS.

Terminal Radar Approach Control Facility (TRACON)

Concerned with the approach and departure portions of IFR flights in relation to a major airport.

Timelines

Timelines are used to graphically display aircraft identification tags at times corresponding to the aircraft's calculated crossing times over a selected reference point. Timelines help TMCs (and in some instances ATCSs) visualize when, and in what order aircraft will cross specified reference points. EDP timelines will show sequencing information referenced to departure fixes and departure gates. EDP timelines may also be used to display departure queue information.

Timeline Graphical User Interface (TGUI)

Displays information to TMCs regarding sequencing and scheduling of aircraft arrivals. Information includes timelines, load graphs, flight plans, and delay statistics. Allows TMCs to manipulate the display of information.

Traffic Management Advisor (TMA)

A CTAS decision support tool that generates runway assignments, landing sequences, and schedules arrival aircraft to runway thresholds and meter fixes. It also assists in runway configuration control and flow management.

Traffic Management Coordinator (TMC)

An air traffic controller located in the Traffic Management Unit, who is responsible for metering traffic as it flows into and out of the Center or TRACON. This person communicates directly with area supervisors (as opposed to communicating directly with pilots). A typical responsibility is that of metering arrivals by closing gates or controlling the traffic clow to meet acceptable rates. Also known simply as Traffic Manager.

Trajectory Synthesizer (TS)

Computes 4-dimensional trajectories for each aircraft.

7. REFERENCES

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