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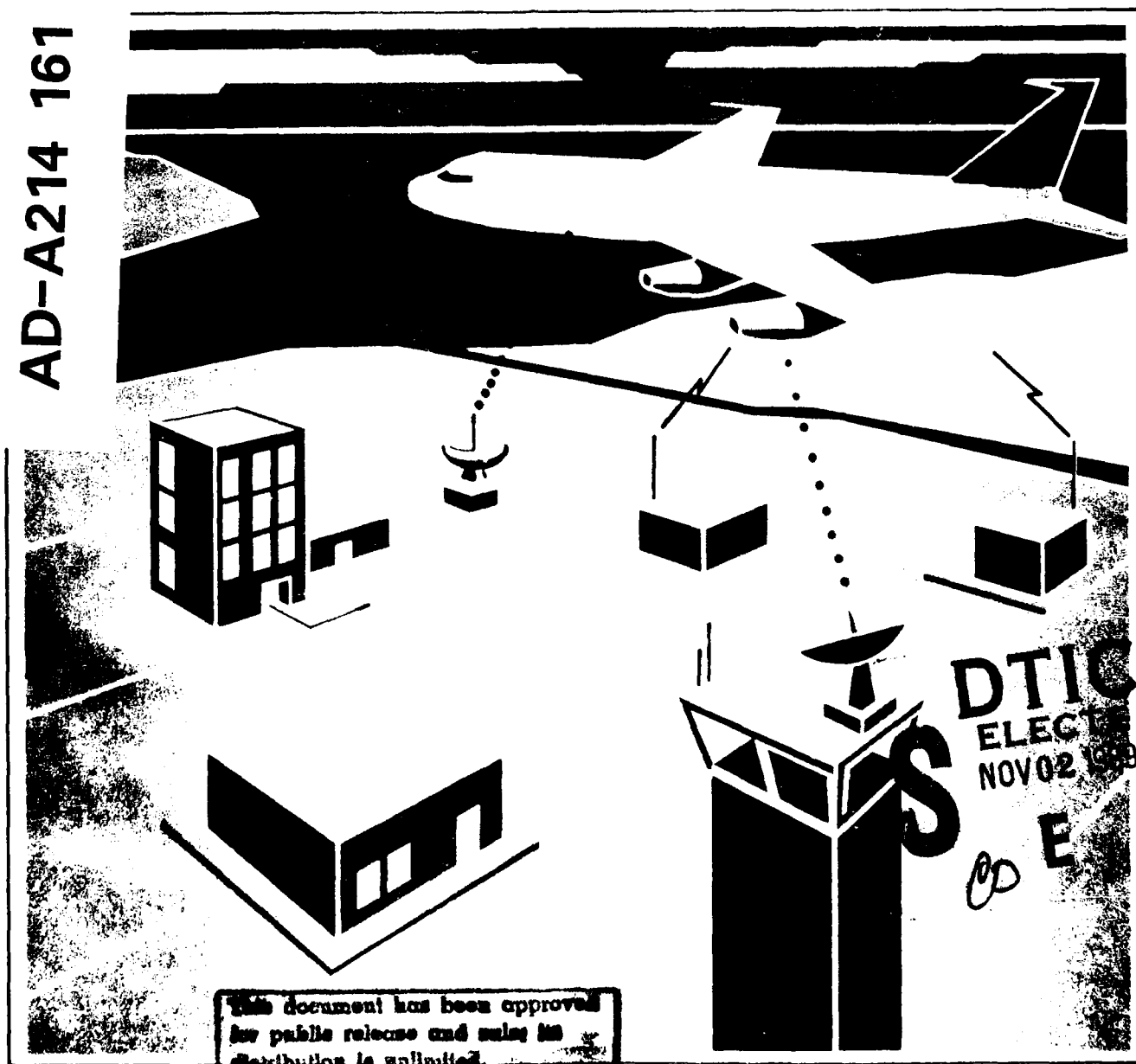
National Airspace System

Collision Avoidance
Operational Concept

NAS-SR-1325

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Advanced System Design Service
Washington, D.C. 20591

National Airspace System Collision Avoidance Operational Concept (NAS-SR-1325)

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Federal Aviation Administration
Washington, D.C. 20591



June 1989

Final Report

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16. Abstract This document is an operational concept for collision avoidance services which will be in place upon implementation of the Federal Aviation Administration (FAA) National Airspace System (NAS) Plan. This operational concept only discusses the ground-base portion of how the Air Traffic Control System (ATCS) provides flight safety by maintaining adequate aircraft separation. This concept discusses the aircraft separation assurance per the National Airspace System Requirement Specification (NASSRS). The objective of this document is to describe the relationship among sub-systems, facilities, information, and operators/users involved in the collision avoidance service. In addition, the elements and operations of the NAS Plan are mapped into the collision avoidance requirements stated in the NASSRS, NAS-SR-1000. Several types of block diagrams are used to illustrate systems connectively and operational flow. Scenarios are also derived to describe the collision avoidance process from a user's perspective.			
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1.0 INTRODUCTION

1.1 Background

The mission of the Federal Aviation Administration (FAA) is to provide for the safe and efficient use of the nation's airspace. The National Airspace System (NAS) System Requirements Specification (NASSRS), NAS-SR-1000, is a compilation of requirements which describe the operational capabilities of the National Airspace System upon completion of the NAS plan (end-state system). The first priority of air traffic control is to maintain safety in flight by separating aircraft in controlled airspace. This operational concept only discusses the ground-based portion of how the Air Traffic Control System (ATCS) provides flight safety by maintaining adequate aircraft separation. This concept discusses aircraft separation assurance per the NASSRS. This operational concept document has been developed using an established standard format and is consistent in structure with a series of operational concepts written about various sections of the NASSRS.

1.2 Objective

The objective of this operational concept is to describe the functions involved in collision avoidance in the NAS "end-state" system. It shows the interrelationships between subsystems, facilities, information, and controllers/users. In addition, it provides management and technical personnel of the FAA and other involved organizations with a general description of how the collision avoidance service of the NAS operates.

1.3 Scope

This document covers the requirements delineated in Section 3.2.5 of the NASSRS. Section 3.2.5 of the NASSRS is called collision avoidance although not all of the requirements are directly related to collision avoidance. It follows the NASSRS convention of calling the functions described in Section 3.2.5 of the NASSRS collision avoidance functions. The operations described are limited to those associated solely with collision avoidance services. The paragraphs in NASSRS Section 3.2.5 and their titles are as follows:

- 3.2.5.A Flight Path Projection and Identification of Potential Collisions
 - 3.2.5.A.1 Track Information
 - 3.2.5.A.2 Conflict Alert (CA)
 - 3.2.5.A.3 CA Display
 - 3.2.5.A.4 Nuisance Alert
- 3.2.5.B Look-ahead Times (20 Minutes & 2 minutes); Avoidance

- actions (Conflict Resolution Advisories and Automated Problem Resolution)
- 3.2.5.C Alerts of Potential Collision
- 3.2.5.D Determine Recommended Maneuvers
- 3.2.5.E Display of Recommended Maneuvers
- 3.3.5.F Collision Avoidance Available Continuously

This document will include separation assurance functions which identify imminent conflicts (less than two minutes to violations) and also the Automated En Route ATC (AERA) functions. AERA functions will assist the controller in prediction and resolution of situations in which the time-to-violation is relatively long (20 minutes look-ahead-time). Section 3.2.5 of the NASSRS states functions that require AERA 2, (generating and evaluating maneuvers to resolve problems). In this sense, a "problem" is a predicted potential loss of adequate separation among aircraft or between aircraft and protected airspace.

This document does not include collision avoidance systems which deal with situations in very short time-frames where a violation of separation minima has already occurred, (e.g., Traffic Alert and Collision Avoidance System (TCAS) and Airspace and Traffic Advisory Service [ATAS]). Section 3.2.5 of the NASSRS clearly states that independent airborne systems (i.e., TCAS) are not a part of NAS Air Traffic Control (ATC).

The Aircraft Separation Operational Concept covers the requirements delineated in Section 3.2.3 of the NASSRS' which generally addresses aircraft separation functions. As the NASSRS requirements in section 3.2.3 and 3.2.5 are very similar, the topics covered in the Aircraft Separation Operational Concept and their operational concept are very similar. The Aircraft Separation Operational Concept provides a more extended view of separation functions than this operational concept.

1.4 Methodology

The methodology used in providing perspective and insight into this operational concept provides information in a number of different ways. The focus of the material is built around four different kinds of diagrams and/or descriptive information described below:

1. OPERATIONAL BLOCK DIAGRAM/DESCRIPTION. The operational block diagram illustrates the connectivity between major elements of the NAS, i.e., processors, specialists/controllers, and the user for those elements that support the service. The operational block diagram in this Operational Concept is extracted from the

overall NAS Operational Block Diagram. Principal features of the operation block diagram/description include the following:

- a. Each specialist/controller is indicated by a number. This number remains the same in every operational concept.
- b. Dotted lines segregate facilities.
- c. Solid lines show digital data flow. Voice data flow is not shown.
- d. The blocks within each facility are the major processors.

2. OPERATIONAL FLOW DIAGRAMS/DESCRIPTIONS. The operational flow diagram and associated description for each specialist/controller provides more detail about the inputs, processors, outputs and interfaces for each operator. Operational flow diagrams are used to functionally describe the products and services of individual specialists/controllers. The diagrams show major actions only. Ancillary actions such as requests for simulation and system conditions are not shown. Principal features of an operational flow diagram include the following:

- a. Dotted lines segregate facilities.
- b. White boxes indicate specialist/controller/user functions. Shaded boxes indicate machines.
- c. The functions listed by lower case alphabetic characters in the white and shaded boxes are explained in the text.

3. OPERATIONAL SEQUENCE DIAGRAMS/DESCRIPTIONS. The operational sequence diagram and associated descriptions shows a typical sequence of steps taken by operators/users in providing the service. Principal features of an operational sequence diagram include the following:

- a. Users and specialists/controllers involved with providing/using the service listed along the vertical axis. When required for clarity, other FAA facilities may also be listed on the vertical axis.
- b. The horizontal axis represents time. Sequential events or functions performed by an operator/user are indicated within separate boxes. Events which may occur simultaneously or

near-simultaneously are indicated by the double number. The numbers on the right side of the blocks refer to numbers in the text.

- c. Decision points or points where alternate paths may be followed are indicated by a diamond shape.
 - d. Circles are connectors and indicate exit to, or entry from, another diagram. Circles with a numeric character connect either to another sheet of the same diagram or to another diagram, the relevant figure number is listed underneath if connection is to a different diagram. Further, functions within the boxes preceded by a lower case alphabetic character reference the same functions listed in the operational flow diagrams. Thus, the relationship between operator/user interactions and relevant NAS subsystems is depicted.
4. OPERATIONAL SCENARIO(S)/DESCRIPTION(S). The operational scenario and associated description depict a specific predefined situation and illustrate a particular subset of the generalized operational sequence diagrams. Principal features of operational scenario diagrams include the following:
- a. Users and specialists/controllers involved with providing the service are listed along the vertical axis.
 - b. The horizontal axis represents time. Sequential events or functions performed by an operator/user are indicated within separate boxes. The numbers on the right side of the blocks refer to numbers in the text.
 - c. Shaded portions of boxes represent machine actions.

1.5 Document Organization

The remainder of this document is organized as follows. Section 2 is the main body of the document and is divided into six subsections. Section 2.1 provides an operational block diagram which illustrates the connectivity between subsystems, facilities, operators, and users that are involved in collision avoidance and provides an operational summary of each position. Section 2.2 describes the information required or used to provide collision avoidance services. Section 2.3 expands the functions performed at each position in operational flow diagrams and provides more detail about inputs, processes, outputs, and the interface with the user. It also summarizes NAS subsystems functions. Section

2.4 correlates the NASSRS with this document. Section 2.5 presents generalized time-sequenced operator/user interactions for Area Control Facility (ACF) controllers and the Airport Traffic Control Tower (ATCT) controller. Section 2.6 provides a scenario to illustrate a specific hypothetical situation where collision avoidance services are provided.

2.0 OPERATIONS

2.1 Support

Figure 2-1, Overview of National Airspace System (NAS)/User Systems for Collision Avoidance, illustrates the NAS facilities, systems, and user systems that are involved with the collision avoidance functions.

Major functions of collision avoidance operations are supported by the Area Control Computer Complex (ACCC), Tower Control Computer Complex (TCCC), Voice Switching And Control System (VSCS), Air Traffic Control (ATC) Radar Beacon System (ATCRBS), Altitude-encoded Beacon Reply (Mode C) and Mode Select-Beacon System (Mode S) Transponders and controllers. NAS subsystems that contain processing capabilities or position equipment that support operational services to avoid collision are discussed in Section 2.3, Functions.

2.1.1 NAS Facilities/Systems/Positions

The NAS facilities, systems, specialist positions, and major information paths that may be involved in a collision avoidance operation are shown in Figure 2-2, Collision Avoidance Operational Block Diagram. The functions provided by each specialist position and a description of each follows. Included with each description is a reference to the existing procedures manual and to those NAS projects that are most likely to affect how the service will be provided.

Position 6 And Position 7: Approach/Departure And En Route Controller Area Control Facility (ACF) Controllers)

Function: Ensure aircraft separation in controlled airspace within the assigned area of responsibility.

Description: The primary responsibility of the radar controllers is to ensure aircraft separation. En route controllers provide the same functions to avoid collision as approach and departure controllers except that their control areas are different. As a departing flight approaches the boundary of the airport control area (approximately 30 miles), the departure controllers hands off control of the aircraft to the en route controllers. Radar controllers review radar situation displays for their area of interest continuously.

Procedures: FAA, "Air Traffic Control (7110.65)."

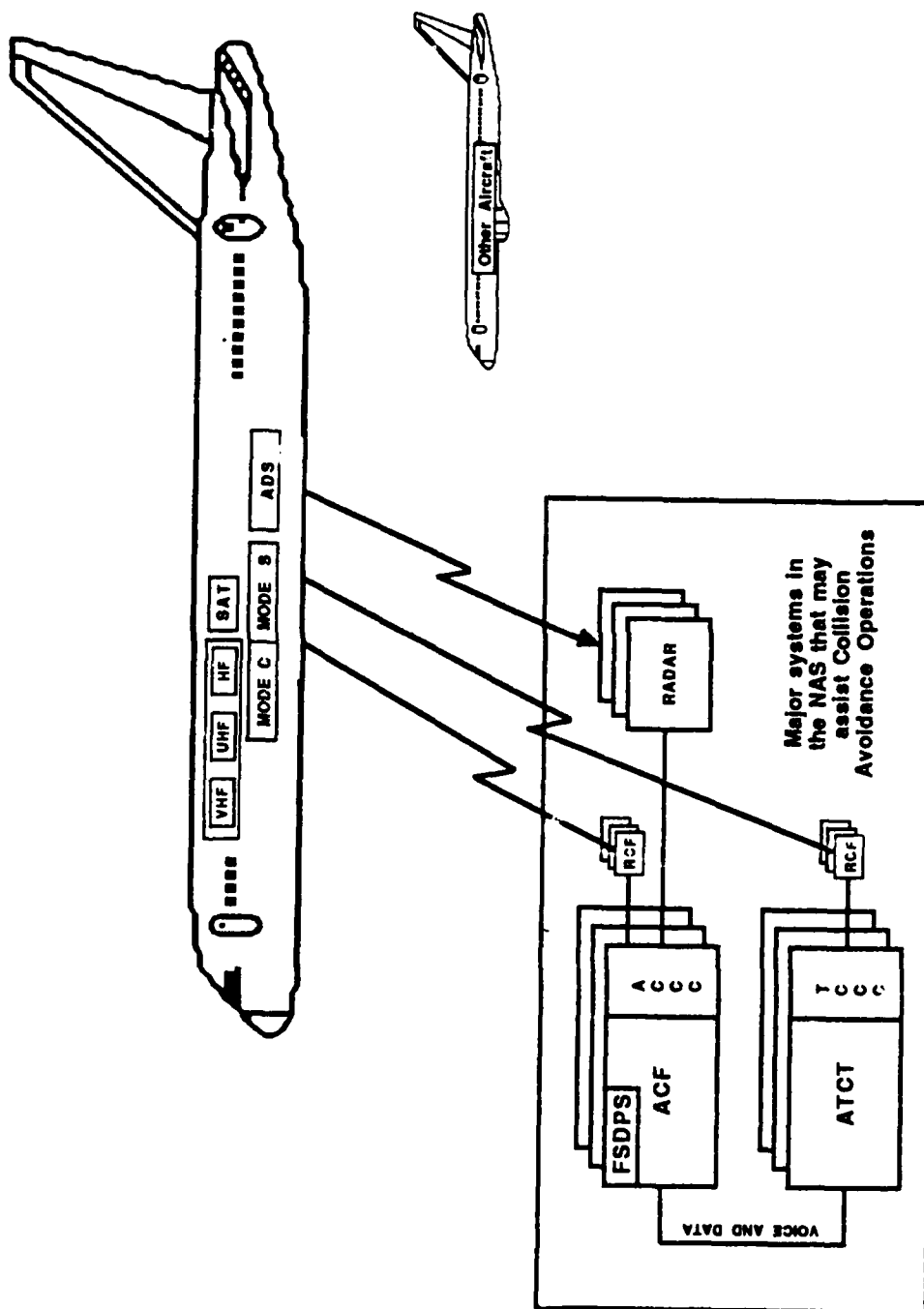
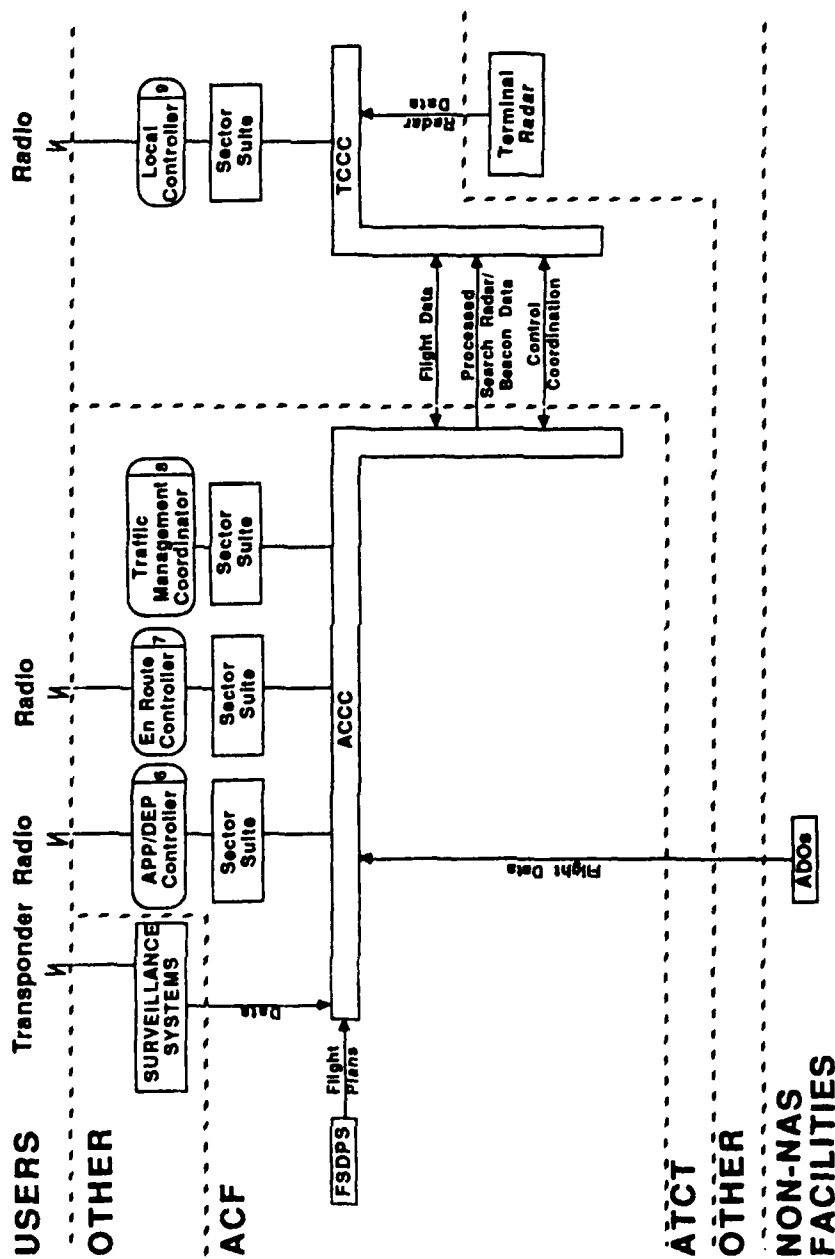


FIGURE 2-1
OVERVIEW OF NAS/USER SYSTEMS FOR COLLISION AVOIDANCE



- Note: 1. All positions have telephone connectivity to each other and outside (others) functions
2. This diagram is derived from an overall NAS operational block diagram

FIGURE 2-2
COLLISION AVOIDANCE OPERATIONAL BLOCK DIAGRAM

Projects: NAS Plan ATC En Route System
Project 7, Modern ATC Host Computer
Project 9, Conflict Resolution Advisory (CRA) Function
Project 10, Conflict Alert Instrument Flight Rules
(IFR)/Visual Flight Rules (VFR) Mode C Intruder
Project 12, Advanced Automation System
Project 13, Automated Enroute Air Traffic Control

Position 9: Local Controller Airport Traffic Control Tower (ATCT)
Controller)

Functions: Departure and arrival spacing, sequencing, and separation of aircraft.

Description: Local controllers are located at ATCT. They are supported by the TCCC through the TCCC position console (TPC). Local controllers' duties include departure and arrival spacing, sequencing, and separation of aircraft.

Procedures: FAA, "Air Traffic Control (7110.65)."

Projects: NAS Plan, Terminal Automation
Project 12, Tower Communication System
Project 13, ATCT/Terminal Radar Approach Control (TRACON)
Establishment Replacement And Modernization

2.1.2 User Systems

The aircraft in Figure 2-1 shows two way radio systems for voice communication; very high frequency (VHF), ultra high frequency (UHF), high frequency (HF), and satellite, and data communication (Mode S) and systems to assist in surveillance (ATCRBS, (Mode C & S)), and Automatic Dependent Surveillance (ADS). Few, if any aircraft will have all of these systems, but most all will have some. A Mode C transponder which reports altitude, is required for VFR aircraft to obtain the collision avoidance service.

2.2 Information

This section describes the information required or used in the collision avoidance service obtained through the NAS.

The ACCC/TCCC will present information/data to the controllers in the form of interactive adaptable alphanumeric and graphic displays.

Information/data that the controllers may need to provide collision avoidance are as follows:

1. Surveillance Data. The ACCC receives, processes and displays surveillance data from both ATCRBS (including Mode S) and primary radar. Primary radar provides information on aircraft position. In addition to position, ATCRBS provides altitude and aircraft identification. Further, the ACCC will calculate and have available for display aircraft speed and direction.
2. Separation Assurance Data. The system will display Conflict Alert (CA), CRA, and incident reporting for each tracked aircraft pair.

CA. The controllers can predict violations of separation minima along the track extrapolation vector line or by extrapolating from history positions for short look-ahead times (normally two minutes or less). CA processing performs this same function using the track extrapolation vector as a backup to the controller. CA functions are implemented for terminal and for enroute airspace. It will provide different alerting criteria for terminal and enroute operations for the following cases for Mode C equipped aircraft:

- IFR/IFR pairs
- IFR/controlled VFR pairs
- IFR/uncontrolled VFR pairs
- Controlled VFR/controlled VFR pairs
- Controlled VFR/uncontrolled VFR pairs

CRA. The ACCC will generate and display alternative resolutions of tactical (short-term) situations that ensure adequate aircraft separation and minimal disruption of system operations.

Incident Reporting. The report given to the controllers will include aircraft identifications, controlling positions, and the proximity in lateral and vertical distance.

3. Automated En Route ATC (AERA) Data. AERA provides Automated Problem Detections (APD) and Automated Problem Resolutions (APR) out to times of about 20 minutes. AERA provides the controllers with tools to evaluate the effects of requesting direct route prior to granting the clearance. The controllers can create, modify, or delete a trial plan. (A trial plan is a flight plan that is proposed as a new flight plan or a possible replacement

for an existing flight plan. It is built or amended either by the controller or automatically by the ACCC). They can also display the route of aircraft associated with a trial plan to help resolve predicted aircraft. The use of AERA tools by the controllers is optional.

2.3 Functions

The following paragraphs elaborate on functions provided by the controller positions introduced in Section 2.1 and by the equipment that support the controllers. The operational flow diagrams associated with each paragraph illustrate the information flow between the controller and the user and between the controller and data processing equipment. The focus is on functions specifically related to collision avoidance service. The pertinent NASSRS paragraphs that specify the functions being performed by the controllers are referenced in each of the paragraphs below.

2.3.1 Functions of Approach/Departure Controller (Position 6) And En Route Controller (Position 7)

En route and approach/departure controllers are analyzed together because for this service they are functionally identical. Approach/Departure controllers monitor terminal control airspace, whereas enroute controllers monitor enroute airspace. They are both radar controllers. They maintain separation between aircraft and between aircraft and restricted airspace by providing users with the maneuvers required to avoid conflicts (separation violations).

Figure 2-3, Approach/Departure and En Route Controllers: Collision Avoidance Operational Flow Diagram, illustrates the collision avoidance functions and services provided by the controllers (position 6 and 7) at the ACF. Lower case letters identify the functions performed by the controllers and their support equipment and are described in the corresponding paragraphs below.

- a. ACCC Processing. One of the purposes of the ACCC is to provide automated assistance to the controllers so that they can maintain safe separation between aircraft. An ACCC includes computers, computer software, displays, input/output devices, and controller/operator workstations. An ACCC will support the continuous control of air traffic. The ACCC provides controllers at an ACF with the ability to track all aircraft within the responsibility of their region. Controllers will interface with the ACCC through sector suites. A sector suite will consist of one to four consoles. Each common console will consist of two physical displays, an interactive display and

input devices (e.g., keyboard and cursor positioning/selecting device). One physical display will be the main display and the other will be used as an auxiliary display. Capabilities are functions which are directly or indirectly related to collision avoidance.

- b. Checks and Evaluates Future Separation. The controllers will ensure separation by mental assessment of the situation presented to them, at the sector suites, augmented by automation tools. They may mentally project an aircraft's future position/altitude path, or project a flight plan to avoid potential conflict. To do this, they may refer to radar/beacon data presented on their display. The controllers may input flight plan data which will be translated by AERA into a four-dimensional trajectory (the three spatial dimensions, plus time) representing the expected flight path of the aircraft. The trajectory is then compared against other flight trajectories by AERA. Any problems detected by this comparison are presented to the controllers for evaluation and resolution. Another use of the AERA trajectory is the construction, by the controllers, of "trial" trajectories to examine flight plan amendments.

NASSRS requirements: 3.2.5.A
3.2.5.B
3.2.5.D
3.2.5.F

- c. Detect Valid Conflicts. A CA can be presented to the controllers on their sector suites display. CA can be suppressed by controllers input action.

NASSRS requirements: 3.2.5.A.2
3.2.5.A.3
3.2.5.A.4
3.2.5.F

- d. Determine CRA. CRA will be determined by the ACCC and presented to the controllers at the sector suites. If the controllers are not satisfied by these machine generated resolutions, they will formulate their own resolution.

NASSRS requirements: 3.2.5.D.3
3.2.5.E
3.2.5.F

- e. Select CRA. The ACCC will rank order conflict resolution maneuvers for each predicted conflict, but the decision as to which maneuver to recommend from the display list or to formulate their own maneuver is the controller's option.

NASSRS requirements: 3.2.5.D.4
3.2.5.F

- f. Inform The Pilot. The controllers (positions 6 and 7) will issue advisories alerts and clearances to the pilot based on the selected conflict resolutions. The pilot will be informed by the controllers, of potential separation violations, the primary threats, and the recommended maneuvers to avoid those threats.

NASSRS requirements: 3.2.5.C (4 & 5)
3.2.5.F

2.3.2 Functions of Local Controllers (Position 9)

Figure 2-4, Local Controller: Collision Avoidance Operational Flow Diagram, illustrates the functions and services provided by the local controllers at an ATCT. Lower case letters identify the functions performed by the controllers and their support equipment. The functions are described in the corresponding paragraphs below.

- a. TCCC Processing. The TCCC provides an automated information system that supports the ATCT controllers. ACCCs and TCCCs will have the same equipment and software to the extent possible. The TCCC has two modes of operation: normal and stand-alone. The TCCC will transition to the stand-alone Mode of operation when communication with an ACCC becomes unavailable. Separation assurance automation capabilities will not be provided in the stand-alone mode. The majority of the external data received by the TCCC are surveillance data, separation assurance assistance, environment data and flight plan data.
- b. Checks and Evaluates Separation. The local controller's job is to ensure the safe flow of air traffic through direct (visual) observation out the tower window. The controller can directly observe an aircraft/aircraft conflict in the local airspace area. Thus, the controller observes the aircraft then judges the separation. The controller will also review the situational display for flight data, radar returns, CAs and CRAs and use that information as appropriate. All of the above functions are performed on a continuous basis.

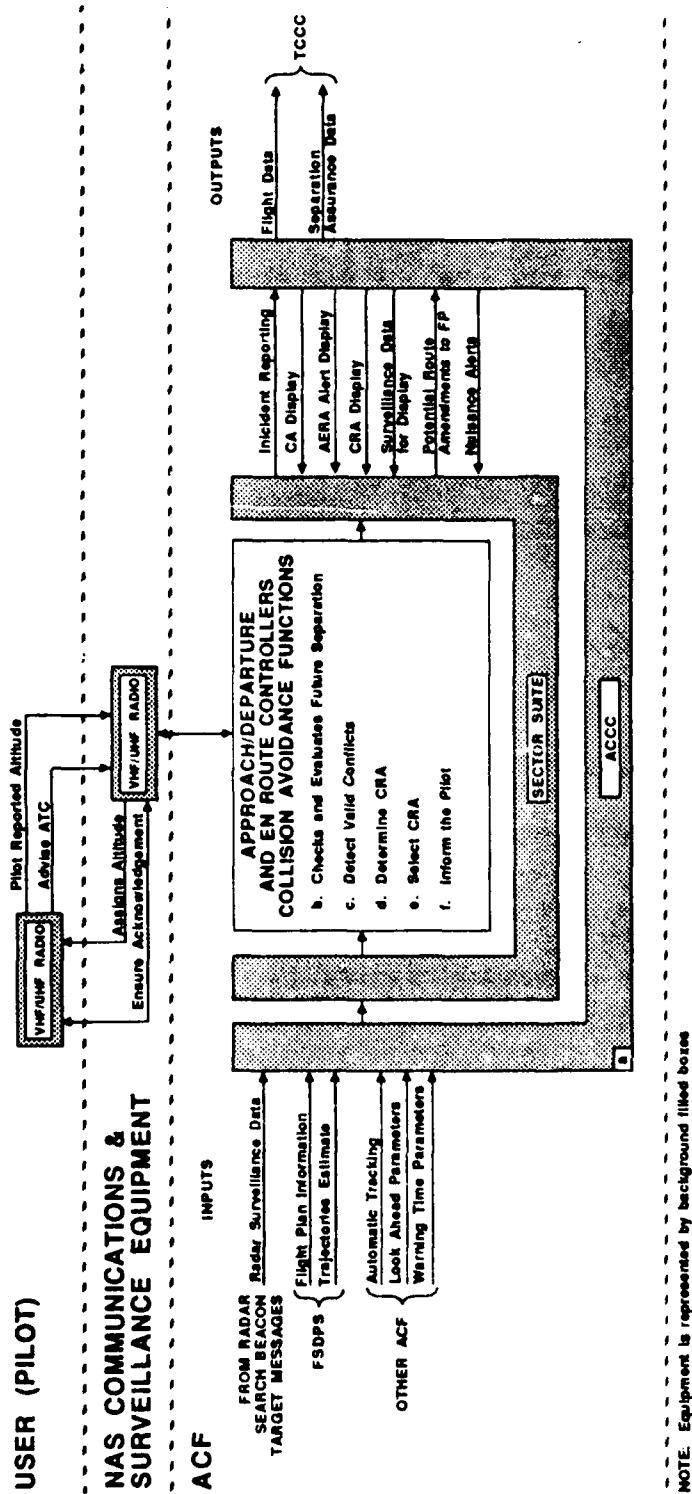


FIGURE 2-4
LOCAL CONTROLLER: COLLISION AVOIDANCE OPERATIONAL FLOW DIAGRAM

NASSRS requirements: 3.2.5.A.1
3.2.5.F

- c. Detect Valid CA(s). A conflict may be detected in many ways. If the automation system detects an aircraft/aircraft conflict, a CA is generated on the situation display. The local controllers determine the validity of the alert.

NASSRS requirements: 3.2.5.A.(3 & 4)
3.2.5.F

- d. Determine CRA. The controllers also review the CRA generated by the automation system or formulate their own advisory when not satisfied by the system generated resolutions. Action to resolve the conflict situation will be taken by the controllers.

NASSRS requirements: 3.2.5.D & E
3.2.5.F

- e. Select CRA. The system will rank order conflict resolution maneuvers for each predicted conflict, but the decision as to which maneuver to recommend from the display list or to formulate their own maneuver is the controller's option.

NASSRS requirements: 3.2.5.D.4
3.2.5.F

- f. Inform The Pilot. The controllers will inform the pilot of the primary threats, and the recommended maneuver based on the selected conflict resolution.

NASSRS requirements: 3.2.5.C. (4 & 5)
3.2.5.F

2.4 Correlation with Operational Requirements

Table 2-1, Collision Avoidance Operational Requirements Correlation, summarizes the correlation of the collision avoidance operational requirements paragraphs of NAS-SR-1000 with the previous paragraphs in this document that describe the functions being performed by the controllers. All collision avoidance paragraphs from Section 3.2.5 of NASSRS which are introductory in nature, do not state an explicit operational requirement, or which reference other portions of NAS-SR-1000 are indicted with a dash. The fact that a correlation is shown between the requirements paragraph and a paragraph describing the

TABLE 2-1
COLLISION AVOIDANCE OPERATIONAL REQUIREMENTS CORRELATION

NAS-SR-1000 Paragraph Position Paragraph	Approach/Departure and En Route Controller						Local Controller					
	2.3.1.a	2.3.1.b	2.3.1.c	2.3.1.d	2.3.1.e	2.3.1.f	2.3.2.a	2.3.2.b	2.3.2.c	2.3.2.d	2.3.2.e	2.3.2.f
3.2.5 Collision Avoidance Requirements	—	—	—	—	—	—	—	—	—	—	—	—
.A Flight Path Protection	X	X					X					
.A-1 Track Information	X	X					X					
.A-2 Conflict Alert (CA)	X		X						X			
.A-3 CA Display	X		X						X			
.A-3a CA in Terminal Airspace	X		X						X			
.A-3b CA in En Route Airspace	X		X									
.A-4 Nuisance Alert	X		X						X			
.B Look-Ahead Times	X	X						X	X			
.B-1 Separation Assurance	X	X	X	X	X	X	X	X	X	X	X	X
.B-2 Long Look-Ahead (20 Min) Time	X	X										
.B-3 Aircraft Routing not Available	X		X					X				
.B-4 Flight Path Updated once per Scan	X	X	X	X	X				X	X		
.C Alerts of Potential Collision	X		X							X		
.C-1 Alert the Controller by Aural/Visual Signal	X		X	X	X				X	X		
.C-2 Display Alert	X		X	X						X		
.C-3 Display of Call Sign	X											
.C-4 Alert Equipped Users	X			X		X						X
.C-5 Notify CRA to User	X					X						X
.D Determine CRA	X	X		X						X		
.D-1 Evaluate Maneuvers	X	X		X						X		
.D-2 Current CRA Status	X	X		X						X		
.D-3 CRA Advisories	X	X		X						X		
.D-4 Rank CRA	X				X						X	
.E Display CRA	X			X	X					X		
.E-1 Display CRA within Specific Time	X			X						X		
.E-2 Display at least one CRA	X	X		X						X		
.F Available on a Continuous Basis	X	X	X	X	X	X		X	X	X	X	X

specialist/controller functions performed should not be construed as indicating that the requirement is completely fulfilled.

2.5 Operational Sequences

Figures 2-5 and 2-6 each illustrate a common sequencing of the functions described in Section 2.3 and show how the various specialists interact with the user, other specialists, and NAS subsystems to provide the collision avoidance service. Figure 2-5 shows a general sequence of operator/user interactions in the ACF environment for controllers in controlled airspace to avoid collision. A similar operational sequence for the ATCT environment is shown in Figure 2-6. In order to ensure separation, specialists will maneuver only the controlled aircraft (IFR or VFR with an available flight plan). In the automated environment, AERA services can be extended to the Controlled Visual Flight Rules (CVFR) aircraft in which the pilot has filed a flight plan requesting ATC separation service. The number in the upper right hand corner of the action rectangles and upper vertices of the decision diamonds are reference numbers and progress more or less as time progresses during the operation. The functions occurring almost concurrently are indicated by the double number. The cross hatching indicates an interaction with, and processing by, automatic data processing equipment (ACCC/TCCC).

2.5.1 Performing Aircraft Conflict Resolution for ACF Controllers

Figure 2-5, Perform Aircraft Conflict Resolution: Operational Sequence Diagram For ACF Controllers, illustrates the interactions necessary to issue an appropriate maneuver to controlled aircraft to avoid collision.

An aircraft routing may or may not be available to the controllers (i.e., no flight plan is available for uncontrolled VFR) (1). If routing information is available (IFR and controlled VFR), the controllers may consider the entire 20 minutes trajectory based on flight path projection into the future by the ACCC (2.1), which will be updated as required (the conditions are stated in the system database) (2.3). If a separation minima violation is predicted (3.1), it may lead to the use of automation tools (AERA capabilities) which are provided by the ACCC. The controllers may review the APD information displayed on the logical display of the sector suite (4). Using the ACCC, controllers may request trial planning (5). The controllers may formulate problem resolutions for the automatically detected problem (6). It is the controllers' option to implement the problem resolution (7). If they decide to implement the resolution, then they will issue an advisory to

USER (PILOT)

ACF CONTROLLERS

ATCT CONTROLLERS

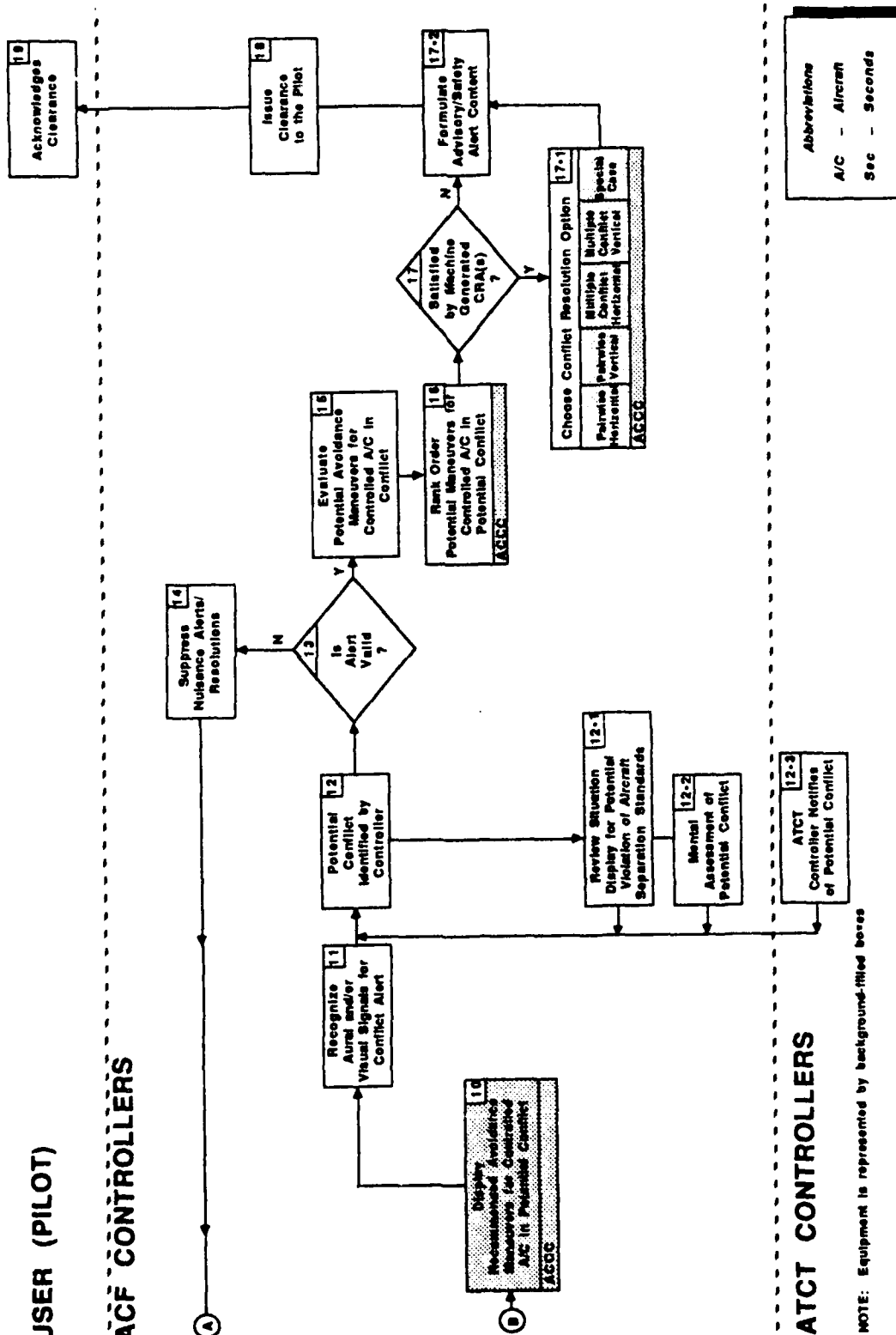


FIGURE 2-5
PERFORM AIRCRAFT CONFLICT RESOLUTION: OPERATIONAL
SEQUENCE DIAGRAM FOR ACF CONTROLLERS

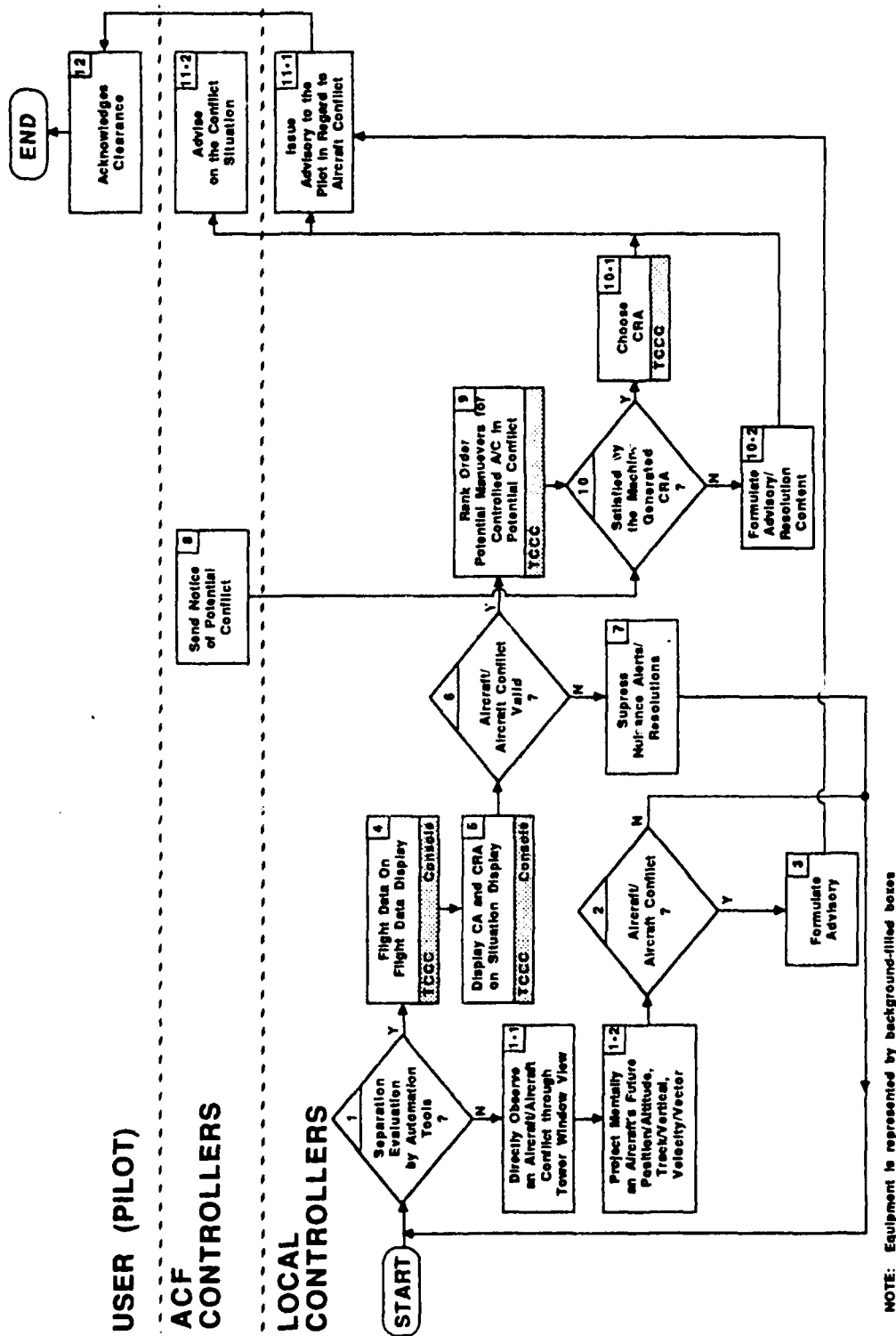


FIGURE 2-6
PERFORM AIRCRAFT CONFLICT RESOLUTION: OPERATIONAL
SEQUENCE DIAGRAM FOR LOCAL CONTROLLER

the pilot(s) (8). Otherwise, they may consider only a two minute track based flight path projection (2.2). Flight path projection will be updated by the surveillance equipment at least once per scan (2.4).

For all aircraft, if parameters associated with a potential separation minima violation have been satisfied (3.2) in the short look-ahead time frame (typically 2 minutes or less), then CA is displayed to the controllers by the system (9) and also recommended avoidance maneuvers for a controlled aircraft in potential conflict are displayed to the controllers by the ACCC (10). The controllers will recognize the the aural and/or visual signals for CA (11). Normally the controllers will be aware of the situation prior to the CA and will be managing the situation, but if they are not, the controllers will identify the potential conflicts (12). The controllers will then review the situation display for potential violation of aircraft separation standards (12.1). The controller's mental assessment of potential conflict is necessary (12.2). (In addition, the ATCT controllers will notify the ACF controllers of any potential conflict for aircraft which are moving towards the ACF environment (12.3)). The controllers determine the validity of the alert (13). If the alert is not valid, then the controllers will suppress the nuisance alerts and resolutions (14) and if the alert is valid, then potential avoidance maneuvers for controlled aircraft in conflict will be evaluated (15). Possible maneuvers (resolutions) for controlled aircraft involved in the conflict will be ranked by the system, but the controllers make their own judgment (16). If the machine generates conflict resolutions and the controllers are satisfied then they will choose the conflict resolutions (17 & 17.1) from those displayed by the ACCC, otherwise the controllers will formulate their own advisory/safety alert (17 & 17.2). The controllers will issue a clearance to the pilot (18), informing the pilot of the relative positions of the primary threats and finally, the pilot will acknowledge the clearance (19).

2.5.2 Operational Sequences For Local Controllers

Figure 2-6, Perform Aircraft Conflict Resolution: Operational Sequence Diagram for Local Controller, illustrates a general sequence of operator/user interactions necessary to issue an appropriate maneuver to avoid collision.

One of the functions of the local controllers is to check and evaluate separation of aircraft to avoid collision. A conflict can be detected in a variety of ways. The conflict can be detected visually or by automation tools (1). First, the local controllers will directly observe aircraft through the tower window (1.1) then mentally project the aircraft's future position/altitude and estimate its track/vertical

vector. To do this, they may refer to radar/beacon data presented on their display (1.2). If a potential conflict is determined (2), they will formulate their own advisory and resolution to the potential conflict (3). But if the conflict is detected by automation tools, then the system will display the flight data (flight plans, and flight plan amendments) on flight data display (4) and display CA and CRA on the situation display (5). The local controllers must determine the validity of the aircraft/aircraft conflict (6). If the CA is not valid then the controller may suppress the alert and resolutions (7). (In addition, the ACF controllers will notify the ATCT controllers of any potential conflict detected in their sector and which are moving towards the ATCT environment (8)). Possible maneuvers for controlled aircraft involved in the predicted collision (resolutions) will be ranked by the system or if the controllers are not satisfied, they may make their own judgment (9). If the conflict is valid and the local controllers are satisfied by the machine generated conflict resolutions, they will choose a CRA generated by the TCCC/ACCC (10 & 10.1), otherwise the controllers will formulate their own advisory/resolution (10.2). The controllers will issue an advisory to the pilot in regard to the aircraft conflict (11.1), they will also advise on the conflict situation to ACF controllers including the positions of primary threats (11.2). Finally, the pilot will acknowledge the clearance (12).

2.6 Operational Scenario

Figure 2-7, Collision Avoidance Scenario: Conflict Detection Between Controlled (IFR) And An Uncontrolled (VFR) Aircraft In En Route Airspace, presents an operational sequence for a specific hypothetical situation. It is similar to the operational sequence diagrams in Figures 2-5 and 2-6; however, the scenario shows more detail. The scenario assumes a conflict detection between a controlled (IFR) and an uncontrolled (VFR) aircraft in en route airspace.

An aircraft pair enters controlled airspace (1). The scenario is entered when the ACF controller becomes responsible for ensuring separation to avoid collision. The specialist can maneuver only the controlled aircraft. The aircraft pair is declared in conflict by the CA algorithms in the ACCC (2). The CRA is displayed for the controlled aircraft in potential conflict within 1.2 seconds after the prediction of a potential separation violation (3). The controller detects a conflict alert on his console, and responds to an aural signal signifying the conflict alert (4). The controller with the assistance of the ACCC will evaluate potential avoidance maneuvers (5). The conflict is classified as IFR-VFR conflict by the system because one aircraft is controlled by the NAS center and the other is not (5.1). Next, both right and left

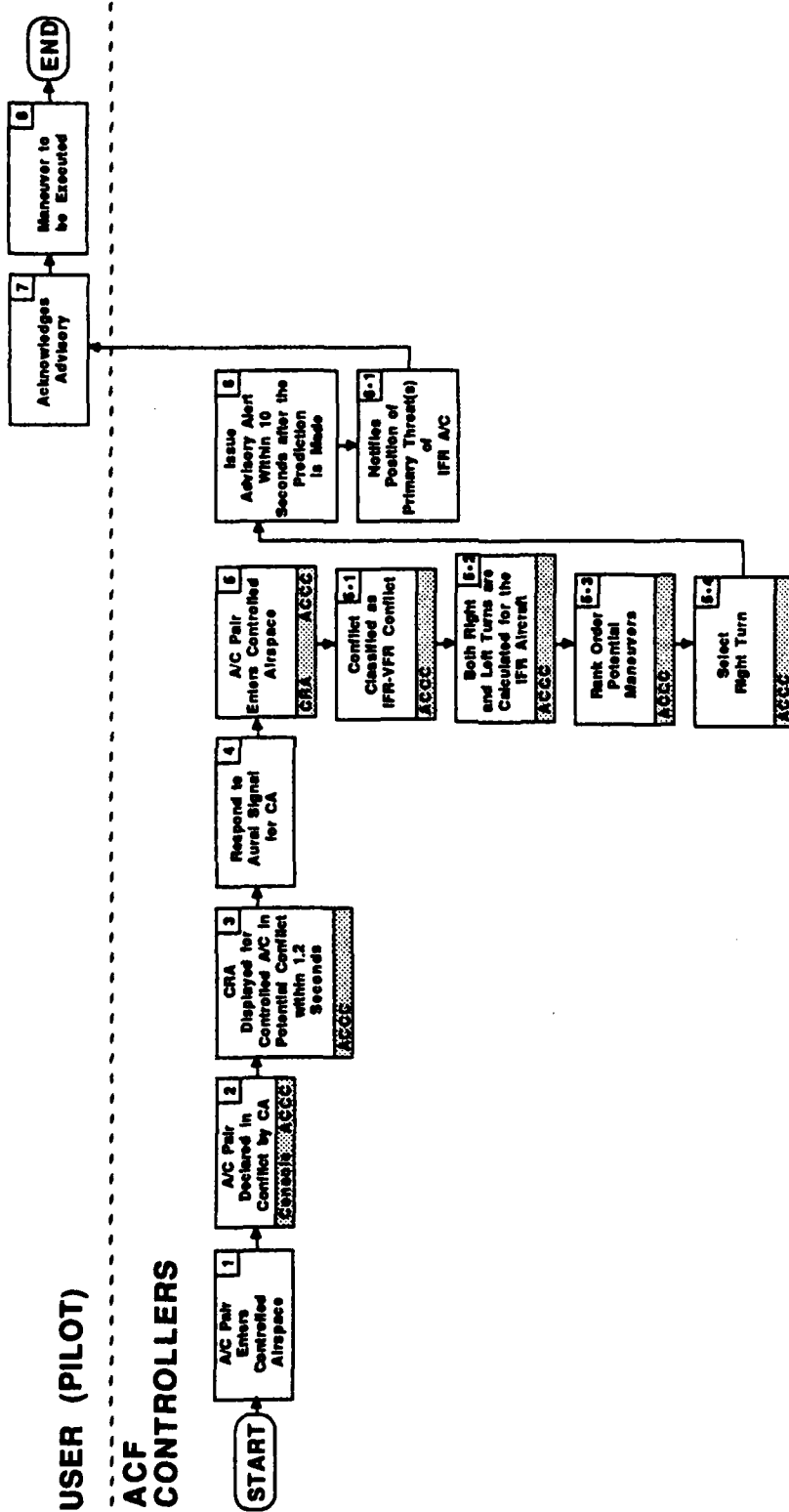


FIGURE 2-7
CONFLICT DETECTION BETWEEN CONTROLLED (IFR) AND UNCONTROLLED (VFR)
AIRCRAFT IN EN ROUTE AIRSPACE: COLLISION AVOIDANCE SCENARIO

turns are calculated for the IFR aircraft (5.2). The system will rank-order potential maneuvers for the controlled aircraft in potential conflict (5.3). The controller selects a right turn (5.4). The controller will issue an advisory alert within 10 seconds after the prediction is made (6), then he notifies the position of the primary threats of IFR aircraft to the pilot (6.1). The pilot acknowledges the controller's advisory (7), and finally, the pilot will maneuver (8).

GLOSSARY OF ACRONYMS

Acronyms

ACCC	Area Control Computer Complex
ACF	Area Control Facility
ADS	Automatic Dependent Surveillance
AERA	Automated En Route ATC
APD	Automated Problem Detection
APR	Automated Problem Resolution
ATAS	Airspace And Traffic Advisory Service
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
ATCS	Air Traffic Control System
ATCT	Airport Traffic Control Tower
CA	Conflict Alert
CRA	Conflict Resolution Advisory
CVFR	Controlled Visual Flight Rules
FAA	Federal Aviation Administration
HF	High Frequency
IFR	Instrument Flight Rules
Mode C	Altitude-encoded Beacon Reply
Mode S	Mode Select Beacon System
NAS	National Airspace System
NASSRS	NAS System Requirements Specification
TCCC	Tower Control Computer Complex
TCAS	Traffic Alert And Collision Avoidance
TPC	TCCC Position Console
TRACON	Terminal Radar Approach Control
UHF	Ultra High Frequency
VFR	Visual Flight Rules
VHF	Very High Frequency
VSCS	Voice Switching And Control System

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