AERA 2 System-Level Information Flows

PB2001-102259

William C. Arthur
Dean F. Dubofsky
Norma J. Taber

REPRODUCED BY:
U.S. Department of Commerce
National Technical Information Service
Springfield, Virginia 22161

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MTR-85W68

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September 1985

MTR-85W68

SPONSOR:
Federal Aviation Administration
Systems Engineering Service
CONTRACT NO.:
DTFA01-84-C-00001
PROJECT:
1762A
DEPT.:
W-42

The MITRE Corporation
Metrek Division
1820 Dolley Madison Boulevard
McLean, Virginia 22102

MITRE Department
and Project Approval: A Haines
A. L. Haines

Group Leader: James A Kingsbury
J. A. Kingsbury

Author Approval: William C Arthur
W. C. Arthur

Dean F. Dubofsky
D. F. Dubofsky

N. J. Taber
N. J. Taber

ABSTRACT

A functional view of AERA 2 processing within the AAS is presented. The AERA 2 functions are identified and located within the data processing activities of the AAS (AERA 1 processing is assumed to be present); processing responsibilities of the AERA 2 functions are addressed; data flows between AERA 2 functions and functions outside of AERA 2 are shown. This document is a product of a structured analysis and system specification technique, and the contents are exhibited accordingly.

AERA 2 introduces an automated capability to derive, and display to an appropriately chosen air traffic controller, resolutions to traffic conflicts, airspace conflicts, predicted noncompliance with certain flow restrictions, and nonconformance problems. The emphasis of this system-level information flows document is to locate these new automation system activities within the context of the other data processing activities of the air traffic control system and to identify needed enhancements to existing data processing functions, especially those belonging to AERA 1. In order to provide a better picture of how AERA 2 functions relate to AERA 2 capabilities and interact with the AAS, the AERA 2 processes are grouped into five categories: Input Processing, Detect Problems, Resolve Problems, Tabulate Workload, and Output Displays. This view is essentially independent of any particular implementation scheme, and addresses the necessary relationships between processing functions associated with AERA 2 and the system environment regardless of the eventual software design.

ACKNOWLEDGMENTS

Many people at MITRE have contributed to the discussions and ideas on which this report is based. Particular thanks are due to James A. Kingsbury for continuing guidance and support. Thanks are also due to Gretchen J. Clark, who provided the graphics, and to the secretaries, particularly Denna L. Black, who helped prepare this document.

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EXECUTIVE SUMMARY

Introduction

The Federal Aviation Administration (FAA) is modernizing and improving the nation's air traffic control (ATC) system, a process which includes the acquisition of a new computer system, the Advanced Automation System (AAS). In addition to existing NAS functions and enhancements, the AAS will incorporate an implementation of Automated En Route ATC (AERA) capabilities. These new capabilities assist the en route sector controller in the detection and resolution of problems: aircraft-aircraft conflicts, aircraft-airspace conflicts, predicted noncompliance with flow restrictions, and aircraft out of conformance with the nominal path predicted for the aircraft. The AERA capabilities are associated with three distinct implementation steps:

- AERA 1 introduces capabilities within the software to detect problems and display problem information to a sector controller. AERA 1 also introduces a method whereby the sector controller can propose flight plan amendments, called trial plans, for aircraft and have these new flight plans examined by the problem detection capabilities.

- AERA 2 introduces capabilities within the software to automatically generate alternatives which resolve problems detected by the AERA 1 problem detection capabilities, and display these alternatives to a sector controller. AERA 2 also introduces automation system support for nonvoice coordination between controllers.

- AERA 3 introduces machine decision-making into the ATC process. The machine is given responsibility for separation for some (as yet undetermined) segment of the traffic population.

This report allocates AERA 2 processing among several identified functions. This report, then, provides a concise explanation of the functions that are associated with AERA 2 and describes the AERA 2 capabilities within the context of the data processing activities of the AAS. The top-down decomposition of AERA 2 provided in this document uses a structured analysis and structured specification methodology, and defines the interfaces, data flows, and logical processing sequences required for each function at each level of decomposition. The system decomposition presented in this document demonstrates certain capabilities which are required in any

implementation of AERA 2 and suggests a reasonable method of achieving the capabilities. The emphasis is upon the additions, extensions, and modifications to the AERA 1 capabilities.

An Operational View of AERA 2

In AERA 2, as in AERA 1, all current plans are continually monitored. Conformance Monitor automatically checks track information and trajectory information to determine if the aircraft is sufficiently close to the planned trajectory. Situation Monitor automatically checks for new aircraft-aircraft conflicts (within the 20 minute horizon) and flow, metering, and airspace restrictions (within and beyond the horizon).

As problems are detected by either of the monitors, the AERA 2 capability, Automated Problem Resolution (APR), provides computer-generated resolutions using machine-encoded rules. Generally, a set of resolutions is provided for display to the controller for a problem identified by the automation system. Resolutions are provided in a rank ordered list (the rank ordering is, again, provided through machine-encoded rules) with that resolution deemed most appropriate appearing first. All proposed resolutions are checked for any new problems and that information provided with the resolution notification. APR is also available to the controller for deriving resolutions to problems in trial plans.

The controller could use Controller-Assisted Resolution (CAR, a subcapability of APR) to customize the output of APR to be responsive to his own current situation and maneuver preferences. The controller may constrain the selection of maneuvers for individual aircraft or for a group of aircraft (e.g., those going through the controller's sector). For example, the controller can specify that APR should attempt only a specific maneuver for a specific problem. In this way, the controller interaction acts as a "rheostat," because the controller can assess his own workload and influence the output of APR by prohibiting controller time-intensive resolutions.

After receiving suggested resolutions, the controller may adopt one and make that computer-generated plan the current flight plan for the aircraft. The controller, conversely, may reject all suggested resolutions. In that event, he may elect to solve the problem via the Trial Planning capabilities of AERA 1.

The controller is assisted in the negotiation of trial plans and computer-generated resolutions by Automated Coordination. Automated Coordination provides for the transfer of trial plans or computer-generated resolutions to other controllers for their information or approval. It can also be used for requests to Traffic Management.

AERA 2 accommodates a digital data link as a communications medium for transmission of control information to properly equipped aircraft. The data link medium could also be utilized to convey other non-AERA 2 data to the aircraft from the ground (e.g., weather information). However, the requirements, constraints, and procedures for utilization of data link are in the very early stages of coordination at the FAA, and those requirements, constraints, and procedures are not implied in this document.

Discussion

AERA 2 achieves its goals by processing flight intent information, which is the integration of pilot intent and ATC intent for a given flight. Pilot intent is provided by the pilot in the filed flight plan and pilot-initiated changes. ATC intent is provided by the ATC system designating proposed or actual changes to the intent for a given aircraft. Together, pilot intent and ATC intent form a basis upon which the path of the aircraft can be predicted. For each aircraft in the system, using predicted paths kept current with a feedback loop from surveillance data processing, AERA 1 functions predict possible problems and AERA 2 functions suggest resolutions to those problems. The resolution process derives alternative resolutions by proposing ATC changes to the intent of one or more of the aircraft involved in the predicted problem. Information generated by the problem prediction and resolution capabilities is tracked in this document.

Furthermore, AERA 2 responds to controller constraints on the resolution process. The controller may set up the resolution process (as he sees it) in several ways, such as prohibiting certain types of maneuvers and preferring others or prohibiting certain aircraft to be maneuvered while preferring to maneuver others. This information must be available for use by APR so that the proper machine response to problems can be given. In this sense, AERA 2 not only processes intent information (as does AERA 1), but processes controller preference information, as well. The interplay of controller preference information is tracked in this document.

In order to provide a better picture of how AERA 2 functions relate to AERA 2 capabilities and interact with the AAS, the AERA 2 processes are grouped into five categories:

- Input Processing--Information is passed through the AAS to AERA. The input processes are grouped here to show that AERA receives the information it needs. Since this is not an AERA-unique function, these processes are not described in detail.

- Detect Problems--These activities include the AERA 1 capability to detect problems with either current or trial plans. The capability has been expanded to allow detection of problems with plans created under the AERA 2 capabilities. The processes required to provide the Automated Reprobe subcapability are described.

- Resolve Problems--The new capabilities required by AERA 2 are shown. The logical operations required to provide the operational functions of Automated Problem Resolution and Controller-Assisted Resolution are included.

- Tabulate Workload--Workload statistics for sectors are accumulated. These processes were defined in the AERA 1 documents and no changes to this definition are suggested by AERA 2.

- Output Displays--The transfers of information from AERA to the equipment or software that deal with displaying the information to the controller are shown. AERA forwards information that may be desired by the controller to the controller-machine interface software. The processes required to provide Automated Coordination and Data Link communication are also included here.

Each area of AERA 2 processing is further amplified and decomposed into lower-level processes until AERA 2 functions are identified; descriptions of the functions' processing responsibilities are given, emphasizing the use and generation of intent information and the use of controller preference information. Important AERA 2 fuctions supporting the resolution process are located within the structure of Automated Problem Resolution:

- Aircraft Conflict Resolution--proposes actions for aircraft intended to resolve aircraft-aircraft conflicts

- Airspace Conflict Resolution--proposes actions for aircraft intended to resolve aircraft-airspace conflicts

- Flow Restriction Problem Resolution--proposes actions for aircraft intended to resolve predicted noncompliance with flow restrictions

- Nonconformance Problem Resolution--proposes actions for aircraft intended to resolve nonconformance problems

- Automated Coordination--assists the sector controller in coordinating with other controllers (or the Traffic Management Unit)

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1. INTRODUCTION

The Federal Aviation Administration (FAA) is modernizing and improving the nation's air traffic control (ATC) system as part of the National Airspace System (NAS) Plan [1]. Changes to the ATC system will include a new computer system. This computer system, the Advanced Automation System (AAS), will consist of new and upgraded hardware and software [2]. The AAS is expected to improve safety, capacity, productivity, and economy, in part, through higher levels of automation assisting the en route air traffic controller.

In addition to existing NAS functions and enhancements, the AAS will incorporate an implementation of AERA capabilities. The term "AERA" refers to the collection of capabilities related to the automatic detection and resolution of problems.

The initial implementation of AERA, termed AERA 1, will be an integral piece of the AAS. AERA 1 provides support to air traffic controllers in detecting problems and evaluating controller-originated solutions [3]. Several enhancements to the AERA component of the AAS software are planned. The first enhancement has been titled "AERA 2". AERA 2 extends the capabilities of AERA 1 by providing functions that suggest resolutions to the en route controller for detected problems and by assisting in planning aircraft paths.

1.1 Purpose

The purpose of this AERA 2 System-Level Information Flows document is to provide a high-level, top-down view of AERA 2 functions within the structure provided by the AAS with AERA 1 functions present. The view point adopted is entirely behind-the-panel; that is, the functions which the software provides will be identified. These functions and the data flows between them must be identified in order to provide a basis for the AERA 2 system level specification [4], which specifies the functions needed in any implementation of AERA 2. The relationships between MITRE documents describing AERA 2 are shown in Figure 1-1.

This document presents a logical, cohesive description of AERA 2 functions within the context of the AAS. The top-down decomposition of AERA 2 provided in this document defines the interfaces, data flows, and logical processing sequences required for each function at each level of decomposition.

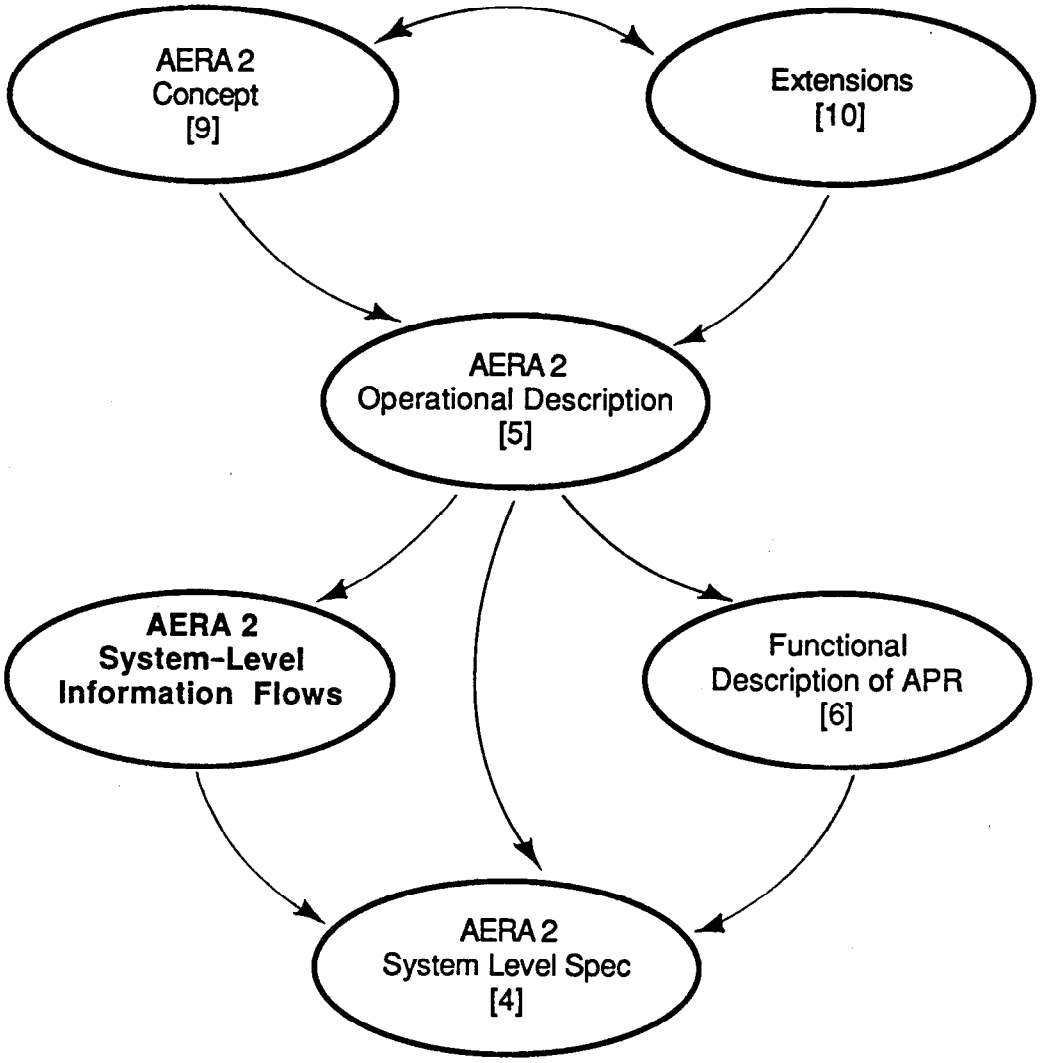


FIGURE 1-1
AERA 2 DOCUMENT DEPENDENCIES

Previous work has defined AERA 1 and its relationship with the AAS [3]. The modifications of the AERA 1 structure required by the AERA 2 capabilities will be discussed in this document.

The system decomposition presented in this document demonstrates certain capabilities which would be found in any implementation of AERA 2 and suggests a reasonable method of achieving those capabilities. The functions described in this document respond to the operational needs described in the AERA 2 Operational Description [5]. This document establishes that the description of the automated problem resolution capability given in the Functional Description of AERA 2 Automated Problem Resolution [6] is consistent with the automated problem resolution capability described by the AERA 2 Operational Description [5]. The creation of this work served to detect and remove any inconsistencies between the AERA 2 Operational Description [5] and the Functional Description of AERA 2 Automated Problem Resolution [6] documents. This presentation is not meant to suggest an implementation scheme, but rather to identify the information necessary to provide the AERA 2 capabilities. It provides enough design details to define and specify the functional components of AERA 2. The level of detail presented here provides a basis for the estimation of the amount of coding and storage required to implement the AERA 2 capabilities. The AERA 2 system level specification [4] will use the information in this document to identify the effort entailed in implementing AERA 2.

1.2 Scope

This report is a description of the logical constructs necessary to provide the AERA 2 functions. The information required to perform the functional needs set forth in the AERA 2 Operational Description [5] and in the Functional Description of AERA 2 Automated Problem Resolution [6] are identified. This document is not concerned with the actual details of the design such as the manner in which the AAS directly interacts with the controller (e.g., displays, data entries, inquires, commands). Other portions of the AAS are assumed to provide all necessary information needed for AERA functions. In turn, AERA is assumed to provide the requested information to the portions of the AAS that respond to controller needs.

While AERA 2 includes all the AERA 1 capabilities, the emphasis of this AERA 2 information flows document is upon the additions, extensions, and modifications of the AERA 1 information flows that are required by AERA 2. The information flow diagrams presented here exhibit AERA 1 processes for

completeness. Since this AERA 2 System-Level Information Flows document is based on the AERA 1 System-Level Design [3], the use of function names and definitions reflect those used in the AERA 1 documents [3, 7] rather than, for example, those in the AAS System Level Specification [2]. The description provided in the AERA 1 documentation [3, 7] remains unchanged for some of the AERA 1 processes. Rather than copy the explanations of purely AERA 1 functions, the description of those AERA 1 capabilities in the AERA 1 design documents will be referenced.

The AAS will receive information from many parts of the NAS. Figure 1-2 provides an overview of the systems that provide information to the AAS. For the purposes of this document, AERA 2 is not portrayed as receiving any data directly from sources outside the AAS, but as receiving information that is maintained by other parts of the AAS. AERA will derive information desired by other portions of the AAS. The diagrams will show the information flow leaving the domain of concern. The real recipient of the information is not important for this document. The emphasis will be on the information content of an information flow, not the origin or destination.

1.3 Organization

This report is organized into four sections. Section 2 provides an abbreviated explanation of AERA 2. Several AERA 2 concepts originate in AERA 1, but are modified in order to conform to the intent of AERA 2. These concepts will be redefined. The explanation is given from two perspectives: operational and functional. The operational perspective is a front-of-the-panel discussion of AERA capabilities, summarized from the AERA 2 Operational Description [5], and given here as an introduction to the functional discussion. The emphasis is on how the controller would interact with AERA. The functional discussion is a behind-the-panel discussion of AERA capabilities. The emphasis is on how the software goes about accomplishing the operational scenario.

The remaining sections, Sections 3 and 4, describe the AERA 2 capabilities within the context of the data processing activities of the AAS. The capabilities are described using data flow diagrams, minispecifications, and a data dictionary. A similar methodology was used in the AERA 1 documents [3, 7]. A synopsis of the methodology is given in Appendix A. The differences from the use of the methodology for AERA 1 are described below. Section 3 describes the data flows and transforming processes which are required by AERA 2. The transformations are successively decomposed until the

Domain of Study Diagram

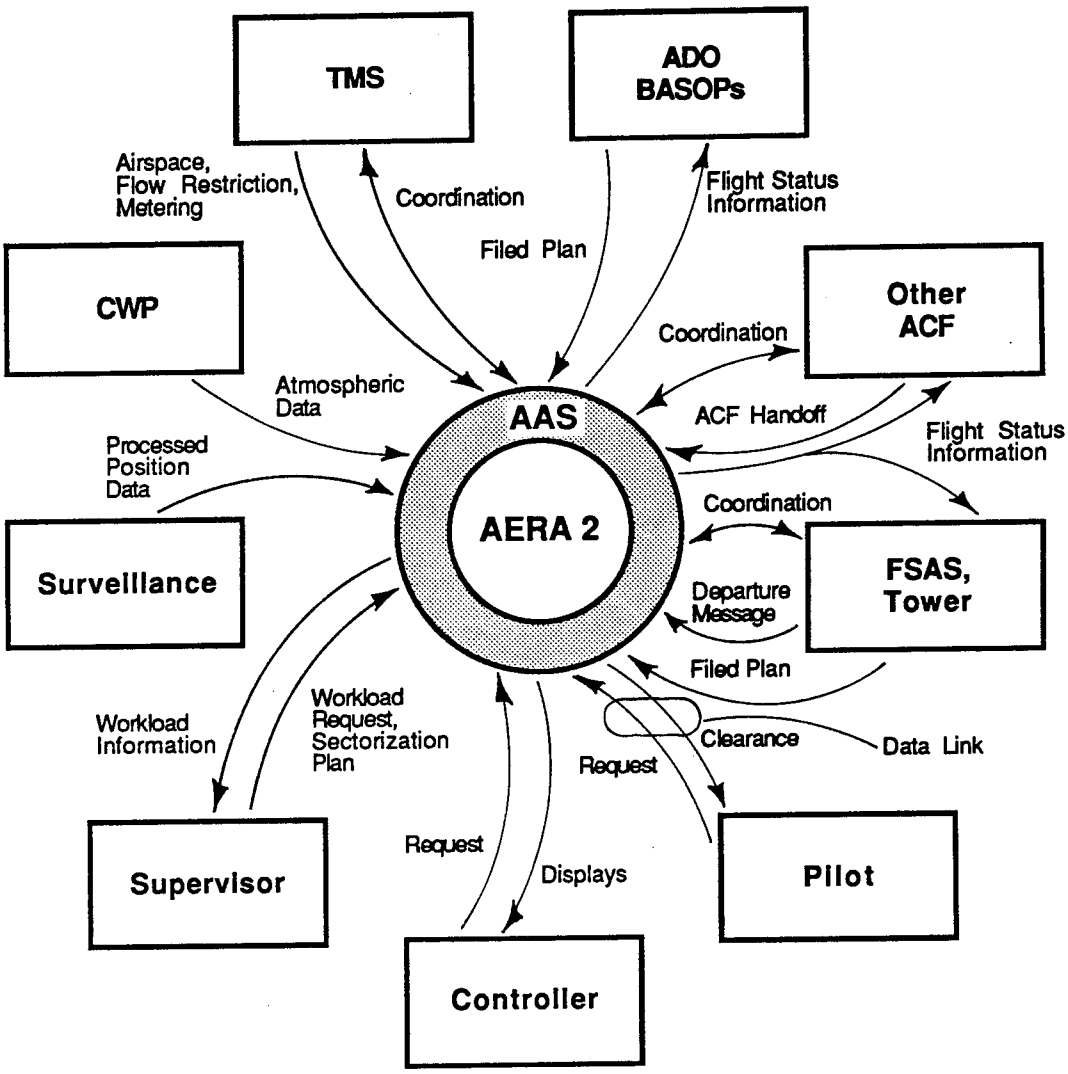


FIGURE 1-2
DOMAIN OF STUDY

decomposition is terminated with the identification of AERA 2 functions. An AERA 2 function is a major building block. Each AERA 2 function performs a definitive, logically cohesive portion of the necessary data processing. Each AERA 2 function is identified and its processing responsibilities briefly described in Section 3. Further detailed functional descriptions of some important AERA 2 functions are provided by the Functional Description of AERA 2 Automated Problem Resolution [6]. The description of the transforming process (at the last level of decomposition) is called a "minispecification" and is written in structured English. Section 4 contains a data dictionary which defines the data manipulated by the processes described in Section 3.

While the methodology is still consistent with the structured specification methodology defined by DeMarco [8] and used for AERA 1, some changes were made to simplify and clarify the information flows. The major change in the methodology is the use of control flows (represented by dashed named vectors) to trigger processes. Instead of passing information directly between two processes along a data path (represented by a solid named vector), the information is stored in a database by one process, a second process is triggered along a control path, and the information is accessed from the database by the second process. This convention avoids redundant data dictionary entries which were needed in AERA 1 to define both the stored and passed data.

1.4 Limitations

This document is based on the information contained in the AERA 2 Operational Description [5] and Functional Description of AERA 2 Automated Problem Resolution [6] documents. The description of AERA 2 represents the understanding of AERA 2 when the source documents were published.

The content of this report has not yet been validated or tested in an operational setting (e.g., an experimental laboratory or field test). This document is an early step towards a product which must undergo tests to discover where modifications and refinements are necessary and whether enhancements might be worthwhile. Once tested and refined, the resulting product will then be incorporated into the AAS. It should also be noted that no work has been done to ensure the feasibility of any design or any man-machine interface. The latter can only be done in the context of the entire AAS with AERA capabilities.

2. OPERATIONAL AND FUNCTIONAL CONCEPTS

This section provides an abbreviated explanation of AERA. The explanation is broken into three parts. The first part describes AERA within the context of the FAA's overall effort to improve the ATC system. The second section describes AERA in terms of the capabilities that AERA provides to a controller. These capabilities respond to the identified needs of en route controllers [5]. The third section describes the software functions provided by AERA. These functions allow AERA to provide the capabilities described in the second section.

2.1 Background

The AAS is a computer-based system developed by the FAA to respond to the requirements presented in the National Airspace System (NAS) Plan [1, 2]. The goal of the system is to provide safe and economical services to the aviation commmunity. New, upgraded hardware and software will be introduced to achieve the requirements set forth in the NAS Plan. The installation of the AAS is scheduled to occur in the 1990s.

The AAS will provide a new environment in which controllers will perform their duties. Every phase of a controller's activities may be influenced by the AAS. The automation of routine activities will allow a controller to spend more time planning and directing aircraft. New aids to help the controller handle more traffic will be introduced.

The new tools provided by the AAS will affect the way in which air traffic is managed. As an example, in addition to dealing with the problems caused by traffic within an overloaded airspace, the AAS will support efforts to prevent the saturation of an airspace. This will require that the traffic flow be regulated and the AAS will provide traffic flow management support.

AERA refers to the software portion of the AAS which provides automated assistence to the en route sector air traffic controller. AERA will provide the controller with timely, accurate, and complete information. AERA 2 will provide capabilities for the automated detection and resolution of problems involving the failure of aircraft to maintain required separation from other aircraft and from airspaces that have been specially designated by the FAA.

The AERA development program is split into three efforts. The first effort, titled AERA 1, is to develop the capability to detect problems. The capability for the controller to examine temporary plans of his own construction for concomitant problems is included. The second effort, AERA 2, is to develop automated capabilities to aid the contoller in the development of resolutions for machine-detected problems. In the first two efforts, the controller is actively involved in all phases of air traffic control and the AERA capabilities are used at the discretion of the controller. In the third effort associated with AERA, AERA 3, the controller will not be actively involved in some phases of air traffic control and, in these areas, use of AERA is mandatory. In certain cases, for example, the automation will be enabled to send clearances to the pilot.

AERA 2 is an incremental enhancement of the automation of the en route air traffic control tasks provided by AERA 1. AERA 1 monitors the intended flight paths of aircraft as described by their filed or amended flight plans and modified by FAA procedures. It provides the capability to detect possible violation of separation standards by the aircraft as well as the capability to determine if an alternative plan would eliminate the predicted loss of separation. The primary goal of AERA 2 software is to provide greater support to the controller in the creation and implementation of problem-free plans. The support aids added as part of AERA 2 include:

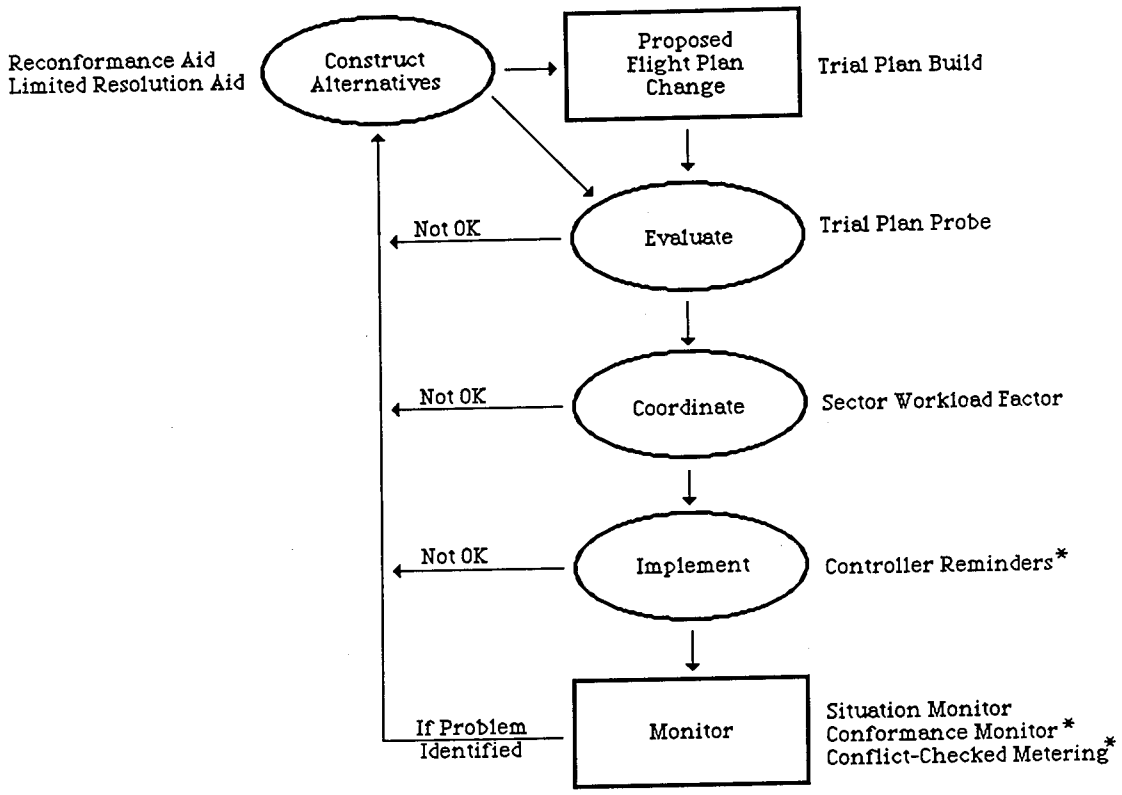
- The capability to generate resolutions to problems detected by the automation
- The capability to provide automated coordination between controllers
- The capability to accommodate, where appropriate, the use of a digital data link for communications between the pilot and the controller

2.2 AERA Operational Concepts

The following three sections summarize the AERA capabilities and the operational concepts associated with their use. A more detailed discussion is available in the AERA 2 Operational Description [5].

2.2.1 A Review of AERA 1 Capabilities

The AERA 1 automated capabilities which are apparent to the controller are illustrated in Figure 2-1. In this discussion,



* Actually an AAS function [2] but described in AERA 1 documents [3, 7] where certain activities were emphasized.

FIGURE 2-1
AERA 1 AUTOMATED CAPABILITIES

the controller's tasks are identified with respect to a request for a flight plan change.

Trial Plan Build assists the controller with the construction of a temporary flight plan, in a form compatible with the automated capabilities, which can be tested for problems by those capabilities.

Upon request by a controller, the trial plan is checked for potential AERA 1 problems in the controller's own sector, in downstream sectors, and with respect to flow constraints. Trial Plan Probe provides an identification of aircraft-aircraft conflicts (to about 20 minutes look-ahead), and potential violations of flow restrictions and airspace restrictions (in both the 20 minute horizon and beyond). As appropriate, the controller coordinates the trial plan with other controllers. Sector Workload Factor provides, upon request, information on the number of aircraft scheduled to be in the controller's sector any time from current time to 20-80 (parameter) minutes from current time. This assists in the evaluation of trial plan coordination requests.

The trial plan may be implemented and made current. All current plans are continually monitored. Conformance Monitor automatically checks to see if the actual aircraft track is sufficiently (parameter distance) close to the planned trajectory. As the ATC environment changes, Situation Monitor automatically checks the trajectory for new aircraft-aircraft conflicts, aircraft-airspace encounters, and predicted violations of flow and metering restrictions. Conflict-Checked Metering automatically checks a proposed metering maneuver for aircraft-aircraft conflicts, aircraft-airspace encounters, and predicted flow restriction violations.

If a problem is detected, AERA 1 provides some assistance in the construction of alternative plans. Reconformance Aid (RA), if invoked by the controller, constructs a trial plan of a type indicated by the controller (e.g., direct to next fix) that would bring an aircraft back into conformance and automatically checks it for problems. Limited Resolution Aid (LRA), if invoked by the controller, constructs up to four plans of a type indicated by the controller (e.g., altitude action), and automatically checks them for problems. The intent of LRA is the exploration of simple maneuvers for conflict resolution purposes, but also may be useful in quickly constructing trial plans to investigate pilot-requested changes to a flight plan.

Additional automation capabilities are provided to the controller to assist in those duties related to the planning and execution of flight plans. Controller Reminders provides the controller with a reminder that a planned aircraft maneuver (e.g., beginning of descent) needs to be accomplished.

2.2.2 AERA 1 Capabilities Modified for AERA 2

AERA 2 provides information not available under AERA 1. Some AERA 1 capabilities could be applied against the new information. Under AERA 2, the AERA 1 automated capabilities are extended in the following ways:

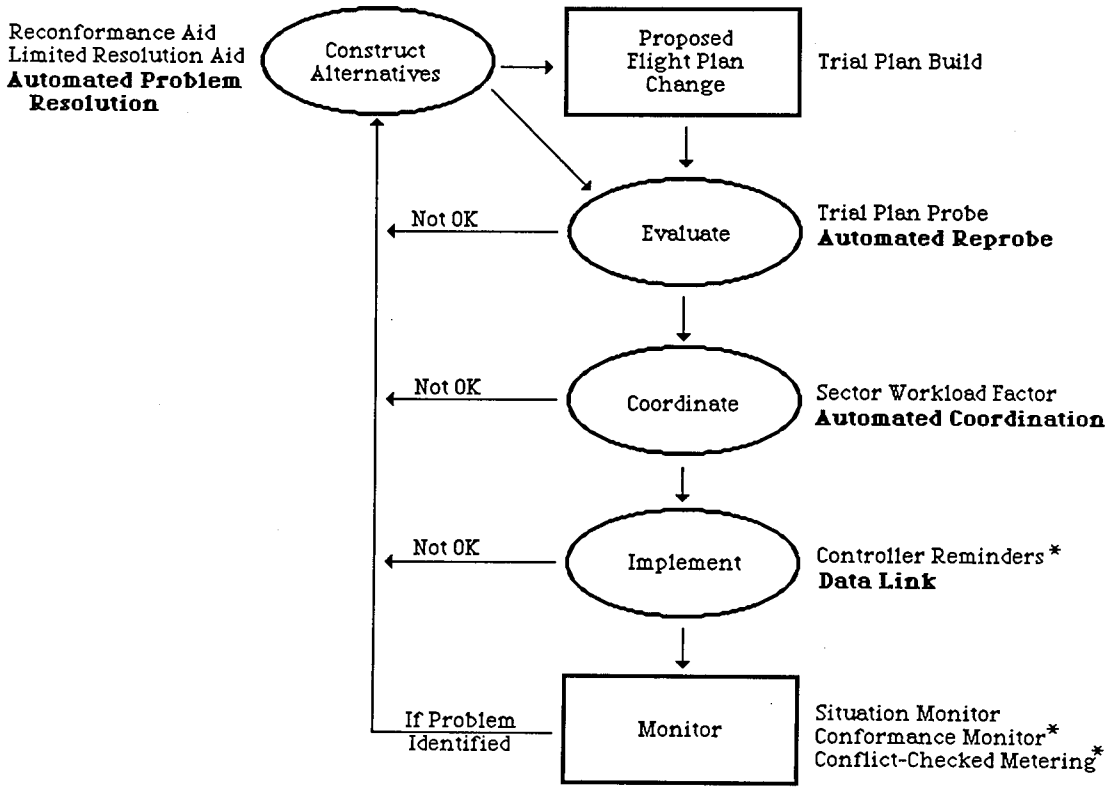
- Situation Monitor includes a capability to identify aircraft which were previously denied a route or altitude request due to a previously existing airspace or flow restriction when the restriction is changed or eliminated.

- Trial Planning includes a capability for the automatic reevaluation of a trial plan at time intervals specified by a controller (Automated Reprobe). (The AERA 1 quick trial planning aids Limited Resolution Aid and Reconformance Aid are subsumed under the AERA 2 Trial Planning capability.)

- Controller Reminders are extended in AERA 2 to provide a more complete list of reminders for the controller. These new reminders concentrate on assisting the controller in maintaining conformance by identifying aircraft which have passed an expected maneuver point.

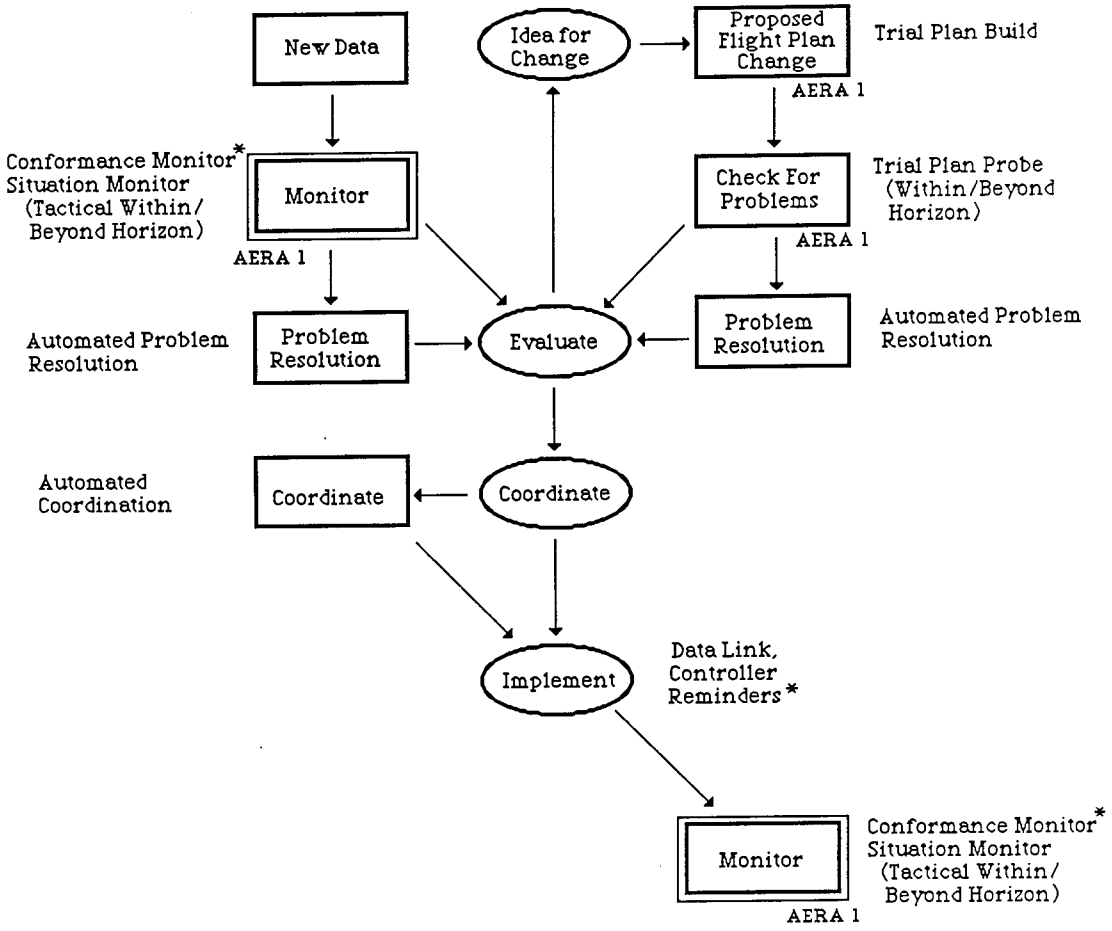
2.2.3 AERA 2

The AERA 2 Automated Capabilities which are apparent to the controller are identified with the aid of Figures 2-2 and 2-3. Figure 2-2 emphasizes the relationship of AERA 2 to AERA 1 by locating AERA 2 Capabilities within the AERA 1 framework (Figure 2-1). Please note that AERA 2 is built upon the entirety of AERA 1 and, in AERA 2, no AERA 1 capability is lost. Figure 2-3 provides an expanded view of AERA 2, emphasizing the resolution of problems detected through Situation Monitor, Conformance Monitor, and Trial Plan Probe. This discussion continues where the discussion of AERA 1 left off.



* Actually an AAS function [2] but described in AERA 1 documents [3, 7] where certain activities were emphasized.

FIGURE 2-2
AERA 1 EXTENDED TO AERA 2



* Actually an AAS function [2] but described in AERA 1 documents [3, 7] where certain activities were emphasized.

FIGURE 2-3
AERA 2 AUTOMATED CAPABILITIES

All current plans are continually monitored. Conformance Monitor automatically checks track information and trajectory information to determine if the aircraft is sufficiently (parameter distance) close to the planned trajectory. Situation Monitor automatically checks the trajectory for aircraft-aircraft conflicts (within the 20 minute horizon), aircraft-airspace conflicts and predicted violations of flow restrictions (within and beyond the horizon).

As problems are detected from either of the monitors, Automated Problem Resolution (APR) provides computer-generated resolutions, in the form of amended plans. A set of resolutions is provided to the controller for each specific problem identified by the automation system. Resolutions are provided in a computer-ranked list with that resolution deemed most appropriate (by the computer, using predefined rules) appearing first. Automated Problem Resolution checks all proposed resolutions for any new problems and provides that information with the resolution notification. APR is also available to the controller for deriving resolutions to problems in trial plans. The controller could use the subcapability of Controller-Assisted Resolution (CAR) to customize the output of APR to be responsive to his own current situation and maneuver preferences. The controller can specify or prohibit the selection of maneuvers for individual aircraft or for a group of aircraft (e.g., those going through the controller's sector). If the controller specifies a maneuver, APR builds machine plans only for those specified maneuvers. If the controller prohibits a maneuver, then APR does not build machine plans for those specified maneuvers, but does build machine plans for other feasible maneuvers. In this way, the controller interaction acts as a "rheostat," because the controller can determine the output of APR by assessing his own workload and prohibiting controller time-intensive resolutions.

After receiving suggested resolutions, the controller may adopt one and make that computer-generated plan the current flight plan for the aircraft. The controller, conversely, may reject all suggested resolutions. In that event, he may elect to solve the problem via Trial Planning capabilities.

The controller is assisted in the negotiation of trial plans and computer-generated resolutions by Automated Coordination. Automated Coordination provides for the transfer of trial plans or computer-generated resolutions to other controllers for their information or approval. It can also be used for requests to the Traffic Management Coordinator (TMC) of the Area Control Facility (ACF).

AERA 2 accommodates a digital data link as a communications medium for transmission of control information to properly-equipped aircraft. The data link medium could also be utilized to convey other non-AERA 2 data to the aircraft from the ground (e.g., weather information). However, the requirements, constraints, and procedures for utilization of data link are in the very early stages of coordination at the FAA, and those requirements, constraints, and procedures are not implied in this document.

2.3 Functional Summary

Section 2.2 discussed the capabilities that should be available under AERA 2. This section will discuss the manner in which AERA 2 is expected to function. The section will be broken into two portions; that is, definitions and functions. The portion containing the definitions will explain the terms and conceptual processing methods used by the functions. The other section will describe the functions developed in response to the AERA 2 capabilities.

2.3.1 Functional Concepts

This section describes terms and concepts used to understand the behind-the-panel operation of AERA 2. The discussion of these concepts will provide an understanding of the way in which the functions will operate.

2.3.1.1 Intent

AERA processes both pilot and ATC intent information. Pilot intent, whose primary expression is the filed or amended flight plan, conveys to the air traffic control system how, when, and where the pilot wishes to conduct the flight. AERA makes no distinction between on-airway flights and off-airway flights when processing pilot intent information. Pilot intent processing is mostly characterized by the processing of flight plan information as originally filed or amended. Since the route a pilot flies frequently requires changes by the ATC system, pilot intent alone is insufficient for the long-range processes of AERA.

ATC intent is embodied in the controller's planning and control activities with individual aircraft. As an aircraft progresses through the sector, a controller may observe a potential problem with the intended path of the aircraft. The controller may clear the aircraft to perform some maneuver in order to avoid the problem. This clearance represents an ATC-originated change

to the pilot's intended flight plan. Pilot intent and ATC intent must be combined to gain enough information to predict the actual path a flight will take.

2.3.1.2 Path Based Problem Detection

AERA 1 and AERA 2 perform problem detection and resolution on the basis of an aircraft's trajectory. The trajectory, or nominal path, is the computer's representation of the path the aircraft is expected to take all the way to the aircraft's destination. The nominal path incorporates both pilot intent and ATC intent as defined above. An aircraft is said to be in conformance with its nominal path if the aircraft's current track position is within parameter distances laterally, vertically, and longitudinally of the planned nominal path position for the same time instant. The nominal path of the aircraft is useful for problem detection and resolution only if the current track position of the aircraft is reasonably close to the position of the aircraft as shown by the nominal path for that time. For AERA 1 prediction and AERA 2 prediction and resolution, the nominal path position is not just a point, but a position within the lateral, vertical, and longitudinal bounds of a conformance region. An aircraft out of conformance with its nominal path may be maneuvered to reestablish conformance or the nominal path may be changed to indicate a new route, altitude, or speed. For longitudinal nonconformance, the system automatically readjusts the nominal path using the aircraft's current position and speed. Reestablishing conformance in this dimension is termed resynchronization.

2.3.1.3 Plans as a Resolution Tool

Trial plans are a mechanism provided to controllers under AERA 1 to evaluate alternative maneuvers for individual flights. This mechanism is sufficient when problem detection is the only service provided for trial plans. Because of the expanded nature of AERA 2, new types of plans are defined. The new types of plans are included to support a controller resolving problems. A plan still includes information necessary for AERA to determine the volume of airspace through which an aircraft following the plan might traverse. The different plan types under AERA 2 are:

- Current Plan - that plan for each aircraft used by the system and specified by a controller as the plan the aircraft is expected to fly.

- Pending Plan - a plan specified by a controller to receive continual monitoring (detection of problems), during negotiation with the pilot or coordination with other controllers, but not necessarily reflecting the intent of a controller for an aircraft.

- Trial Plan - a plan that a controller has entered but not designated as being current and which is not continually monitored.

- Machine Plan - a plan generated by the automated problem resolution capability of AERA 2 for the purpose of resolving a problem detected by AERA functions.

- Dormant Plan - a trial plan which has "timed out" or has been removed from the trial plans list for an aircraft.

The type of plan determines:

- How often AERA monitors the plan for problems

- What causes the plan's type to be changed automatically

- Whether problem resolution is attempted

- Who is notified of problems

The following discussion will elaborate on each plan type individually. Figure 2-4 shows plan interactions. Figures 2-5 and 2-6 summarize the characteristics of each plan type.

Current Plan

That plan specified by a controller to the automation system as the plan the aircraft is currently flying is called the current plan. The current plan for an aircraft is used by any part of the system requiring estimates of aircraft timing or position. Only the current plan is known to AAS functions outside AERA. The current plan for an aircraft remains valid as long as it accurately represents the current position of the aircraft and the current intent of ATC for that aircraft. The current plan for an aircraft is continually monitored for problems. Resolutions to detected problems are provided when appropriate. If the aircraft goes out of conformance with its current plan, the normal detection of problems ceases.

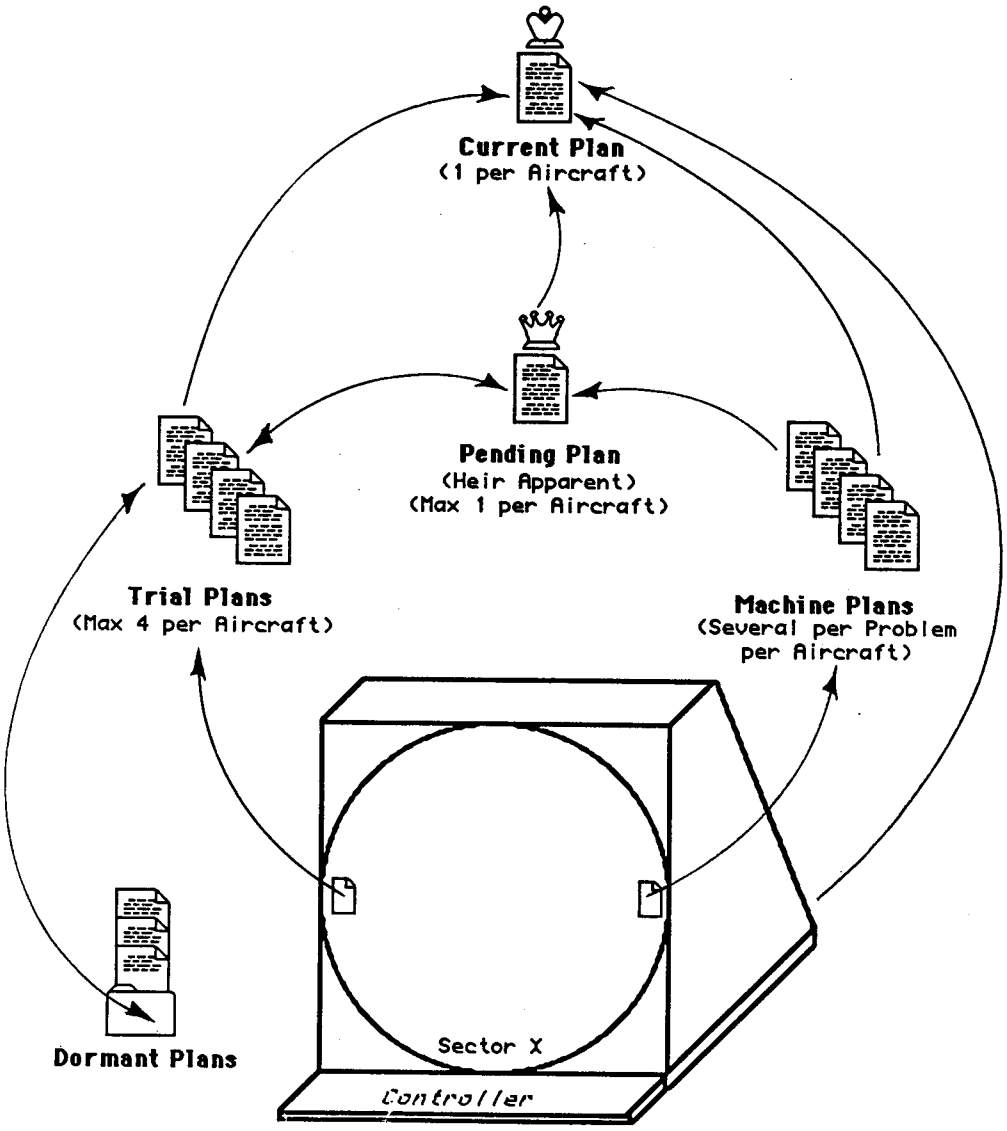


FIGURE 2-4
PROGRESSION OF PLANS

Plan Type Causing Probing* / Plan Type Probed Against	Current	Pending	Trial	Machine	Dormant
Current	Always	Always	Usually** (Controller Must Override)	Always	Never
Pending	Always	Always	Usually** (Controller Must Override)	Always	Never
Trial	Never	Never	At Controller's Instruction	Never	Never
Machine	Never	Never	Never	Never	Never
Dormant	Never	Never	Never	Never	Never

* See Section 3.2.1 for definition of conditions causing plan probing.

** Using CAR, controller can select a trial plan in lieu of a current or pending plan.

FIGURE 2-5
PLAN PROBING

Plan Type	Probing	Automated Resolution Invocation	Automatic Plan Removal Stimuli
Current	Continual	Automatic	Termination by AAS*
Pending	Continual	None	Termination by AAS* Handoff (Controller Can Override)
Trial	Snapshot**	Automatic at Controller's Request	Termination by AAS* New Current Plan Handoff (Controller Can Override)
Machine	Snapshot**	None	Termination by AAS* Disappearance of Problem Handoff Expiration Time Reached
Dormant	None	None	Termination by AAS* Handoff

* AAS flight plan data terminated.

** Only probed at creation of plan.

FIGURE 2-6
PLAN PROCESSING

A controller can replace the current plan with another plan. Information about the old plan is not available to the controller after it is replaced by a new current plan.

Pending Plan

A pending plan is a plan that is expected to become the current plan of the aircraft. There can be only one pending plan per aircraft. Only the owner of a plan can designate the plan as pending. A pending plan is monitored in the same way a current plan is monitored, but only the owner of the pending plan receives notice of problems with current plans. The purpose which a pending plan serves is operational in nature [5]; for example, the controller may be negotiating the details of the plan. Pending plans are not automatically forwarded to APR for resolution.

The current controller can promote a pending plan to current. A controller may remove a pending plan that he owns from the system at any time or demote it to a trial plan. Pending plans may be handed off from sector to sector. If a pending plan is not handed off with the aircraft at the time of transfer of sector control, the plan is automatically removed from the AERA database.

Trial Plan

A trial plan is any plan that the controller creates (including plans generated using LRA or RA). A controller may create a trial plan from scratch or by copying any other plan (and possibly, but not necessarily, modifying it), whether it is a current plan, a pending plan, another trial plan, or a machine plan. The controller may also create a trial plan by requesting a dormant plan from the dormant plan file and modifying it. Finally, a trial plan can always be created from the pilot's originally filed flight plan.

Trial plans are checked for problems with other current or pending plans ONLY at the time of the Trial Plan Probe. Thus, Trial Plan Probe results are only snapshots in time. New problems could arise between the time of the Trial Plan Probe and a subsequent make current or pending request, but they will not be automatically detected by AERA.

A trial plan remains valid as long as that trial plan is less than (parameter) time old and as long as the current plan for

the aircraft remains unchanged from the one in effect at the time of the trial plan's creation. Notification of an invalid trial plan is provided to the trial plan's owner. Within (parameter) time, an invalid trial plan becomes a dormant plan if the controller takes no action.

If a trial plan is promoted to pending or current, the information about the plan must be updated. A trial plan can be removed from the AERA database by the owning controller. The controller can create a limited number of trial plans per aircraft. When the number of trial plans exceeds the limit, the oldest trial plan for that aircraft is made dormant. Upon sector handoff for an aircraft, its trial plans owned by the current controller are made dormant unless the current controller forwards them to the downstream controller.

Machine Plan

A machine plan is any plan generated by AERA 2 Automated Problem Resolution (APR) for the purpose of resolving a problem detected by the AERA functions. (Machine plans do not include plans generated by the controller using the AERA 1 quick trial planning aids LRA and RA; these are trial plans.) A machine plan may itself harbor problems as detected by the AERA problem detection capabilities, or it may specify a maneuver that is less than ideal (e.g., a vector has been prescribed that crosses an additional sector boundary). Machine plans with problems (or that are less than ideal) are said to have objections. APR provides an expiration time for each machine plan. Beyond the expiration time, the machine plan is considered invalid.

Machine plans are treated differently from trial plans as follows:

- Machine plans are not automatically forwarded to APR, even if the controller has set up his sector to have automatic conflict resolution for trial plans.

- Machine plans which are invalid are immediately resubmitted to APR to be replaced by a new version using the same maneuver (described below in Section 2.3.2.1).

If a machine plan is promoted to pending or current, the information in the machine plan is updated. A controller can remove a machine plan from the AERA database. (This will also prevent regeneration of the machine plan.) Since a set of

machine plans is provided by APR for a problem, all of the machine plans in a set are removed from the AERA database when one of the set is promoted to current (or to current after promotion to pending). Machine plans are also removed from the AERA database automatically when the problem addressed by a machine plan no longer exists.

Dormant Plan

A dormant plan is a trial plan whose status was automatically lowered because of one of the following:

- The current plan is now different from the current plan in force when this trial plan was created.
- The trial plan reached a system parameter time limit in age.
- The maximum number (parameter) of trial plans for this aircraft is exceeded, causing the oldest trial plan for this aircraft to be removed from the list of trial plans.

A dormant plan still exists within the AERA database. A dormant plan contains enough information for regeneration of a nominal path. A controller can ask the system to retrieve a dormant plan and convert the dormant plan to a trial plan. The controller can edit the dormant plan before its conversion to a trial plan. Dormant plans for an aircraft are removed from the AERA database when the aircraft is handed off to an adjacent sector or facility.

Display and Manipulation of Plans

Various types of plans will be displayed to the controller. The method and organization of the display are beyond the scope of this document. This document will assume that the controller can copy any displayed plan to a working area. The copy of the plan can be modified and/or submitted as a current, pending, or trial plan. Upon entering AERA, it will be treated as a new plan and given a unique identifier.

2.3.1.4 Problem Sets

When several problems are detected, it is necessary to determine which of the problems should be selected for resolution. One choice is to create resolutions for each problem without information about the other problems. This choice has two drawbacks. The resolution of some problems close together in space and time could be accomplished by using information about the problems to build machine plans intended to resolve more than one problem. Secondly, resolution of an earlier problem for an aircraft plan changes downstream events (e.g., timing, location) making the downstream machine plan inappropriate or invalid for the aircraft plan. An alternative choice which avoids either or both of the above drawbacks is to group problems together into "problem sets." A problem set contains problems that are related based upon the aircraft plans in the problems [6] and identify single problems, one-on-many problems, and many-on-many problems. The controller can use CAR to specify that a problem set only contains a specific problem or problems from controller-specified plans.

2.3.2 AERA 2 Functional Areas

Three functions have been developed to meet the capabilities identified by the AERA 2 Operational Description [5]. These functions are:

- Automated Problem Resolution
- Automated Reprobe
- Automated Coordination

2.3.2.1 Automated Problem Resolution

Automated Problem Resolution produces computer-generated solutions to machine-detected problems with other aircraft, with airspaces and flow restrictions, and with conformance. This function can be initiated automatically or at a controller's request.

Automatic Mode

Automated Problem Resolution is initiated automatically to solve problems in current plans whenever either of the following occurs:

- A problem is detected for a current plan by Situation Monitor or Conformance Monitor.

- A previously detected problem disappears (for example, an aircraft whose current plan has a predicted noncompliance with a flow restriction is granted an exemption to that flow restriction).

Automated Problem Resolution is initiated automatically to solve problems in trial plans (as long as the plan was not created by Reconformance Aid or Limited Resolution Aid) whenever Trial Plan Probe detects a problem and the controller has enabled APR for trial plans.

APR is reinitiated when the end of the range of starting times of the earliest maneuver in any machine plan is past; i.e., the machine plan expires. However, APR only replaces a plan with a new version, using the same maneuver type as the plan which expired. APR does not reorder the display of plans at that time.

APR is not automatically initiated by the detection of problems in pending or machine plans.

A number of options are available to the controller with respect to the automatic mode of the Automated Problem Resolution capability. These options may be entered at any time for aircraft currently being controlled by, or for trial plans owned by, the controller. These options are:

- Enabling or disabling the generation of machine plans created to solve problems in trial plans

- Prohibiting types of resolution maneuvers

  - All types for a given aircraft

  - Certain types for all aircraft (e.g., vectors, climbs, right turns)

  - Certain types for a given aircraft

- Specifying that certain types of maneuvers be used

  - For all aircraft

  - For a given aircraft

Controller-Assisted Resolution Mode

The Controller-Assisted Resolution (CAR) mode refers to manual initiation of APR by a controller. The controller has a number of options in using CAR. The options are specifying:

- One (or more) aircraft whose current plans is (are) not to be changed by APR.
- One (or more) aircraft and associated trial plan(s) (invocation of CAR to solve a problem in a machine plan causes it to become a trial plan) such that APR is to assume that the trial plan is the aircraft's current plan; i.e., APR should consider modifying other aircraft plans first.
- A specific problem to be solved in a plan, if more than one exists, but only as long as the problem has been identified by Situation Monitor, Trial Plan Probe, or Conformance Monitor.
- The maneuvered aircraft and maneuver type to be tried, and, if specified, also a starting location or time, turn angle, or magnitude of speed change value.
- Prohibited maneuvers, i.e.,
  - All types for a given aircraft
  - Certain types for all aircraft (e.g., vectors, climbs, right turns)
  - Certain types for a given aircraft
  - Whether the prohibition applies indefinitely or only until the aircraft is handed off to another controller

2.3.2.2 Automated Reprobe

Automated Reprobe is a capability that allows the controller to be notified if a specific clearance change is available for a specific aircraft. A trial plan is created from the controller's specification and is probed every (parameter) minutes or at specified fixes. If and when the plan has no problems, the results are presented to the controller. Automated Reprobe will continue for (parameter) minutes or

until the plan has no problems. Automated Reprobe can be terminated by the controller or by the computer, as described below.

Entries for Automated Reprobe are made through a form of Trial Plan Build, but are limited (for example, by a menu) to only four choices:

- A reroute, starting from the present position (e.g., direct to a specified fix from wherever the aircraft is at the time of the reprobe).
- A reroute, starting at a specific fix on the current route.
- An altitude change from present position.
- An altitude change at a specified fix.

The controller can specify only one trial plan per aircraft per sector to be automatically reprobed.

The trial plan for Automated Reprobe is transferred to the receiving controller at handoff.

If the trial plan that is being automatically reprobed is terminated or made current by the controller, Automated Reprobe stops. If the current plan is updated in a way that affects how the trial plan is to be reprobed, the reprobe stops. However, the reprobed trial plan is not automatically deleted from storage but becomes dormant. The manner in which the current plan is updated may affect the continued desirability of the original reprobed trial plan. For example, if the current plan is changed so that it no longer includes the specified fix at which the reprobe amendment applies, the reprobe is affected and stops.

The controller has the option to edit the reprobed trial plan, terminate the plan, or build a new trial plan to be reprobed.

2.3.2.3 Automated Coordination

Automated Coordination is a capability intended to assist a controller in communicating intent to other controllers or to the local (within the ACF) Traffic Management Coordinator (TMC). In the AERA 2 timeframe, Automated Coordination can be

used when coordination between controllers is required in the acceptance of trial or machine plans for the resolution of problems with a current plan.

The controller of the sector for which Automated Coordination is invoked is the initiating controller; the controllers with whom he coordinates are the receiving controllers. The initiating controller can be any controller. Any receiving controllers are usually designated by AERA 2 with optional modifications to the list of receiving controllers by the initiating controller.

A controller initiates Automated Coordination by designating a pending plan, a trial plan, or a machine plan for coordination. The computer makes the plan a pending plan (if it is not already a pending plan and no pending plan exists for the aircraft) and determines the receiving controllers (if any) for coordination. A current controller can request a list of the receiving controller which the current controller can modify. Automated Coordination will use the controllers specified on the updated list as receiving controllers. If the initiating controller is not the current controller of the aircraft which is the subject of the plan, the only receiving controller is the current controller.

Automated Coordination routes coordination requests to the receiving controllers and/or the TMC. The initiating controller is informed of the reply, if any, that was made by the receiving controllers and/or the TMC within a (parameter) time.

Automated Coordination sends a final response to each receiving controller (except the current controller). If the initiating controller is not the current controller, he receives a final reply of "no response," "unable," or "made current." If the current controller does not make the pending plan current within a parameter time, then Automated Coordination returns the plan to the initiating controller's ownership as a trial plan.

3. SYSTEM DECOMPOSITION

Diagram 0 (Figure 3-1), Intent Processing, displays the initial decomposition of AERA 2 within the structure of the AAS. The decomposition emphasizes the information flow to and from AERA. Certain functions that might be considered to be part of the AAS are included. Those that are included were chosen to make it possible to show the information flow through the AAS destined to affect AERA processing.

The processing is divided into five parts:

- Input Processing (Bubble 1)
- Detect Problems (Bubble 2)
- Resolve Problems (Bubble 3)
- Tabulate Workload (Bubble 4)
- Output Displays (Bubble 5)

Bubble 1, Input Processing, is concerned with the passage of information through the AAS to AERA. The input processes are grouped in this bubble to show that AERA receives the information it needs. Since this is not an AERA-unique function, the processes of Bubble 1 will not be described in detail.

Bubble 2, Detect Problems, includes the AERA 1 capability to detect problems with either current or trial plans. The capability has been expanded in AERA 2 to allow detection of problems with machine and pending plans. The processes required to provide the Automated Reprobe subcapability are also described in this bubble.

Bubble 3, Resolve Problems, describes capabilities required by AERA 2. The logical operations required to provide Automated Problem Resolution and Controller-Assisted Resolution are described in this bubble.

Bubble 4, Tabulate Workload, was defined in the AERA 1 documents [3, 7]. No changes to this definition are suggested by AERA 2, so it will not be described further in this document.

Bubble 5, Output Displays, describes the transfer of information from AERA to the equipment or software that deal with displaying the information to the controller. Various methods of trans-

Diagram 0: Intent Processing (AERA 2)

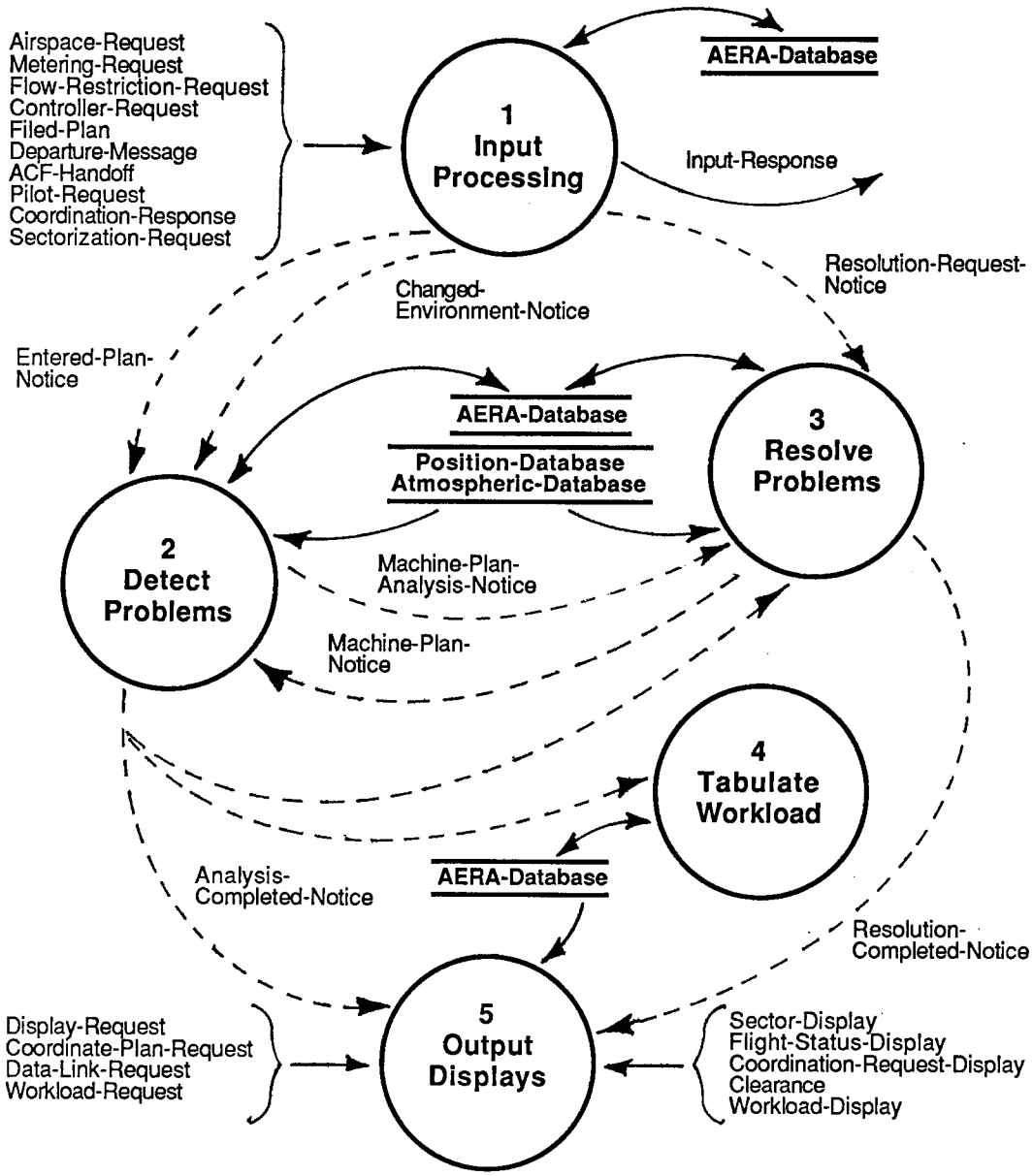


FIGURE 3-1
INTENT PROCESSING

ferring the information are conceivable. Bubble 5 will describe AERA as forwarding all the information that may be desired by the controller to the controller-machine interface. For the purposes of this document, the controller-machine interface is assumed to determine whether, how, and what information to display to the controller. The processes required to provide Automated Coordination and Data Link communication are also described in this bubble.

AERA 2 is defined below by a decomposition of Bubbles 1, 2, 3, and 5 into lower-level bubbles in Sections 3.1-3.4, respectively. Table 3-1 lists the AERA 2 system-level decomposition included in upcoming data flow diagrams.

3.1 Input Processing

Input Processing includes converting flight plans and amendments into machine-useable form, recording updates to airspace and flow restrictions, recording coordination responses, and keeping sectorization information up-to-date. These are AAS processes not unique to AERA, but they are included to show how information becomes available to the AERA processes. The pertinent figures are Figures 3-2 through 3-4.

3.1.1 Description by Levels

Input Processing

Diagram 1 (Figure 3-2), Input Processing, shows four distinct activities:

- Record Airspaces and Flow Restrictions (Bubble 1.1)
- Accept Plan Entries (Bubble 1.2)
- Record Controller Coordination Responses (Bubble 1.3)
- Update Sectorization (Bubble 1.4)

Information is received from external sources via the AAS and recorded in the appropriate AERA database. If an input indicates the need for AERA processing, the required processes are triggered. Each input is acknowledged to the AAS, which passes along any error messages or other responses to external sources.

TABLE 3-1
OUTLINE OF SYSTEM DECOMPOSITION

Process Number	Process Name
0.	Intent Processing (AERA 2)
1.	Input Processing
1.1	Record Airspaces and Flow Restrictions
1.1.1	Record Airspace Change
1.1.2	Record Metering Change
1.1.3	Record Flow Restriction Change
1.2	Accept Plan Entries
1.2.1	Record Resolution Request
1.2.2	Record New Plan
1.2.3	Record Amended Plan
1.3	Record Controller Coordination Responses
1.4	Update Sectorization
2.	Detect Problems
2.1	Build Nominal Path
2.2	Probe Nominal Path
2.2.1	Probe for Aircraft Conflicts
2.2.2	Probe for Airspace Conflicts
2.2.3	Probe for Flow Restriction Problems
2.3	Monitor Nominal Path
2.3.1	Monitor Conformance
2.3.2	Monitor for Reconformance
3.	Resolve Problems
3.1	Form Problem Sets
3.1.1	Form Machine Problem Set
3.1.2	Form Controller-Invoked Problem Set
3.1.3	Monitor Machine Plans
3.2	Build Machine Plans
3.2.1	Airspace Problem Resolution
3.2.2	Aircraft Problem Resolution
3.2.3	Flow Restriction Problem Resolution
3.2.4	Nonconformance Problem Resolution
3.3	Prioritize Machine Plans
3.3.1	Form Objection List
3.3.2	Rank Machine Plans
4.	Tabulate Workload
5.	Output Displays
5.1	Display Plan Data
5.2	Display Controller Reminders
5.3	Coordinate
5.4	Data Link
5.5	Display Workload Statistics

Diagram 1: Input Processing

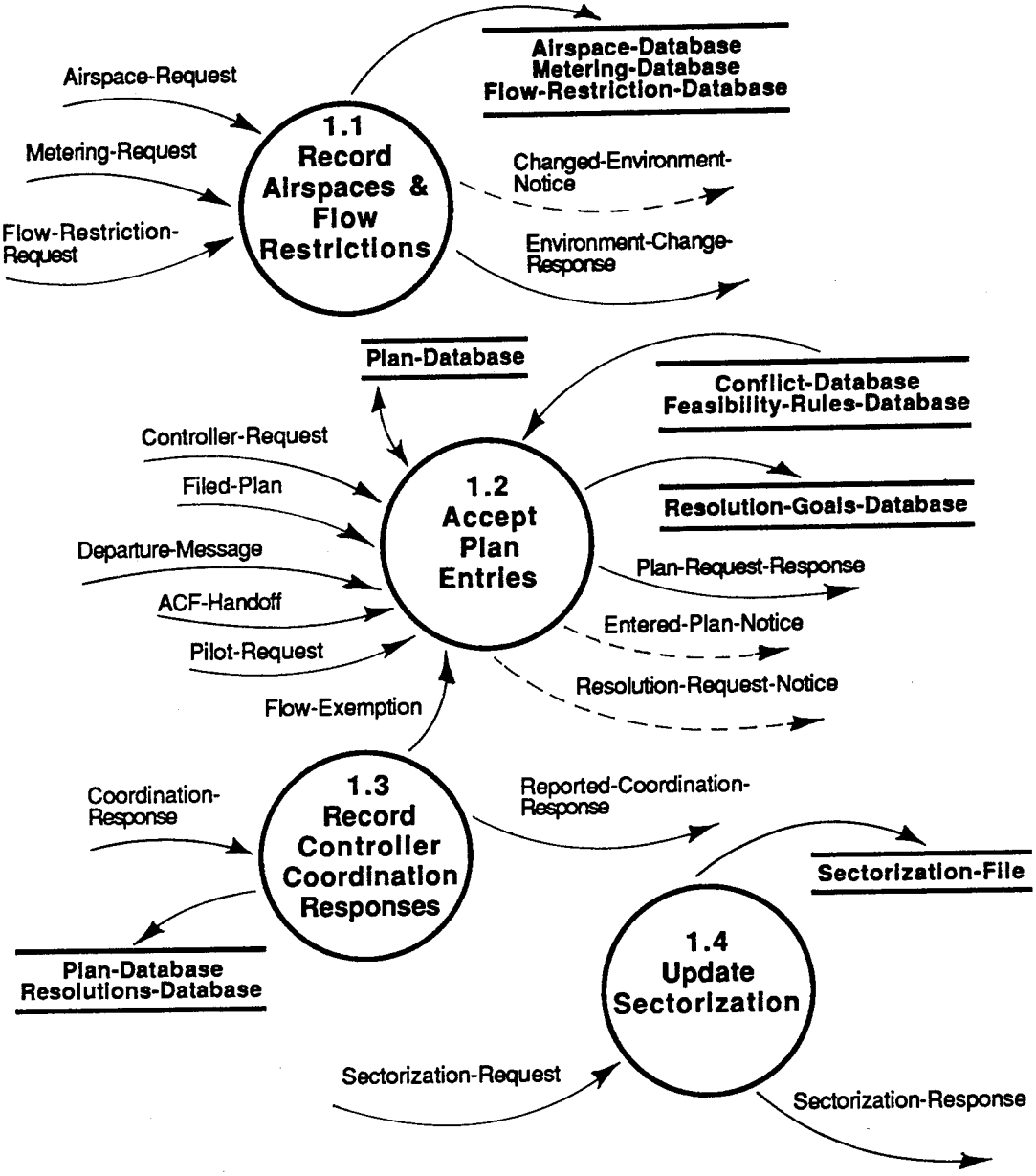


FIGURE 3-2
INPUT PROCESSING

Diagram 1.1: Record Airspaces and Flow Restrictions

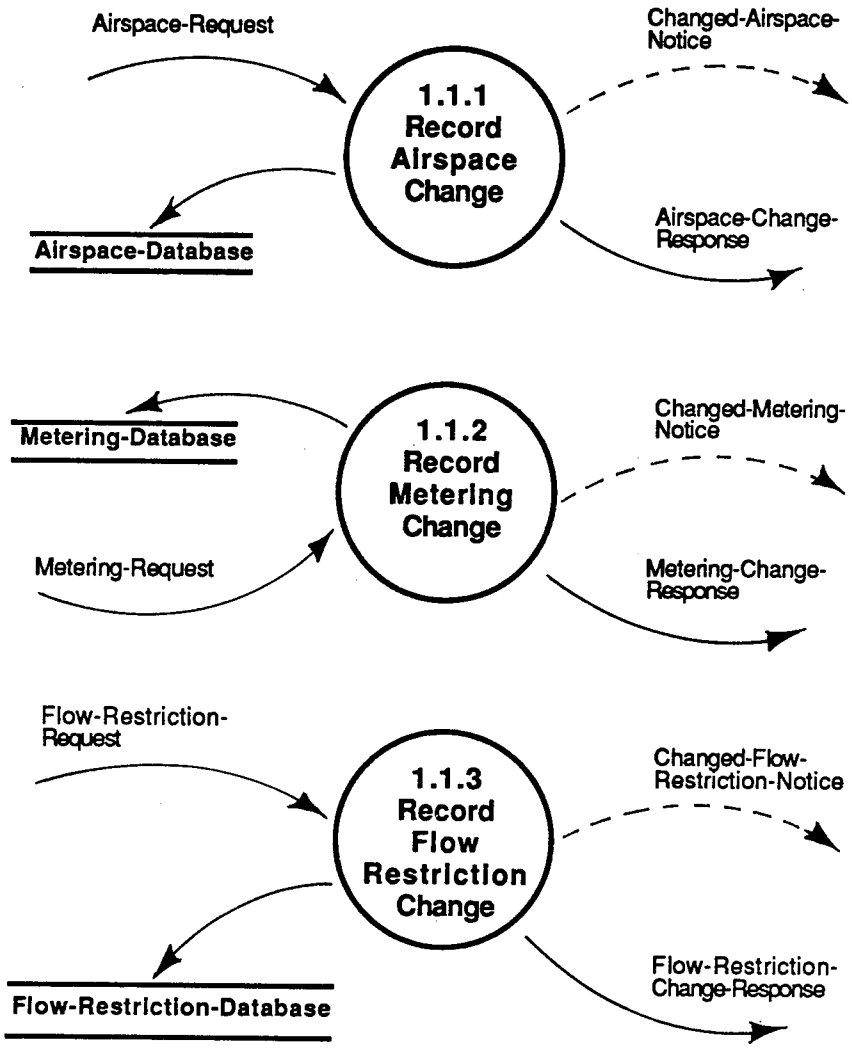


FIGURE 3-3
RECORD AIRSPACES AND FLOW RESTRICTIONS

Diagram 1.2: Accept Plan Entries

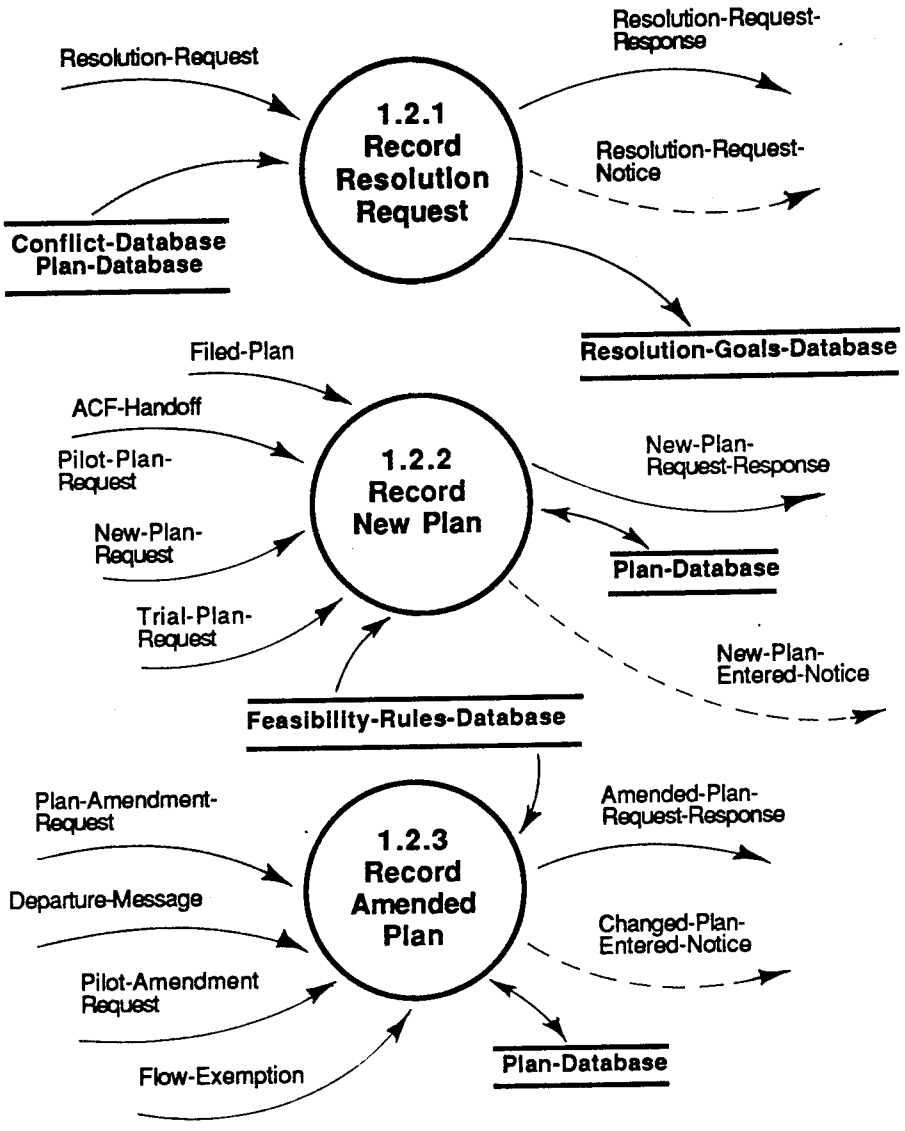


FIGURE 3-4
ACCEPT PLAN ENTRIES

Record Airspaces and Flow Restrictions

Diagram 1.1 (Figure 3-3), Record Airspaces and Flow Restrictions, shows the three parallel processes involved in Bubble 1.1:

- Record Airspace Change (Bubble 1.1.1)
- Record Metering Change (Bubble 1.1.2)
- Record Flow Restriction Change (Bubble 1.1.3).

Record Airspace Change includes essentially the same processes as Bubble 1.1.1 in AERA 1 [3, 7]. Any change to the activation schedule of an airspace or any activation of an ATC-designated airspace must be recorded in the airspace database. Upon completing the change to the data or detecting an error in the request, this process sends a response to that effect to the source of the request. In addition, the probing processes (in Bubble 2) are notified that the airspace database has been changed.

Record Metering Change and Record Flow Restriction Change include essentially the same processes as Bubble 1.1.2 in AERA 1 [3, 7]. Changes to the metering assignments for individual aircraft are handled by Bubble 1.1.2 and changes to flow restrictions which apply to populations of aircraft are handled by Bubble 1.1.3. Upon completing the change to the data or detecting an error in the request, these processes respond to that effect by sending an appropriate message to the source of the request. In addition, the probing processes (in Bubble 2) are notified that the metering or flow restriction databases have been changed.

Accept Plan Entries

Diagram 1.2 (Figure 3-4), Accept Plan Entries, shows three ways plan requests and changes are processed:

- Record Resolution Request (Bubble 1.2.1)
- Record New Plan (Bubble 1.2.2)
- Record Amended Plan (Bubble 1.2.3)

Bubble 1.2.1, Record Resolution Request, accepts a controller's request for Controller-Assisted Resolution. The request is checked for errors. If none are found, the details of the

request are recorded, the resolution processes (in Bubble 3) are notified, and a response is sent to the source of the request that the request was processed. If errors are found, a response to that effect is sent to the source of the request.

The processes of Bubble 1.2.2, Record New Plan, are essentially the same as those in Bubbles 2.1.1, 2.1.2, 2.2, and 2.3.1 in AERA 1 [3, 7] and those in Bubble 3.6, which provide Limited Resolution Aid (LRA) and Reconformance Aid (RA) capabilities in AERA 1 [3, 7]. In addition, requests to use Automated Reprobe are handled by these processes. As happens under LRA and RA, an Automated Reprobe request initiates the automatic formation of trial plans based upon a current plan. New plans are converted and checked for feasibility. If no errors are found, the plan data are recorded, the nominal path building and probing processes (in Bubble 2) are notified, and a response is sent to the source of the request that the request was processed. For a new trial plan, this response includes a list of any other trial or pending plans which apply to the aircraft. If errors are found, a response to that effect is sent to the source of the request.

The processes of Bubble 1.2.3, Record Amended Plan, are essentially the same as those in Bubbles 2.1.3, 2.3.2, 2.3.3, and 2.3.4 in AERA 1 [3, 7], which handle amendments to the plan database. Plan amendments are converted and checked for feasibility. If no errors are found, the plan amendment is recorded, the nominal path building and probing processes (in Bubble 2) are notified, and a response is sent to the source of the request that the request was processed. For an amended trial plan, this response includes a list of any other trial or pending plans which apply to the aircraft. If errors are found, a response to that effect is sent to the source of the request.

3.1.2 Minispecifications

The minispecifications for Bubble 1 follow. Notes for each minispecification provide additional guidelines and information.

Process Name: Record Airspace Change

Process Number: 1.1.1

Processing logic is provided, for the most part, by the minispecification for Bubble 1.1.1 in Section 3.1.2, "System-Level Design of AERA 1 in the Context of the AAS" [3]. Further decomposition of this process is presented in Section 2.1, Maintain Airspace Data, "Automated En Route Air Traffic Control Algorithmic Specifications - AERA 1: Manage NAS Airspace" [7].

Notes:

1. The logic of this process must be modified so that, when an airspace is deleted or its schedule is changed, the probe for airspace conflicts is triggered. This is necessary to determine whether any aircraft has had its plan changed because of a problem with the airspace (that is, its current plan was replaced by a machine plan which resolved a problem it had with the airspace).

2. The logic must also be modified to return Airspace-Change-Response, indicating either that the input Airspace-Request had an error or that the request was carried out.

Process Name: Record Metering Change

Process Number: 1.1.2

SELECT CASE based on Metering-Request type:

CASE 1 (input is Add-Metering-Assignment):

IF the Metering-Database contains any metering assignments with Aircraft-Id (in Metering-Applicability) identical to that of the Metering-Request,

THEN

Form and send Metering-Change-Error-Response.

OTHERWISE,

FOR EACH Metering-Assignment, record it in Metering-Database as follows:

Set Metering-Assignment-Id, assigning a unique identifier.
Set Metering-Applicability, using Aircraft-Id (from Metering-Request).
Set Metering-BAV-Correlations, using Location (from Metering-Request) to determine the appropriate BAVs.

Set Metering-Constraints, using Location and Time.

FOR EACH plan in Plan-Database with Aircraft-Id identical to that of the Metering-Request, set its Metering-Status (in Plan-File) to 'Metered'.

Send Changed-Metering-Notice.

Form and send Metering-Assignment-Added-Response.

CASE 2 (input is Change-Metering-Assignment):

IF the Metering-Database does not contain any metering assignments with Aircraft-Id (in Metering-Applicability) identical to that of the Metering-Request,

THEN

Form and send Metering-Change-Error-Response.

OTHERWISE, replace metering assignments which have Aircraft-Id (in Metering-Applicability) identical to that of Metering-Request, using data in Metering-Request.

Send Changed-Metering-Notice.

Form and send Metering-Assignment-Changed-Response.

CASE 3 (input is Delete-Metering-Assignment):

IF the Metering-Database does not contain any metering assignments with Aircraft-Id identical to that of the Metering-Request,

THEN

Form and send Metering-Change-Error-Response.

OTHERWISE, delete all records in Metering-Database which are keyed on Aircraft-Id in Metering-Request.

FOR EACH plan in Plan-Database with Aircraft-Id identical to that of the Metering-Request, set its Metering-Status (in Plan-File) to 'Unmetered'.

Form and send Metering-Assignment-Deleted-Response.

Notes:

None.

Process Name: Record Flow Restriction Change

Process Number: 1.1.3

Processing logic is provided, for the most part, by the minispecification for Bubble 1.1.2 in Section 3.1.2, "System-Level Design of AERA 1 in the Context of the AAS" [3]. Further decomposition of this process is presented in Section 2.2, Maintain Flow Restriction Data, "Automated En Route Air Traffic Control Algorithmic Specifications - AERA 1: Manage NAS Airspace" [7].

Notes:

1. The logic of this process must be modified so that, when a flow restriction is deleted or its schedule is changed, the probe for flow restriction problems is triggered. This is necessary to determine whether any aircraft has had its plan changed because of a problem with the flow restriction (that is, its current plan was replaced by a machine plan which resolved a problem it had with the flow restriction).

Process Name: Record Resolution Request

Process Number: 1.2.1

SELECT CASE based on type of input Resolution-Request:

CASE 1 (input is Plan-Resolution-Request):

IF plan in request exists (that is, there is a record in Plan-File with same Plan-Id as in request),

THEN

Record input Resolution-Request in Resolution-Request-File (in Resolution-Goals-Database).

Form and send Resolution-Request-Received-Response, using Plan-Id from request.

Send Resolution-Request-Notice.

OTHERWISE,

Form and send Resolution-Request-Error-Response, using Plan-Id from request.

CASE 2 (input is Problem-Resolution-Request):

IF problem in request exists (that is, there is a record in Conflict-Database for which problem information matches Problem-Id in request),

THEN

Record input Resolution-Request in Resolution-Request-File (in Resolution-Goals-Database).

Form and send Resolution-Request-Received-Response, using Problem-Id from request.

Send Resolution-Request-Notice.

OTHERWISE,

Form and send Resolution-Request-Error-Response,
using Problem-Id in request.

Notes:

None.

Process Name: Record New Plan

Process Number: 1.2.2

Processing logic is provided, for the most part, by the minispecifications for Bubbles 2.1.1, 2.1.2, 2.2, and 2.3.1 in Section 3.2.2 and Bubble 3.6 in Section 3.3.1, "System-Level Design of AERA 1 in the Context of the AAS" [3] and Section 2.3, "Automated En Route Air Traffic Control Algorithmic Specifications - AERA 1: Capabilities for Managing Sector Traffic" [7].

Notes:

1. The logic of this process must be modified [5] so that a controller can request that a plan be automatically reprobed with one of a specified set of amendments to a current plan. Upon receiving such a request, the requested amendment and current plan identifier should be stored. Every parameter minutes an amended plan request should be processed, producing a Reprobe-type trial plan (Plan-Status in Plan-File). This plan's Planned-Clearance-Change list should be formed from the current plan's list and the requested amendment.

Each resubmitted plan replaces whichever one was last reprobed for that flight and the results are NOT displayed unless NO problems are found with the plan. If no problems are found, stop reprobing, make the plan a standard trial plan, display the plan to the then-current controller, and report that it is now problem-free. At any time in this process, the controller may request the status of the reprobe and receive a display of the current version and the problems with it. The reprobe expires at the time entered by the requesting controller, when the flight is removed from the system, or upon request from the current controller.

2. The logic must also be modified [5] so that, when a new trial plan is formed, the process returns to the requestor a list of other trial and pending plans which apply to the aircraft.

3. Trial plans produced by the processes described in Bubble 3.6 of AERA 1 must be marked as LRA/RA-type trial plans (Plan-Status in Plan-File), since these trial plans cannot automatically trigger APR [5].

Process Name: Record Amended Plan

Process Number: 1.2.3

Processing logic is provided, for the most part, by the minispecifications for Bubbles 2.1.3, 2.3.2, and 2.3.3 in Section 3.2.2, "System-Level Design of AERA 1 in the Context of the AAS" [3] and Bubble 2.3.4 in Section 1.3.1, "Automated En Route Air Traffic Control Algorithmic Specifications - AERA 1: Management of Flight Intent Data" [7].

Notes:

1. The logic for this process must be modified so that a controller can amend a plan to include the following information:

    - The aircraft is in a nonradar area
    - The aircraft has a failed Mode C transponder

2. The logic must also be modified so that, when a trial amended plan is formed, the process returns to the requestor a list of other trial and pending plans which apply to the aircraft.

3. The logic must also be modified so that, when a machine plan is made current, the process checks to see whether the machine plan resolved airspace or flow restriction problems. If so, the airspace or flow restriction identifier, the aircraft identifier, and the time of exit from the problem must be recorded. For an airspace problem, this is recorded in Airspace-Affected-Plans in Airspace-Conflict-File in Conflict-Database. For a flow restriction problem, the information is recorded in Flow-Restriction-Affected-Plans in Flow-Restriction-Problem-File.

Process Name: Record Controller Coordination Responses

Process Number: 1.3

SELECT CASE based on Coordination-Response type:

CASE 1 (input is 'Approved' or 'Unable' response from a sector to plan coordination):

Record Sector-Response (from Coordination-Response) in Coordination-File, for the coordinated plan and receiving sector (in Coordination-Response).

IF all receiving sectors (and TMC, if appropriate) for that plan have responded,

THEN

IF the plan was forwarded (that is, there is a record in Forwarding-File for it),

THEN record the forwarding sector, setting Receiving-Sector in Coordination-File, with a response of 'Accepted' and remove the record from Forwarding-File.

Summarize coordination responses for plan (from Coordination-File) and record in Coordination-Response-Summary, then remove records for this coordination (from Coordination-File).

Form and send Reported-Coordination-Response, using Coordination-Response-Summary, identifier of plan, and identifier of sector initiating coordination.

CASE 2 (input is 'Unable' response to forwarding of plan):

Set plan status for plan forwarded (in Coordination-Response) to 'trial'.

Determine the sector which initiated forwarding (from Forwarding-File), using the plan identifier from Coordination-Response, then remove record for this forwarding from Forwarding-File.

Return plan ownership to the initiating sector.

Form and send Reported-Coordination-Response, setting Coordination-Response-Summary from 'Unable' response of receiving sector, and using the identifier of the plan forwarded, and the identifier of the sector which initiated forwarding.

CASE 3 (input is response from TMC):

Record TMC-Response (from Coordination-Response) in Coordination-File, for the coordinated plan and TMC.

IF response is 'Approved',

THEN

Form Flow-Exemption, setting Plan-Id and Flow-Restriction-Id from Coordination-Response.

IF all receiving sectors for coordinated plan have responded,

THEN proceed as in Case 1.

In addition, periodically perform the following checks.

FOR EACH Coordination-File record for which Time-Out is less than the current time:

IF the plan was forwarded (that is, there is a record in Forwarding-File for it),

THEN record the forwarding sector in Coordination-File with a response of 'Accepted' and remove the record from Forwarding-File.

Summarize coordination responses for plan (from Coordination-File) in Coordination-Response-Summary, then remove records for this coordination (from Coordination-File).

Form and send Reported-Coordination-Response, using Coordination-Response-Summary, identifier of plan, and identifier of sector initiating coordination.

FOR EACH record Forwarding-File for which Time-Out is less than the current time:

Set plan status for plan forwarded (in Coordination-Response) to 'trial'.

Determine the sector which initiated forwarding (from Forwarding-File), using the plan identifier from Coordination-Response, then remove record for this forwarding from Forwarding-File.

Return plan ownership to the initiating sector.

Form and send Reported-Coordination-Response, setting Coordination-Response-Summary from 'No-Response' of receiving sector, and using the identifier of the plan forwarded, and the identifier of the sector which initiated forwarding.

Notes:

None.

Process Name: Update Sectorization

Process Number: 1.4

Processing logic is provided by a part of the minispecifications for Bubble 1.2.4 in Section 3.1.2, "System-Level Design of AERA 1 in the Context of the AAS" [3] and for Bubble 1.2.4 in Section 2.4.2, "Automated En Route Air Traffic Control Algorithmic Specifications - AERA 1: Manage NAS Airspace" [7].

Notes:

None.

3.2 Detect Problems

The functions developed under AERA 1 for building, probing, and monitoring nominal paths are grouped together in Bubble 2. These functions convert intent data into nominal path information. The nominal path is used to determine whether there are any aircraft-aircraft conflicts, aircraft-airspace conflicts, potential violations of flow restrictions, or nonconformance problems. Enhancements to the probes check for plans affected by changed or deleted airspaces or flow restrictions. In addition, this bubble includes a function to determine when an out-of-conformance aircraft returns to conformance.

The pertinent figures are Figures 3-5 through 3-7.

3.2.1 Description by Levels

Detect Problems

Diagram 2 (Figure 3-5), Detect Problems, shows the three processes involved in building, checking, and monitoring the nominal path:

- Build Nominal Path (Bubble 2.1)
- Probe Nominal Path (Bubble 2.2)
- Monitor Nominal Path (Bubble 2.3)

Building the nominal path in Bubble 2.1, Build Nominal Path, is triggered whenever plan data is changed or added, either from inputs processed in Bubble 1 or from resolutions developed in Bubble 3. Also, Bubble 2.1 is triggered whenever Bubble 2.3 finds that a nominal path needs updating. Upon completing the building of a nominal path, a notice is sent to trigger the probing processes in Bubble 2.2.

Bubble 2.2, Probe Nominal Path, is triggered either by a notice that a nominal path has been completed, as mentioned above, or by a notice from Bubble 1.1 that data on airspaces, flow restrictions, or metering assignments has been changed or added. In either case, the appropriate probe is triggered, previously detected problems for the changed entity are deleted from the Conflict-Database, and any newly detected problems are recorded. Upon completing the probing for a machine plan, the processes in Bubble 3.3 are notified using analysis notices.

Diagram 2: Detect Problems

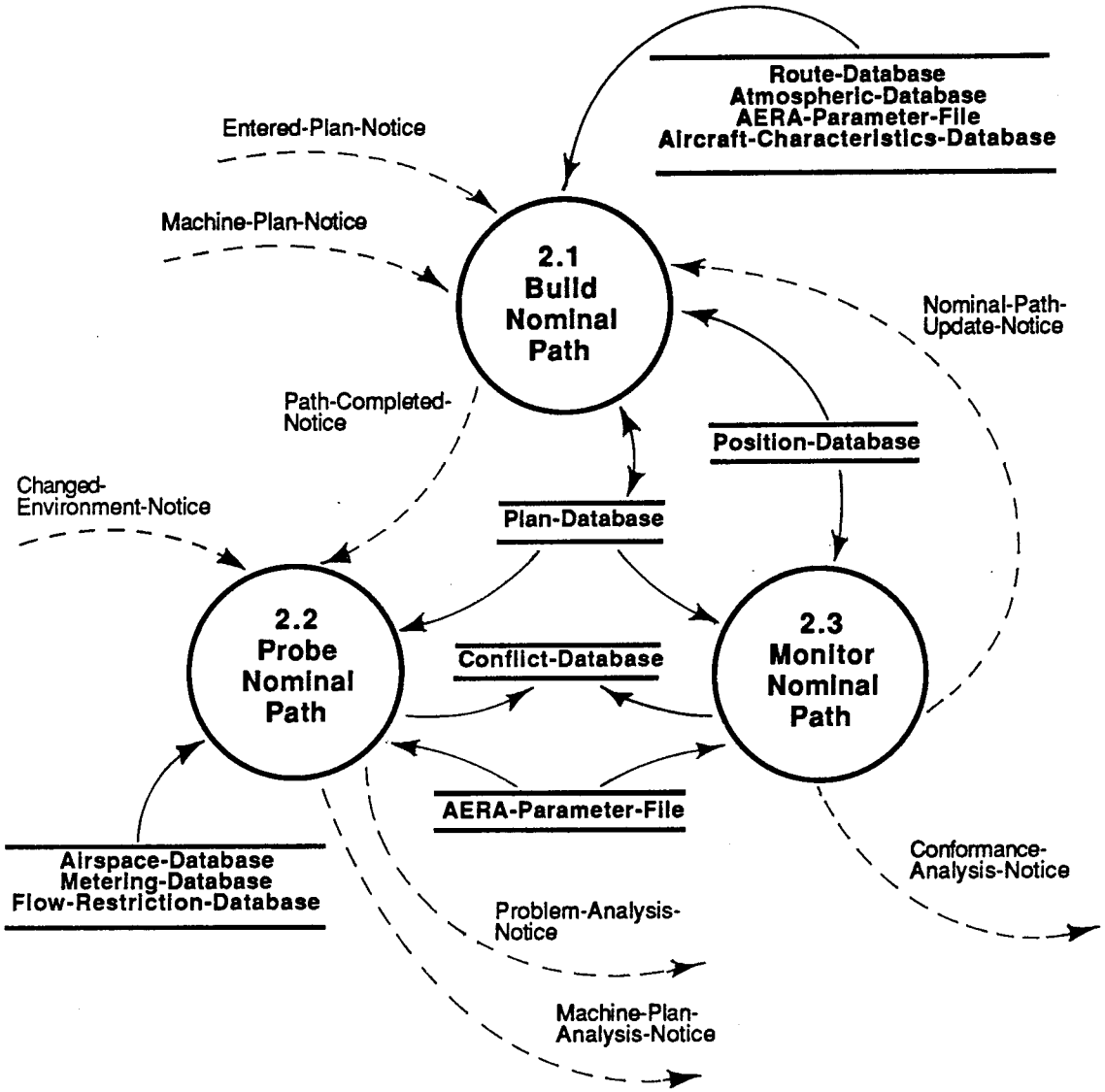


FIGURE 3-5
DETECT PROBLEMS

Diagram 2.2: Probe Nominal Path

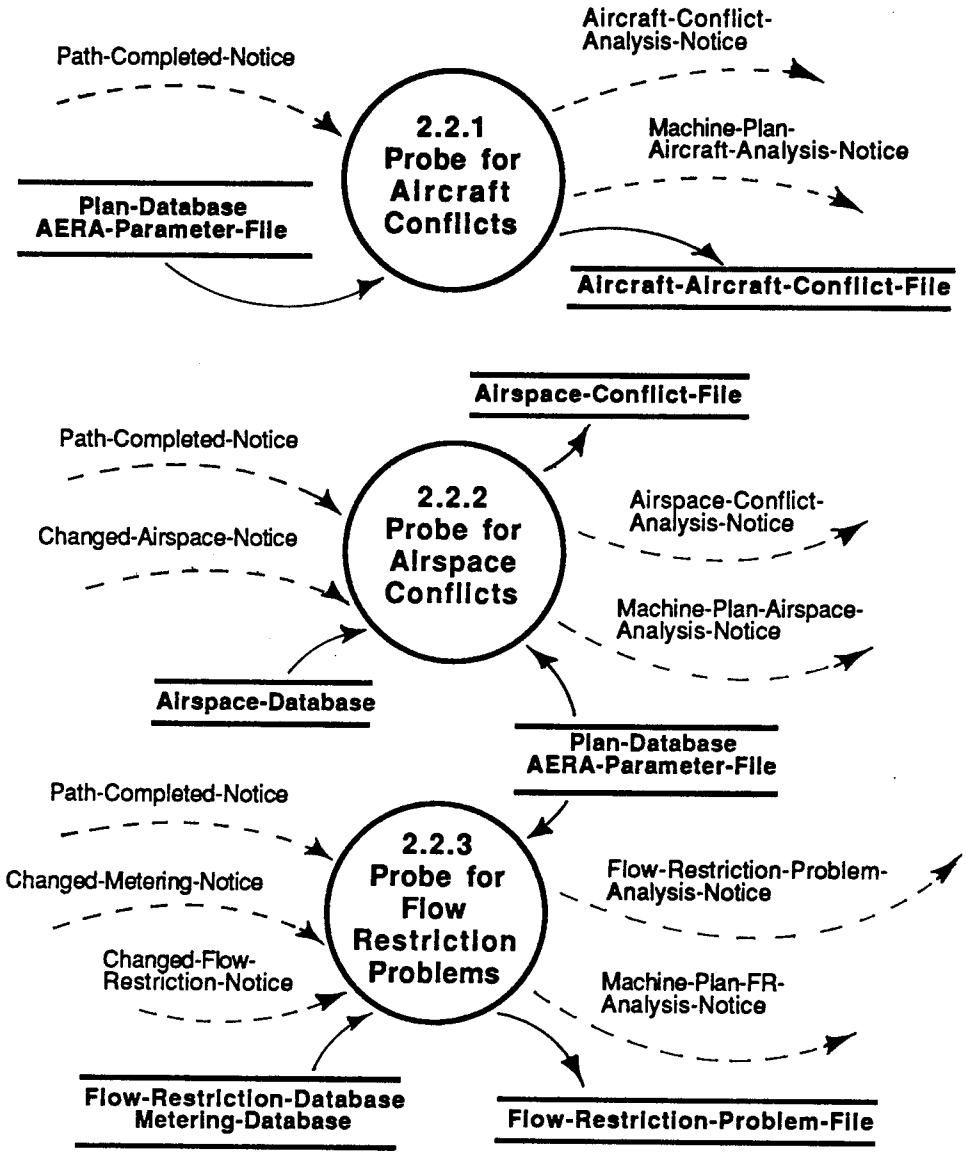


FIGURE 3-6
PROBE NOMINAL PATH

Diagram 2.3: Monitor Nominal Path

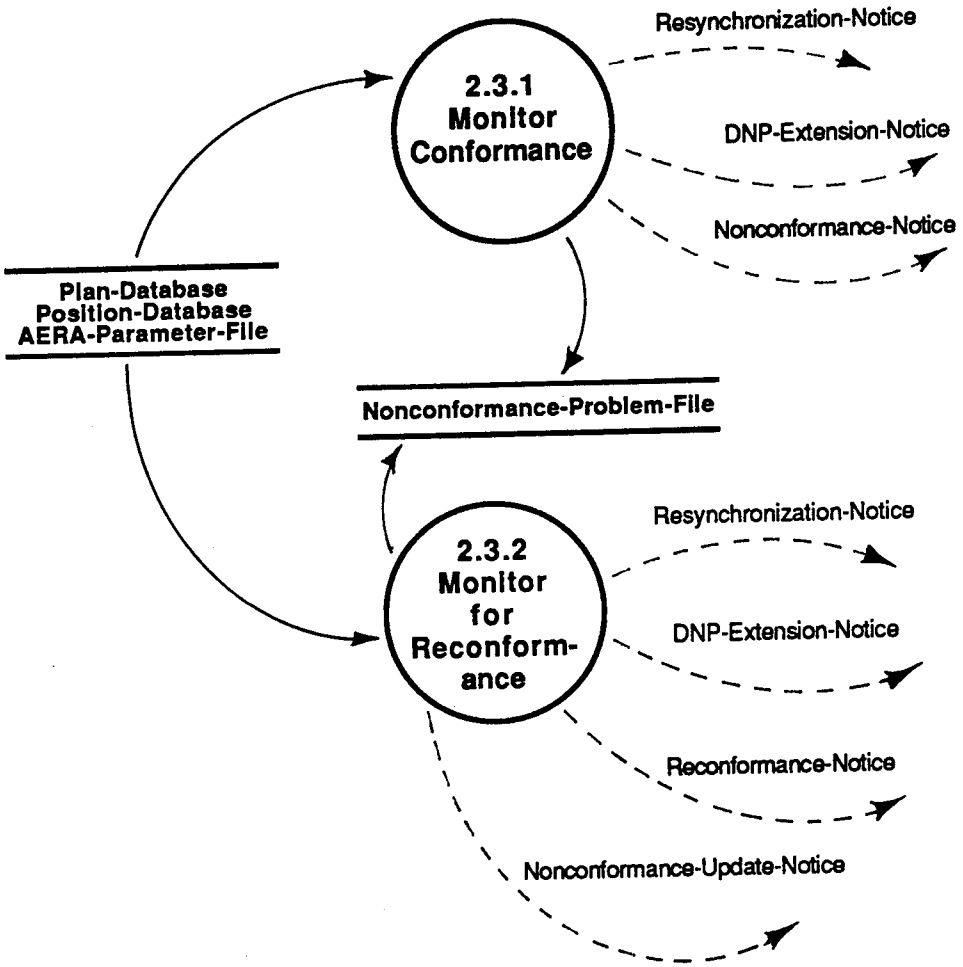


FIGURE 3-7
MONITOR NOMINAL PATH

Upon completing the probing for plans other than machine plans, the resolution and display processes (in Bubble 3.1 and Bubble 5 respectively) are notified that the Conflict-Database has been updated.

The processes in Bubble 2.3, Monitor Nominal Path, are periodically triggered, probably linked to the radar position data update rate. The position data and nominal path data are compared, checking each current and pending plan to determine whether it needs resynchronization, detailed nominal path (DNP) extension, or nonconformance problem resolution. In addition, all current and pending plans with nonconformance problems are rechecked to determine whether the aircraft is now back in conformance. If a need for resynchronization or detailed nominal path extension is found, Bubble 2.1 is triggered to rebuild the path. If a nonconformance problem is detected, Bubble 3.1 is triggered to resolve the problem. The display processes in Bubble 5 are also triggered whenever conformance information is updated.

Probe Nominal Path

Diagram 2.2 (Figure 3-6), Probe Nominal Path, shows the three probing processes:

- Probe for Aircraft Conflict (Bubble 2.2.1)
- Probe for Airspace Conflicts (Bubble 2.2.2)
- Probe for Flow Restiction Problems (Bubble 2.2.3)

Bubble 2.2.1, Probe for Aircraft Conflicts, is triggered whenever the nominal path for a plan is built. The path is probed against the nominal paths of other plans and any detected conflicts recorded. If the path is associated with a machine plan, completion of the probing triggers the final resolution process, in Bubble 3.3. Otherwise, the resolution processes in Bubble 3.1 and the display process in Bubble 5 are notified that probing of an aircraft for aircraft-aircraft conflicts has been completed.

Bubble 2.2.2, Probe for Airspace Conflicts, is triggered whenever the nominal path for a plan is built or information on an airspace is added, changed, or deleted. In the first case, the path is probed against all airspaces and any detected conflicts recorded. In the second, all current and pending plans are probed against the new or changed airspace. When an airspace has been deleted, the current controllers for any current plans

which were changed because of conflicts with that airspace are notified. Appropriate notices are sent upon completion of probing.

Bubble 2.2.3, Probe for Flow Restriction Problems, is triggered whenever the nominal path for a plan is built or information on a flow restriction or metering assignment is added, changed, or deleted. In the first case, the path is probed against all flow restrictions and metering assignments which apply to it and any detected violations are recorded. In the second, all current and pending plans are probed against the new or changed flow restriction or metering assignment. When a flow restriction is deleted, the current controllers for any current plans which were changed because of conflicts with that flow restriction are notified. Again, appropriate notices are sent upon completion of probing.

Monitor Nominal Path

Diagram 2.3 (Figure 3-7), Monitor Nominal Path, shows the processes for detecting nonconformance and reconformance:

- Monitor Conformance (Bubble 2.3.1)
- Monitor for Reconformance (Bubble 2.3.2)

Buble 2.3.1, Monitor Conformance, checks aircraft position reports against nominal paths for current and pending plans. When the reported position of an aircraft is not within the vertical and lateral comformance bounds around the expected position on the nominal path, a nonconformance problem is recorded for that plan and the resolution processes in Bubble 3 are notified. If the reported position deviates longitudinally from the expected position, Bubble 2.1 is triggered to resynchronize the nominal path. If a parameter time has passed since the last rebuilding of the nominal path, Bubble 2.1 is triggered to extend the detailed nominal path.

Bubble 2.3.2, Monitor for Reconformance, checks aircraft position reports against nominal paths for current and pending plans which were found to have nonconformance problems. If the reported position is found to be within the vertical and lateral conformance bounds around the expected position on the nominal path, the nonconformance problem is removed and the display processes in Bubble 5 are notified. If the reported position, for a plan which no longer has a conformance problem, deviates longitudinally from the expected position, Bubble 2.1 is triggered to resynchronize the nominal path. If a parameter

time has passed since the last rebuilding of the nominal path, Bubble 2.1 is triggered to extend the detailed nominal path. Otherwise, if the plan still has a nonconformance problem, the description of the problem is updated and the display processes notified.

3.2.2 Minispecifications

The minispecifications for Bubble 2 follow. Notes for each minispecification provide additional guidelines and information.

Process Name: Build Nominal Path

Process Number: 2.1

Processing logic is provided, for the most part, by the minispecifications for Bubbles 2.4.1 and 2.4.2 in Section 3.2.2, "System-Level Design of AERA 1 in the Context of the AAS" [3]. Further decomposition of this process is presented in Sections 2.2 and 2.3, "Automated En Route Air Traffic Control Algorithmic Specifications - AERA 1: Management of Flight Intent Data" [7].

Notes:

1. The logic for this process must be modified so that, when an aircraft's path enters a nonradar area, the conformance bounds for the portion of the path within the nonradar area are assigned accordingly. The nonradar areas must be made available to the path building processes, just as the boundaries of sectors and wind grid cells are. Appropriate cusps should then be added to the nominal path where it crosses the region boundaries and appropriate conformance bound set between entry and exit.

2. If a controller has specified that an aircraft is in a nonradar area, its entire nominal path must be built with the appropriate conformance bounds. Upon receiving the controller request, the nonradar status of the flight should be recorded in Flight-Plan-Descriptors (in Current-Clearance in Plan-File) for each plan applying to the flight. The path building and probing processes should be triggered, rebuilding the nominal path with the appropriate conformance bounds, as described above.

3. The logic for this process must be modified so that, when a controller has specified that an aircraft has a failed Mode C transponder, its nominal path is built with expanded vertical conformance bounds within the vicinity of an altitude transition. Upon receiving the controller request, the Mode C status of the flight should be recorded in Flight-Plan-Descriptors (in Current-Clearance in Plan-File) for each plan applying to the flight. The path building and probing processes should be triggered, rebuilding the nominal path with expanded vertical conformance bounds on the sections of the path for which the flight is in altitude transition.

4. The logic must also be modified to calculate and record the controller reminders detailed in the AERA 2 Operational Description [5]. Of the two types of reminders described, deliver-clearance reminders and monitor-maneuver reminders, the first type are covered in the AERA 1 documents referenced above. For the second type, the time associated with the controller reminder should be set to some parameter time after the nominal starting point of each turn and altitude change. The reminder message should be set to the appropriate phrase to be delivered to the controller if Bubble 5.2 determines that the reminder is needed.

Process Name: Probe for Aircraft Conflicts

Process Number: 2.2.1

Processing logic is provided, in part, by the minispecification for Bubble 2.5.4 in Section 3.2.2, "System-Level Design of AERA 1 in the Context of the AAS" [3]. Further decomposition of this process is presented in Section 2.7, Checking a Nominal Path Against Other Aircraft Paths, "Automated En Route Air Traffic Control Algorithmic Specifications - AERA 1: Management of Flight Intent Data" [7].

Notes:

1. The logic for this process must be modified to do IFR/VFR intruder alert checking for trial plans against the extrapolated tracks of VFR aircraft and out-of-conformance aircraft.

Process Name: Probe for Airspace Conflicts

Process Number: 2.2.2

Processing logic is provided, for the most part, by the minispecification for Bubble 2.5.3 in Section 3.2.2, "System-Level Design of AERA 1 in the Context of the AAS" [3]. Further decomposition of this process is presented in Section 2.6, Checking a Nominal Path Against an Airspace, "Automated En Route Air Traffic Control Algorithmic Specifications - AERA 1: Management of Flight Intent Data" [7].

Notes:

1. The logic of this process must be modified so that, when an airspace is deleted or its schedule is changed, this process responds to the trigger by determining whether any aircraft has had its plan changed because of a problem with the airspace (that is, its current plan was replaced by a machine plan which resolved a problem it had with the airspace). For each such aircraft, its current controller is notified of this fact. The information needed to determine whether a plan was affected is recorded in Airspace-Conflict-File in Conflict-Database. It is set whenever a machine plan which resolves an airspace problem is made current and includes the airspace identifier, the aircraft identifier, and the time of exit from the airspace problem. If the current plan is then changed, updated, or replaced with any plan which was not a machine plan resolving the problem, the information is removed. In addition, when the above notice is sent, the current time exceeds the exit time recorded, or the aircraft leaves the system, the information is removed.

Process Name: Probe for Flow Restriction Problems

Process Number: 2.2.3

Processing logic is provided, for the most part, by the minispecification for Bubble 2.5.5 in Section 3.2.2, "System-Level Design of AERA 1 in the Context of the AAS" [3]. Further decomposition of this process is presented in Section 2.8, Checking a Nominal Path Against a Flow Restriction, "Automated En Route Air Traffic Control Algorithmic Specifications - AERA 1: Management of Flight Intent Data" [7].

Notes:

1. Although the recording of metering assignments for individual aircraft (Bubble 1.1.2) was shown separately from the recording of other types of flow restrictions (Bubble 1.1.3), this process also checks metering assignments (time at a fix or time at a boundary crossing) for individual aircraft as was described in the AERA 1 documents referenced above.

2. The list of flow restrictions for which this process checks must be enhanced to include two additional types of restrictions:

   - Speed constraint, applied over a defined area on sequence of airways. The filed speed profile and any assigned speeds must be checked against the speed constraint, if this restriction applies.

   - Route constraint, applied to some subset of aircraft, which specifies a sequence of route segments and fixes which must be followed through a specified region.

3. The logic of this process must be modified so that, when a flow restriction is deleted or its schedule is changed, this process responds to the trigger by determining whether any aircraft has had its plan changed because of a problem with the flow restriction (that is, its current plan was replaced by a machine plan which resolved a problem it had with the flow restriction). For each such aircraft, its current controller is notified of this fact. The information needed to determine whether a plan was affected is recorded in Flow-Restriction-Problem-File in Conflict-Database. It

is set whenever a machine plan which resolves a flow restriction problem is made current and includes the flow restriction identifier,the aircraft identifier, and the time of exit from the flow restriction problem. If the current plan is then changed, updated, or replaced with any plan which was not a machine plan resolving the problem, the information is removed. In addition, when the above notice is sent, the current time exceeds the exit time recorded, or the aircraft leaves the system, the information is removed.

Process Name: Monitor Conformance

Process Number: 2.3.1

Processing logic is provided, in part, by the minispecifications for Bubbles 3.5.1 and 3.5.2 in Section 3.3.2, "System-Level Design of AERA 1 in the Context of the AAS" [3]. Further decomposition of this process is presented in Section 2.2, Monitor Aircraft Position Versus Intent, "Automated En Route Air Traffic Control Algorithmic Specifications - AERA 1: Capabilities for Managing Sector Traffic" [7].

Notes:

1. Logic must be added to this process to check conformance with a controller-assigned speed adjustment. This would be done only for changes by the current controller for a current plan. The aircraft ground speed should be sampled a parameter time after the speed change was to start. If the speed change is not within an interval around the requested adjustment, then the current controller is notified of the plan identifier, the assigned speed adjustment, and the detected speed change.

2. This process must also be modified to check conformance for pending plans and trial plans.

3. In AERA 1, the plan identifier of a plan which was to be resynchronized was passed directly to the path building processes. To be consistent with the methodology for AERA 2, this should be done by marking the plan and triggering the path building processes.

Process Name: Monitor for Reconformance

Process Number: 2.3.2

FOR EACH current or pending plan for which a nonconformance problem has been detected (that is, there is a record in the Nonconformance-Problem-File which contains its plan identifier):

Find the most recent position report (from Position-Database) for the aircraft.

Compare the reported position to the expected position (calculated using Cusp-File and interpolating to time of position report) and calculate the lateral, vertical, and longitudinal differences between the two.

IF the differences in all three dimensions are less than the tolerance of the conformance parameters (from Conformance-Parameter-File in Plan-Database) for this plan at the expected position on the nominal path,

THEN

Remove record for plan from Nonconformance-Problem-File.

IF more than a (parameter) time (from AERA-Parameter-File) has elapsed since the last path update (Last-Update-Time in Plan-File),

THEN

Mark this plan (Action-Flag in Plan-File) for nominal path extension.

Send DNP-Extension-Notice.

Send Reconformance-Notice.

OTHERWISE,

IF only the longitudinal difference is greater than the tolerance of the conformance parameters,

THEN

Mark this plan (Action-Flag in Plan-File) for resynchronization.

Send Resynchronization-Notice and Reconformance-Notice.

OTHERWISE,

Update the nonconformance problem description (in Nonconformance-Problem-File of Conflict-Database).

Send Nonconformance-Update-Notice.

Notes:

None.

3.3 Resolve Problems

Bubble 3, Resolve Problems, includes the processes required by Automated Problem Resolution. Problem sets are formed to group associated problems. Problems which cannot be resolved are eliminated from the resolution process and the rationale stored for display. For each problem set with no resolutions, a subset (ususally one problem) is targeted for resolution. Well-defined sets of data, called "specific maneuvers" and intended to resolve the subset, are generated by the appropriate problem resolution function. These specific maneuvers are combined with the current plan to form machine plans, which are sent to the detection processes (Bubble 2) for nominal path construction and probing. The machine plans intended to resolve a problem are ranked, based upon objections, for display to the controller.

The pertinent figures are Figures 3-8 through 3-11.

3.3.1 Description by Levels

Resolve Problems

Diagram 3 (Figure 3-8), Resolve Problems, shows the sequence of steps involved in formulating resolutions to problems detected by Bubble 2:

- Form Problem Sets (Bubble 3.1)
- Build Machine Plans (Bubble 3.2)
- Prioritize Machine Plans (Bubble 3.3)

Bubble 3.1, Form Problem Sets, selects and groups problems that are eligible for resolution. This process is triggered by completion of the problem detection processes discussed in Section 3.2, by a request from a controller, or by a determination that an existing machine plan should be replaced. Any problem which cannot be resolved by the machine or which is not to be automatically resolved is identified. The display processor (Bubble 5) is notified that this process is finished with the resolution of that problem. Otherwise, all problems which are eligible for machine resolution are partitioned so that all problems detected for a given aircraft plan are grouped together. Thus, if an aircraft plan has more than one problem, each of its problems which can be resolved (according to the

Diagram 3: Resolve Problems

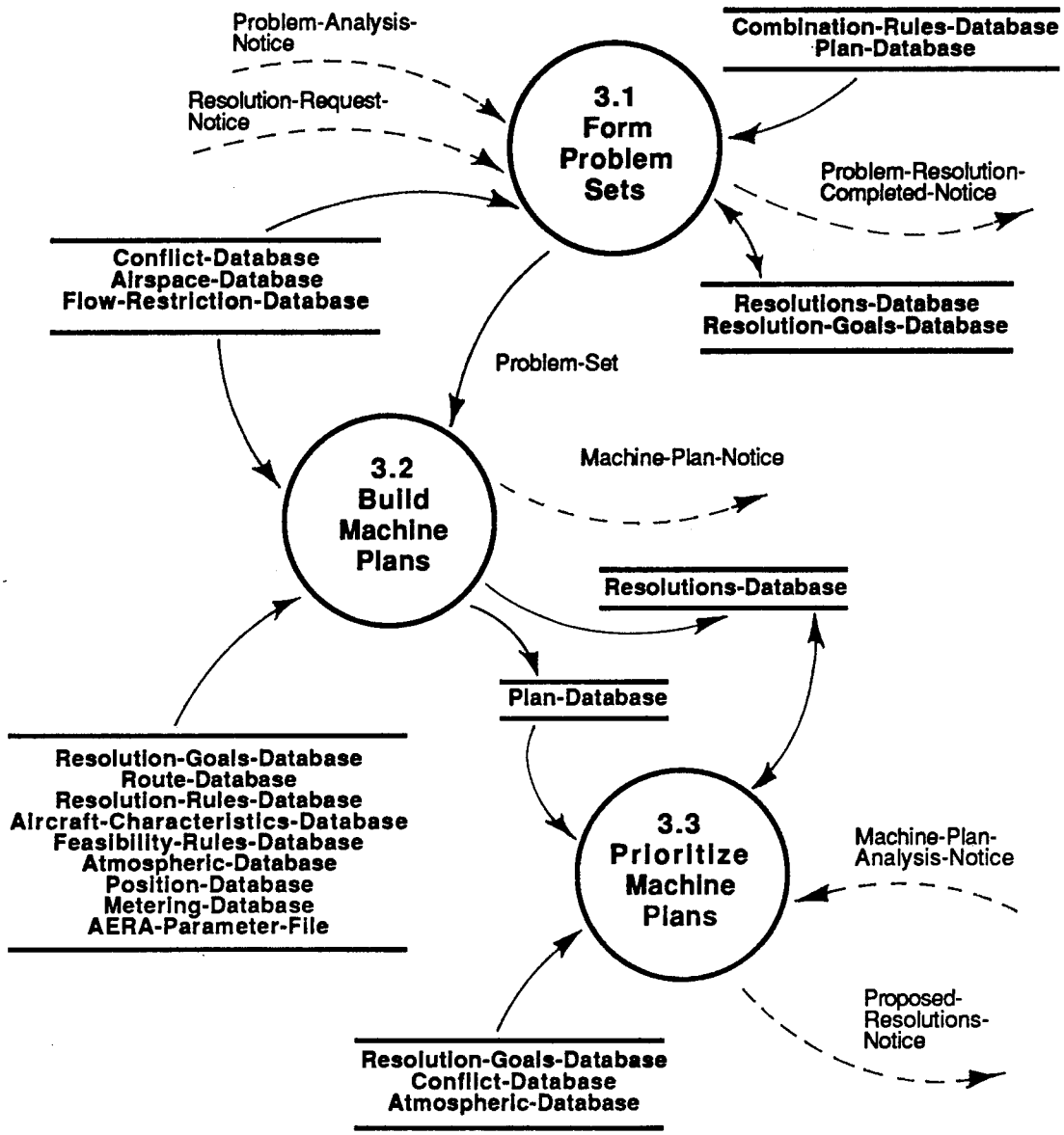


FIGURE 3-8
RESOLVE PROBLEMS

Diagram 3.1: Form Problem Sets

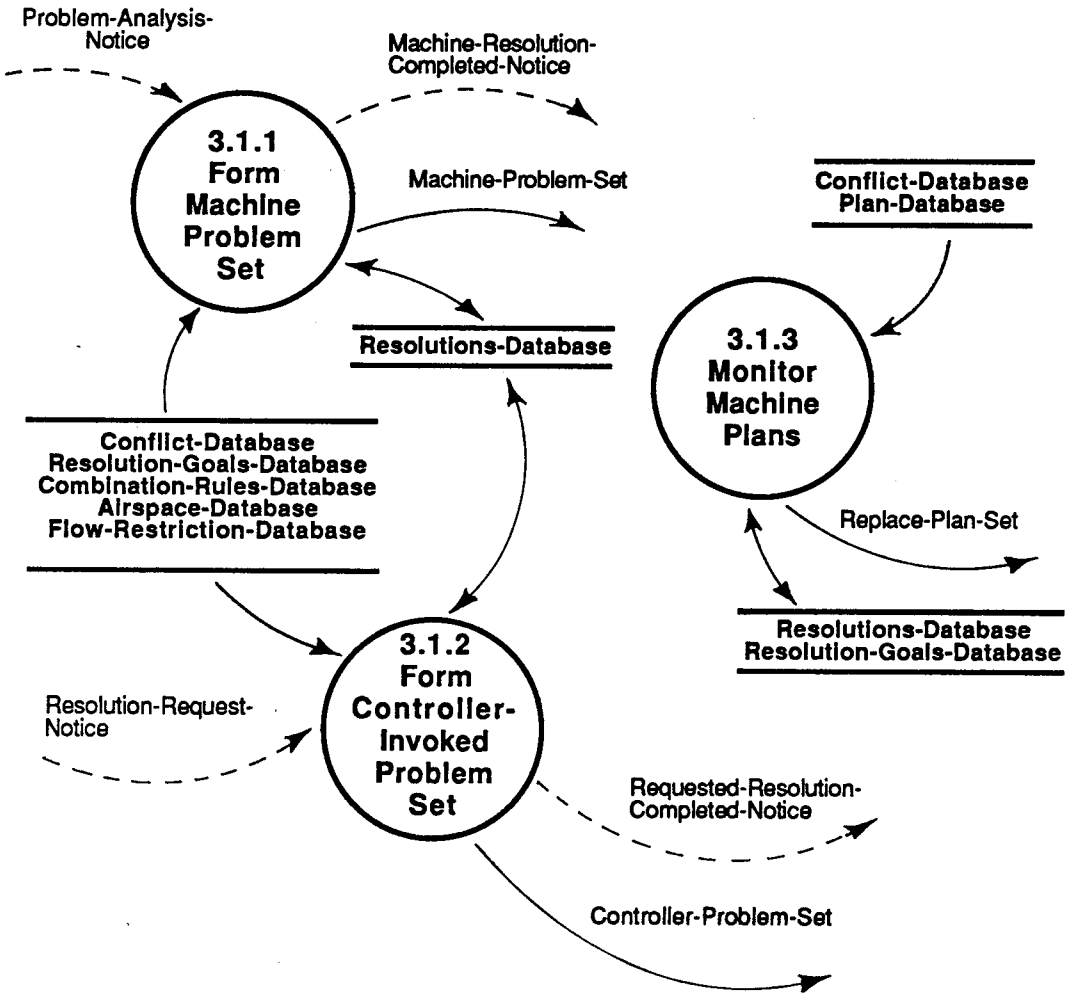


FIGURE 3-9
FORM PROBLEM SETS

Diagram 3.2: Build Machine Plans

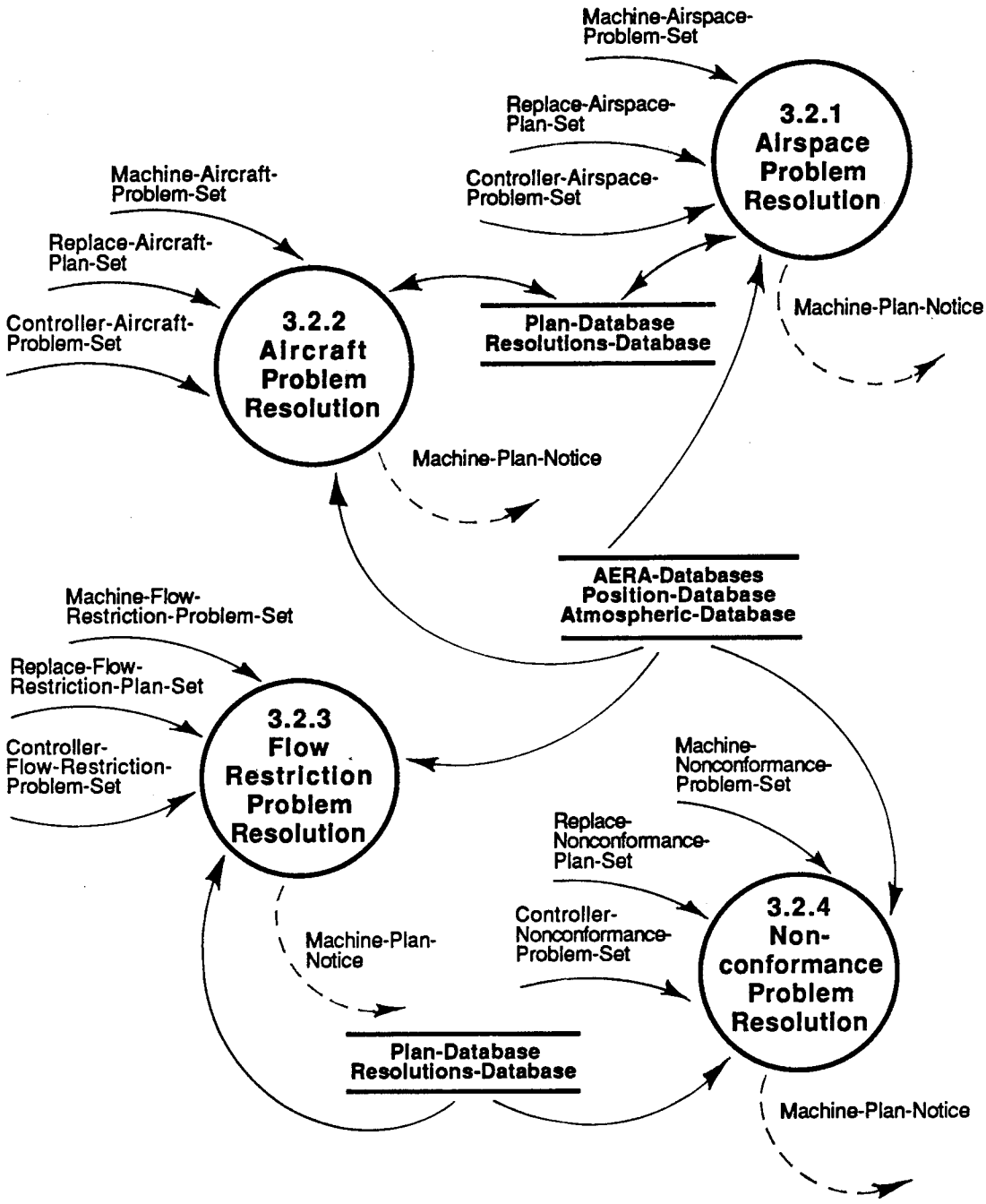


FIGURE 3-10
BUILD MACHINE PLANS

Diagram 3.3: Prioritize Machine Plans

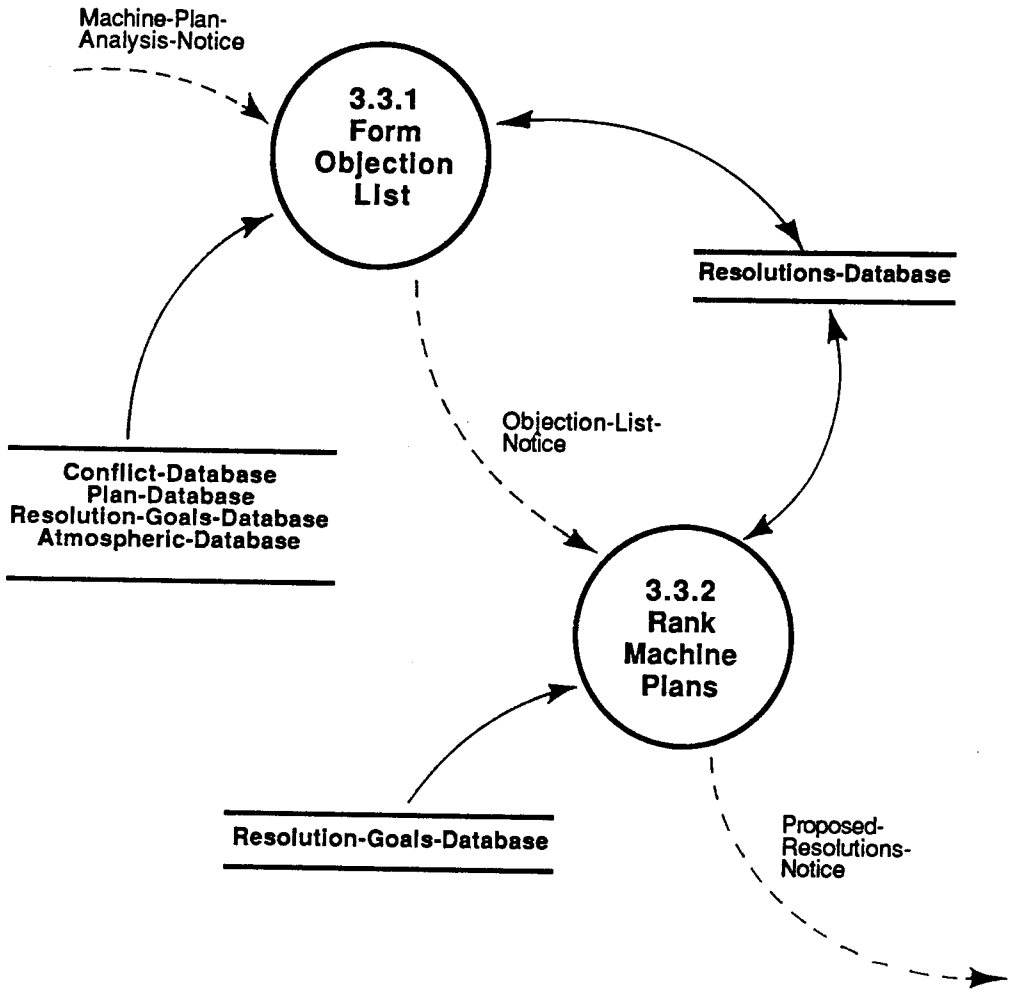


FIGURE 3-11
PRIORITIZE MACHINE PLANS

criteria for applying Automated Problem Resolution) is placed into the same problem set. A subset (usually one problem) is selected from each problem set and Bubble 3.2 is informed.

In Bubble 3.2, Build Machine Plans, machine plans are constructed for the selected subset in each problem set. Machine plans are based upon the aircraft plan, general plans of action (strategies), specific methods of implementing each strategy (maneuver types), and feasible parameter values. Each subset is analyzed to determine its characteristics, which are used to identify the appropriate strategies. For each strategy, maneuver types which are appropriate for this problem are identified. Parameter values are assigned for each appropriate maneuver type. The processes in Bubble 2 are notified, triggering the building and probing of nominal paths for each machine plan.

When all the machine plans for a given problem set have had their nominal paths built and checked by the probes, Bubble 3.3, Prioritize Machine Plans, forms a list of detected problems and other ATC objections for each machine plan. Each machine plan is then assigned a rank based on its problems and objections. This ranking determines the order in which the machine plans will be displayed to the controller. When the ranking process is completed, the machine plans are made available for display.

Form Problem Sets

Diagram 3.1 (Figure 3-9), Form Problem Sets, shows the division of processing involved in forming the problem sets. Depending on the input, one of three processes will be invoked:

- Form Machine Problem Set (Bubble 3.1.1)
- Form Controller-Invoked Problem Set (Bubble 3.1.2)
- Monitor Machine Plans (Bubble 3.1.3)

For Bubble 3.1.1, Form Machine Problem Set, the input is a notice that the Bubble 2 processes have finished probing. This process determines the problems eligible for resolution. The eligible problems are partitioned into sets in such a manner that each problem involving a given plan is included in the same set. Problems with trial plans are separated from current plan problems and placed into their own sets. The newly created sets are compared with the sets in the Resolutions-Database. Any set in the Resolutions-Database that is not one

of the newly created sets is removed from the Resolutions-Database. A list containing the newly created sets that are not already in the Resolutions-Database is formed. A subset out of each set is targeted for resolution. Each targeted subset is identified for Bubble 3.2.

Bubble 3.1.2, Form Controller-Invoked Problem Set, receives a notice that a controller has requested resolution of a particular problem or plan. When a plan has been specified, the problems involving that plan are grouped into sets of problems. A subset out of each set is targeted for resolution. Each targeted subset is identified for Bubble 3.2.

Bubble 3.1.3, Monitor Machine Plans, detects machine plans that are about to expire and that should be replaced by a similar machine plan. The expiration time is checked against the current time to determine whether that machine plan should be replaced. If a plan does need to be replaced, its obsolete information is removed. The remaining information, forwarded to Bubble 3.2, serves as the basis for regenerating the plan.

Build Machine Plans

Diagram 3.2 (Figure 3-10), Build Machine Plans, shows the four processes which attempt to resolve sets of problems of the same type, one process for each type of problem:

- Airspace Problem Resolution (Bubble 3.2.1)
- Aircraft Problem Resolution (Bubble 3.2.2)
- Flow Restriction Problem Resolution (Bubble 3.2.3)
- Nonconformance Problem Resolution (Bubble 3.2.4)

These processes are described in greater detail in the Functional Description of AERA 2 Automated Problem Resolution [6].

Bubble 3.2.1, Airspace Problem Resolution, proposes machine plans, in a preferred order, that are intended to resolve the targeted airspace problem in the problem set. The proposed maneuvers are based on the aircraft's plan, nearby obstructions (other aircraft, airspaces, or flow restrictions), and the details of the problem. Some maneuver type may be ruled out due to controller-specified prohibitions, machine-deduced restrictions, or aircraft performance characteristics.

Bubble 3.2.2, Aircraft Problem Resolution, proposes machine plans, in a preferred order, that are intended to resolve the targeted subset. The proposed machine plans are based on the aircraft flight plan, nearby obstructions (other aircraft, airspaces, or flow restrictions), and the specific details describing each of the problems in the subset. Some maneuver types may be ruled out due to controller-specified prohibitions, machine-deduced restrictions, or aircraft performance characteristics.

Bubble 3.2.3, Flow Restriction Problem Resolution, proposes machine plans, in a preferred order, that are intended to resolve the targeted flow restriction problem. The proposed machine plans are based on the aircraft flight plan, nearby obstructions (other aircraft, airspaces, or flow restrictions), and the details that describe the problem. Some maneuver types may be ruled out due to controller-specified prohibitions, machine-deduced restrictions, or aircraft performance characteristics.

Bubble 3.2.4, Nonconformance Problem Resolution, proposes machine plans, in a preferred order, that will bring the aircraft back into conformance with the nominal path derived from a plan. The proposed machine plans are based on the aircraft flight plan and the details of the particular problem. Some maneuver types may be ruled out due to controller-specified prohibitions or aircraft performance characteristics.

Prioritize Machine Plans

Diagram 3.3 (Figure 3-11), Prioritize Machine Plans, has two parts:

- Form Objection List (Bubble 3.3.1)
- Rank Machine Plans (Bubble 3.3.2)

In Bubble 3.3.1, Form Objection List, the results of building and probing a nominal path for each machine plan are evaluated. This process determines whether any problems were found for the machine plan or whether the machine plan has other objections (for example, the plan enters an additional sector). Any objections discovered are recorded for use by the next processing step.

Bubble 3.3.2, Rank Machine Plans, assigns a rank to each machine plan associated with a given problem set. To establish the ranking, this process uses the objections noted by Bubble 3.3.1, the a priori ordering of the maneuver types each plan initiates, and other ordering rules. The ranks are recorded and the display processors are notified that resolution has been completed for the given problem set.

3.3.2 Minispecifications

The minispecifications for Bubble 3 follow. Notes for each minispecification provide additional guidelines and information.

Process Name: Form Machine Problem Set

Process Number: 3.1.1

FOR EACH problem recorded in Conflict-Database:

IF Plan-Status (in Plan-File) for plan(s) involved in problem has value 'Current' or 'Trial',

THEN

Form Problem-Id for this problem from problem information in Conflict-Database.

IF no Problem-Id in Nonresolvable-File matches Problem-Id formed for this problem,

THEN

Determine whether problem is considered unresolvable, using prohibitions in Resolution-Goals-Database, Airspace-Database (if this problem is an airspace-aircraft conflict), and Flow-Restriction-Database (if this problem is a flow restriction noncompliance).

* For example, any one of the following would result in deciding the problem was unresolvable:

- Resolution-Goals-Database contains a global prohibition against solving this type of problem
- The airspace is for detection only
- The problem involves Flow-Restriction whose constraint is not machine-resolvable *

IF the problem is not resolvable,

THEN

Record Problem-Id and Rationale (in Nonresolvable-File), using Problem-Id formed and the reason found above for not attempting automated resolution.

Send Machine-Plan-Resolution-Notice.

OTHERWISE,

Record Problem-Id in Machine-Partition-Set, using Problem-Id formed for this problem.

FOR EACH Problem-Id in Machine-Partition-Set:

* Group problems into problem sets *

Record Problem-Id in Machine-Problem-Group (in Machine-Problem-Group-List), choosing the Machine-Problem-Group to which to add it by applying the criteria in Combination-Rules-Database to Plan-Id and Plan-Status (in Plan-File) for the plan(s) involved.

FOR EACH Problem-Group in Problem-Group-File which has Initiator set to value of 'Machine':

IF Problem-Ids (in Group-List) in this Problem-Group match one-for-one with Problem-Ids in a Machine-Problem-Group in Machine-Problem-Group-List (that is, this group of problems was found and recorded before, and therefore has already been subjected to automated resolution),

THEN

Remove that Machine-Problem-Group from Machine-Problem-Group-List.

OTHERWISE,

Remove any conflicts (from Conflict-Database) involving machine plans (in Proposed-Resolutions-List) associated with this Problem-Group (in Problem-Group-File).
Remove any machine plans (in Proposed-Resolutions-List) associated with this Problem-Group from Plan-Database.

Remove this Problem-Group from Problem-Group-File.

FOR EACH remaining Machine-Problem-Group in Machine-Problem-Group-List:

Form Problem-Group record (in Problem-Group-File), setting Group-List from Machine-Plan-Group, assigning a unique Problem-Group-Id, and setting Initiator to 'Machine'.
Determine which problem in Group-List to resolve and set Target-Problem-Id to its Problem-Id.

Form and send Machine-Problem-Set, using Problem-Group-Id and type of target problem (that is, Aircraft, Airspace, Flow Restriction, or Nonconformance) from Conflict-Database.

Notes:

None.

Process Name: Form Controller-Invoked Problem Set

Process Number: 3.1.2

FOR EACH Resolution-Request (in Resolution-Request-File from Resolutions-Goals-Database) for which there is no corresponding Resolution-Request-Result:

SELECT CASE based on type of request:

CASE 1 (request is Plan-Resolution-Request):

FOR EACH problem (in Conflict-Database) involving plan in request (that is, with same Plan-Id) and (if problem is aircraft-aircraft conflict) involving only current plans which are not for same aircraft as plan in request:

Determine whether problem is considered resolvable, using information in Resolution-Goals-Database (including Controller-Constraint list in Plan-Resolution-Request), Airspace-Database (if an airspace is involved), and Flow-Restriction-Database (if a flow restriction or metering assignment is involved).

IF the problem is resolvable,

THEN

Record Problem-Id in Controller-Partition-Set, using problem information (from Conflict-Database).

CASE 2 (request is Problem-Resolution-Request):

Determine whether problem (with Problem-Id in Problem-Resolution-Request) is considered completely unresolvable, using Flow-Restriction-Database (if a flow restriction or metering assignment is involved). * For example, a flow restriction with only text for its constraint *

IF the problem is resolvable,

THEN

Record Problem-Id in Controller-Partition-Set, using problem information (from Conflict-Database).

* In either case, do the following: *

IF no problems were found that can be resolved (that is, Controller-Partition-Set is empty),

THEN

Record Rationale (in Resolution-Request-Result) with this Resolution-Request, stating that no machine resolvable problems were found.

Send Requested-Resolution-Completed-Notice.

OTHERWISE,

FOR EACH Problem-Id in Controller-Partition-Set:

Record Problem-Id in Controller-Problem-Group (in Controller-Problem-Group-List), choosing the Controller-Problem-Group to which to add it by applying the criteria in Combination-Rules-Database to Plan-Id and Plan-Status (in Plan-File) for the plan(s) involved.

FOR EACH Controller-Problem-Group in Controller-Problem-Group-List:

Form Problem-Group record (in Problem-Group-File), setting Group-List from Controller-Problem-Group, assigning a unique Problem-Group-Id, and setting Initiator to 'Controller'. Determine which problem (from Group-List) to resolve and set Target-Problem-Id to its Problem-Id.

Record Problem-Group-Id in Resolution-Request-Result (with this Resolution-Request in Resolution-Request-File).

Form and send Controller-Problem-Set, using Problem-Group-Id and type of target problem (that is, Aircraft, Airspace, Flow Restriction, or Nonconformance) from Conflict-Database.

Notes:

1. It is assumed that the only current or trial plans can be the subject of a controller resolution request; that is, either machine or pending plans will have been made trial plans before resolution requests are made for them or they will be converted to trial plans upon receiving a controller resolution request involving them.

Process Name: Monitor Machine Problems

Process Number: 3.1.3

FOR EACH machine plan such that Replace-Machine-Plan-Time (in Ranking-File) for that plan has passed (that is, current time is later than or equal to Replace-Machine-Plan-Time):

Form Replace-Plan-Set, using Strategy and Maneuver-Type (from Proposed-Resolutions-List) for this machine plan, Plan-Id of this machine plan, and Problem-Group-Id (from Problem-Group) for group with which this machine plan is associated.

Remove Objection-List and Problem-List (in Ranking-File) for this machine plan and reset Replace-Machine-Plan-Time.

Remove all records from Plan-Database and Conflict-Database which include Plan-Id for this machine plan.

Send Replace-Plan-Set.

Notes:

None.

Process Name: Airspace Problem Resolution

Process Number: 3.2.1

SELECT CASE based on type of input:

CASE 1 (input is Machine-Airspace-Problem-Set):

Form Proposed-Resolutions-List in Problem-Group-File for Problem-Group with input Problem-Group-Id. For each Strategy and Maneuver-Type pair from Strategy-Maneuver-File (in Resolution-Rules-Database), form one record in Proposed-Resolutions-List.

Determine inappropriate strategies based on information (from Conflict-Database and Airspace-Database) about the problem identified by Target-Problem-Id (from Problem-Group-File) for input Problem-Group-Id and information (from Plan-Database) for plan involved in target problem. * This information includes such data as lead-time (time to predicted airspace violation), flight phase (arrival, departure, or overflight), flight intent (climbing, level, or descending), and encounter geometry. * Record Rationale in Proposed-Resolutions-List for each inappropriate strategy.

Determine inappropriate maneuver types, based on such factors as aircraft equipage (in Plan-File), aircraft performance characteristics (in Aircraft-Characteristics-Database), controller prohibitions (in Resolutions-Goals-Database), machine-deduced prohibitions, and information on aircraft and plan involved (from Plan-Database). Record Rationale in Proposed-Resolutions-List for each inappropriate maneuver type.

FOR EACH record in Proposed-Resolutions-List for this problem group which does not have Rationale:

Set Parameter-Values for Maneuver-Type (in this record), based on preferred range of values (in Preferred-Maneuver-Parameter-File in Resolution-Rules-Database) and such factors as availability of navigational aids, presence of neighboring aircraft or airspaces, and aircraft performance characteristics. * Additional calculations may be necessary to derive this information from problem and plan data. *

IF Parameter-Values could not be set,

THEN

Record Rationale in this record.

OTHERWISE,

Record machine plan (in Plan-File in Plan-Database), copying information from that of plan involved in this problem group's target problem and setting unique plan identifier for this plan.
Amend Planned-Clearance-Change list (in Current-Clearance in Plan-File) for this new machine plan, converting Parameter-Values for this maneuver.
Record Machine-Plan-Id in Proposed-Resolutions-List (in Problem-Group-File) for this Problem-Group, using unique plan identifier assigned above.
Send Machine-Plan-Notice.

IF (parameter) number of machine plans have been formed for this problem group, stop this process.

CASE 2 (input is Controller-Airspace-Problem-Set):

IF Controller-Constraint list (in Resolution-Request) associated with input Problem-Group-Id (in Resolution-Request-Result) in Resolution-Request-File includes controller-specified maneuvers,

THEN

Form Proposed-Resolutions-List in Problem-Group-File for Problem-Group with input Problem-Group-Id, setting Strategy and Maneuver-Type for each controller-specified maneuver in Controller-Constraint list.

OTHERWISE,

Form Proposed-Resolutions-List in Problem-Group-File for Problem-Group with input Problem-Group-Id. For each Strategy and Maneuver-Type pair from Strategy-Maneuver-File (in Resolution-Rules-Database), form one record in Proposed-Resolutions-List.

Determine inappropriate strategies based on information (from Conflict-Database and Airspace Database) about the problem identified by Target-Problem-Id (from Problem-Group-File) for input Problem-Group-Id and information (from Plan-Database) for plan involved in target problem. * This information includes such data as lead-time (time to predicted airspace violation), flight phase (arrival, departure, or overflight), flight intent (climbing, level, or descending), and encounter geometry. * Record Rationale in Proposed-Resolutions-List for each inappropriate strategy.

Determine inappropriate maneuver types, based on such factors as aircraft equipage (in Plan-File), aircraft performance characteristics (in Aircraft-Characteristics-Database), controller prohibitions (in Resolutions-Goals-Database), machine-deduced prohibitions, and information on aircraft and plan involved (from Plan-Database). Record Rationale in Proposed-Resolutions-List for each inappropriate maneuver type.

FOR EACH record in Proposed-Resolutions-List for this problem group which does not have Rationale:

Set Parameter-Values for Maneuver-Type (in this record), based on preferred range of values (in Preferred-Maneuver-Parameter-File in Resolution-Rules-Database) and such factors as availability of navigational aids, presence of neighboring aircraft or airspaces, aircraft performance characteristics, and any limits entered by controller (in Controller-Constraint list). * Additional calculations may be necessary to derive this information from problem and plan data. *

IF Parameter-Values could not be set,

THEN

Record Rationale in this record.

OTHERWISE,

Record machine plan (in Plan-File in Plan-Database), copying information from that of plan involved in this problem group's target problem and setting unique plan identifier for this plan.

Amend Planned-Clearance-Change list (in Current-Clearance in Plan-File) for this new machine plan, converting Parameter-Values for this maneuver.
Record Machine-Plan-Id in Proposed-Resolutions-List (in Problem-Group-File) for this Problem-Group, using unique plan identifier assigned above.
Send Machine-Plan-Notice.

CASE 3 (input is Replace-Airspace-Plan-Set):

Set Parameter-Values for this Maneuver-Type (in input), based on preferred range of values (in Preferred-Maneuver-Parameter-File in Resolution-Rules-Database) and such factors as availability of navigational aids, presence of neighboring aircraft or airspaces, and aircraft performance characteristics. * Additional calculations may be necessary to derive this information from problem and plan data. *

IF Parameter-Values cannot be set within the preferred range,

THEN

Set Rationale of record in Ranking-File with same Machine-Plan-Id as input to 'Maneuver no longer feasible'.

OTHERWISE,

Record machine plan (in Plan-File in Plan-Database), copying information from that of plan involved in this input problem group's target problem (in Target-Problem-Id in Problem-Group in Problem-

Group-File, with input Problem-Group-Id) and setting plan identifier from input Machine-Plan-Id.

Amend Planned-Clearance-Change list (in Current-Clearance in Plan-File) for this machine plan, converting Parameter-Values for maneuver.

Send Machine-Plan-Notice.

Notes:

1. Further explanation of Airspace Conflict Resolution (ASCR) is available in Volume 3 of the Draft Functional Description of AERA 2 Automated Problem Resolution [6].

Process Name: Aircraft Problem Resolution

Process Number: 3.2.2

SELECT CASE based on input type:

CASE 1 (input is Machine-Aircraft-Problem-Set):

Form Proposed-Resolutions-List in Problem-Group-File for problem group with input Problem-Group-Id, setting Strategy from Strategy-Maneuver-File (in Resolution-Rules-Database) for each applicable strategy. Choose applicable strategies based on such factors as encounter geometry, route characteristics, altitudes, and Flight-Phase (from Plan-Database) of both aircraft involved in target problem (identified by Aircraft-Id in Aircraft-Aircraft-Conflict-File in Conflict-Database for problem identified by Target-Problem-Id in Problem-Group-File for record with input Problem-Group-Id).

FOR EACH Strategy in Proposed-Resolutions-List for this Problem-Group:

Choose aircraft to maneuver and Maneuver-Type (from Strategy-Maneuver-File) for this Strategy, for which Parameter-Values can be found, based on such factors as encounter geometry, aircraft navigational equipage, availibility of navigational aids in the vacinity of the conflict, radar coverage, controller prohibitions, and machine-deduced prohibitions.
* see Note 2 *

IF no such Maneuver-Type is found,

THEN

Record Rationale in this Proposed-Resolutions-List record.

OTHERWISE,

Record machine plan (in Plan-File in Plan-Database), copying information from that of plan involved in this problem group's target problem and setting unique plan identifier for this plan.

Amend Planned-Clearance-Change list (in Current-Clearance in Plan-File) for this new machine plan, converting Parameter-Values for this maneuver.

Record Maneuver-Type and Machine-Plan-Id in this Proposed-Resolutions-List record, using Maneuver-Type choosen and unique plan identifier assigned above.

Send Machine-Plan-Notice.

CASE 2 (input is Controller-Aircraft-Problem-Set):

IF Controller-Constraint list (in Resolution-Request) associated with input Problem-Group-Id (in Resolution-Request-Result) in Resolution-Request-File includes controller-specified maneuvers,

THEN

Form Proposed-Resolutions-List in Problem-Group-File for Problem-Group with input Problem-Group-Id, setting Strategy and Maneuver-Type for each controller-specified maneuvers in Controller-Constraint list.

FOR EACH record in Proposed-Resolutions-List for input Problem-Group-Id:

Set Parameter-Values for Maneuver-Type.
* See Note 2 *

IF Parameter-Values cannot be set,

THEN

Record Rationale in this Proposed-Resolutions-List record.

OTHERWISE,

Record machine plan (in Plan-File in Plan-Database), copying information from that of plan involved in this problem group's target problem and setting unique plan identifier for this plan.

Amend Planned-Clearance-Change list (in Current-Clearance in Plan-File) for this new machine plan, converting Parameter-Values for this maneuver.
Record Maneuver-Type and Machine-Plan-Id in this Proposed-Resolutions-List record, using Maneuver-Type chosen and unique plan identifier assigned above.
Send Machine-Plan-Notice.

OTHERWISE,

Form Proposed-Resolutions-List in Problem-Group-File for problem group with input Problem-Group-Id, setting Strategy from Strategy-Maneuver-File (in Resolution-Rules-Database) for each applicable strategy. Choose applicable strategies based on such factors as encounter geometry, route characteristics, altitudes, and Flight-Phase (from Plan-Database) of both aircraft involved in target problem (identified by Aircraft-Id in Aircraft-Aircraft-Conflict-File in Conflict-Database for problem identified by Target-Problem-Id in Problem-Group-File for record with input Problem-Group-Id).

FOR EACH Strategy in Proposed-Resolutions-List for this Problem-Group:

Choose Maneuver-Type (from the Strategy-Maneuver-File) for this Strategy, for which Parameter-Values can be found, based on such factors as encounter geometry, aircraft navigational equipage, availibility of navigational aids in the vacinity of the conflict, radar coverage, machine-deduced prohibitions, and controller prohibitions.
* See Note 2 *

IF no such Maneuver-Type is found,

THEN

Record Rationale in this Proposed-Resolutions-List record.

OTHERWISE,

Record machine plan (in Plan-File in Plan-Database), copying information from that of plan involved in this problem group's target problem and setting unique plan identifier for this plan.
Amend Planned-Clearance-Change list (in Current-Clearance in Plan-File) for this new machine plan, converting Parameter-Values for this maneuver.
Record Maneuver-Type and Machine-Plan-Id in this Proposed-Resolutions-List record, using Maneuver-Type chosen and unique plan identifier assigned above.
Send Machine-Plan-Notice.

CASE 3 (input is Replace-Aircraft-Plan-Set):

Set Parameter-Values for Strategy and Maneuver-Type in input, using information on target problem identified for Problem-Group-Id in input. * see Note 2 *

IF Parameter-Values cannot be set,

THEN

Record Rationale in Ranking-File record for input Machine-Plan-Id.

OTHERWISE,

Record machine plan (in Plan-File in Plan-Database), copying information from that of plan involved in input problem group's target problem and setting plan identifier from input Machine-Plan-Id.

Amend Planned-Clearance-Change list (in Current-Clearance in Plan-File) for this new machine plan, converting Parameter-Values for this maneuver.

Send Machine-Plan-Notice.

Notes:

1. Further explanation of Aircraft Conflict Resolution (ACCR) is available in Volume 2 of the Draft Functional Description of AERA 2 Automated Problem Resolution [6].

2. The process of creating a machine plan includes the determination of the parameters required to define a maneuver and the assignment of values for each of the parameters. The values assigned to the parameters will be based on such factors as the availability of navigational aids, presence of neighboring aircraft, and performance characteristics of the aircraft. The parameter values must be within a preferred range of values (from Preferred-Maneuver-Parameter-File) for the Maneuver-Type and may be limited by the controller (in Controller-Constraint list for CAR).

Process Name: Flow Restriction Problem Resolution

Process Number: 3.2.3

SELECT CASE based on type of input:

CASE 1 (input is Machine-Flow-Restriction-Problem-Set):

IF applicability-criteria (in Flow-Restriction-Database) defines a region (ACF, sector, or arbitrary region and associated applicability times),

THEN

Determine the information that would be required to avoid the specified region.

Form Proposed-Resolutions-List in Problem-Group-File for problem with input Problem-Group-Id. For each applicable Strategy and Maneuver-Type from Strategy-Maneuver-File (in Resolution-Rules-Database), form one record in Proposed-Resolution-List.

Determine inappropriate strategies based on the flight plan and avoidance region. * The selections are based on information such as time to entering region, flight phase, flight intent, and encounter geometry. * Record Rationale in Proposed-Resolutions-List for each inappropriate strategy.

Determine inappropriate maneuver types, based on such factors as aircraft performance characteristics (in Aircraft-Characteristics-Database), controller prohibitions (in Resolutions-Goals-Database), and information on aircraft and plan involved (from Plan-Database). Record Rationale in Proposed-Resolutions-List for each inappropriate maneuver type.

Form Proposed-Resolutions-List in Problem-Group-File for problem with input Problem-Group-Id. For each applicable Strategy and Maneuver-Type pair from Strategy-Maneuver-File (in Resolution-Rules-Database), form one record in Proposed-Resolutions-List.

Determine inappropriate maneuver types. * See Note 2 *
Record Rational in Proposed-Resolutions-List for each inappropriate maneuver type.

FOR EACH record in Proposed-Resolutions-List for this problem group which does not have Rationale:

Set Parameter-Values for Maneuver-Type (in this record), based on preferred range of values (in Preferred-Maneuver-Parameter-File in Resolution-Rules-Database) and such factors as availability of navigational aids, presence of neighboring aircraft or airspaces, aircraft performance characteristics, and any limits entered by controller (in Controller-Constraint list). * Additional calculations may be necessary to derive this information from problem and plan data. *

IF Parameter-Values could not be set,

THEN

Record Rationale in this record.

OTHERWISE,

Record machine plan (in Plan-File in Plan-Database), copying information from that of plan involved in this problem group's target problem and setting unique plan identifier for this plan.

Amend Planned-Clearance-Change list (in Current-Clearance in Plan-File) for this new machine plan, converting Parameter-Values for this maneuver.
Record Machine-Plan-Id in Proposed-Resolutions-List (in Problem-Group-File) for this Problem-Group, using unique plan identifier assigned above.
Send Machine-Plan-Notice.

CASE 2 (input is Controller-Airspace-Problem-Set):

IF Controller-Constraint list (in Resolution-Request) associated with input Problem-Group-Id (in Resolution-Request-Result) in Resolution-Request-File includes controller-specified maneuvers,

THEN

Form Proposed-Resolutions-List in Problem-Group-File for Problem-Group with input Problem-Group-Id, setting Strategy and Maneuver-Type for each controller-specified maneuver in Controller-Constraint list.

OTHERWISE,

Form Proposed-Resolutions-List in Problem-Group-File for Problem-Group with input Problem-Group-Id. For each Strategy and Maneuver-Type pair from Strategy-Maneuver-File (in Resolution-Rules-Database), form one record in Proposed-Resolutions-List.

Determine inappropriate strategies based on information (from Conflict-Database and Flow-Restriction-Database) about the problem identified by Target-Problem-Id (from Problem-Group-File) for input Problem-Group-Id and information (from Plan-Database) for plan involved in target problem. * This information includes such data as lead-time (time to predicted violation), and encounter geometry. * Record Rationale in Proposed-Resolutions-List for each inappropriate strategy.

Determine inappropriate maneuver types, based on such factors as aircraft equipage (in Plan-File), aircraft performance characteristics (in Aircraft-Characteristics-Database), controller prohibitions (in Resolutions-Goals-Database), machine-deduced prohibitions and information on aircraft and plan involved (from Plan-Database). Record Rationale in Proposed-Resolutions-List for each inappropriate maneuver type.

IF applicability-criteria (in Flow-Restriction-Database) defines a region (ACF, sector, or arbitrary region and associated applicability times),

THEN

Determine the information that would be required to avoid the specified region.
Form Proposed-Resolutions-List in Problem-Group-File for problem with input Problem-Group-Id. For each applicable Strategy and Maneuver-Type pair from Strategy-Maneuver-File (in Resolution-Rules-Database), form one record in Proposed-Resolutions-List.
Determine inappropriate strategies based on the flight plan and avoidance region. * The selections are based on information such as time to entering region, flight phase, flight intent, and encounter geometry. * Record Rationale in Proposed-Resolutions-List for each inappropriate strategy.
Determine inappropriate maneuver types, based on such factors as aircraft performance characteristics (in Aircraft-Characteristics-Database), controller prohibitions (in Resolutions-Goals-Database), and information on aircraft and plan involved (from Plan-Database). Record Rationale in Proposed-Resolutions-List for each inappropriate maneuver type.

Form Proposed-Resolutions-List in Problem-Group-File for problem with input Problem-Group-Id. For each applicable Strategy and Maneuver-Type pair from Strategy-Maneuver-File (in Resolution-Rules-Database), form one record in Proposed-Resolutions-List.
Determine inappropriate maneuver types. * See Note 2 * Record Rational in Proposed-Resolutions-List for each inappropriate maneuver type.

FOR EACH record in Proposed-Resolutions-List for this problem group which does not have Rationale:

Set Parameter-Values for Maneuver-Type (in this record), based on preferred range of values (in Preferred-Maneuver-Parameter-File in Resolution-Rules-Database) and such factors as availability of navigational aids, presence of neighboring aircraft or airspaces, aircraft performance characteristics, and any limits entered by controller (in Controller-Constraint

list). * Additional calculations may be necessary to derive this information from problem and plan data. *

IF Parameter-Values could not be set,

THEN

Record Rationale in this record.

OTHERWISE,

Record machine plan (in Plan-File in Plan-Database), copying information from that of plan involved in this problem group's target problem and setting unique plan identifier for this plan.

Amend Planned-Clearance-Change-list (in Current-Clearance in Plan-File) for this new machine plan, converting Parameter-Values for this maneuver.
Record Machine-Plan-Id in Proposed-Resolutions-List (in Problem-Group-File) for this Problem-Group, using unique plan identifier assigned above.
Send Machine-Plan-Notice.

CASE 3 (input is Replace-Airspace-Plan-Set):

Set Parameter-Values for this Maneuver-Type (in input), based on preferred range of values (in Preferred-Maneuver-Parameter-File in Resolution-Rules-Database) and such factors as availability of navigational aids, presence of neighboring aircraft or airspaces, and aircraft performance characteristics. * Additional calculations may be necessary to derive this information from problem and plan data. *

IF Parameter-Values cannot be set within the preferred range,

THEN

Set Rationale of record in Ranking-File with same Machine-Plan-Id as input to 'Maneuver no longer feasible'.

OTHERWISE,

Record machine plan (in Plan-File in Plan-Database), copying information from that of plan involved in this input problem group's target problem (in Target-Problem-Id in Problem-Group in Problem-Group-File, with input Problem-Group-Id) and setting plan identifier from input Machine-Plan-Id.
Amend Planned-Clearance-Change list (in Current-Clearance in Plan-File) for this machine plan, converting Parameter-Values for maneuver.
Send Machine-Plan-Notice.

Notes:

1. Further explanation of Flow Restriction Problem Resolution (FRPR) is available in Volume 4 of the Draft Functional Description of AERA 2 Automated Problem Resolution [6].

2. The process of creating a machine plan includes the determination of the parameters required to define a maneuver and the assignment of values for each of the parameters. The values assigned to the parameters will be based on such factors as controller-entered prohibitions and CAR constraints, TMU-entered prohibitions and parameter values, the availability of navigational aids, the presence of neighboring aircraft, sector boundaries, and performance characteristics of the aircraft. The parameter values must be within a preferred range of values (from Preferred-Maneuver-Parameter-File) for the Maneuver-Type.

Process Name: Nonconformance Problem Resolution

Process Number: 3.2.4

Processing logic is provided, for the most part, by the decomposition and minispecifications for Bubble 3.6.1 in Section 3.3, "System-Level Design of AERA 1 in the Context of the AAS" [3]. Further decomposition of this process is presented in Section 2.3, "Automated En Route Air Traffic Control Algorithmic Specifications - AERA 1: Capabilities for Managing Sector Traffic" [7].

Notes:

1. Rather than send the data flows shown in the referenced sections, the new plans are stored in the Plan-Database and the control flows trigger Bubble 2 processing.

2. The receipt of Replace-Nonconformance-Plan causes the processing to determine which of the plans has timed out and the appropriate subprocess is triggered.

3. When this process is triggered by the detection processes, all applicable maneuver types are considered in order to form machine plans to resolve the nonconformance problem.

Process Name: Form Objection List

Process Number: 3.3.1

FOR EACH Problem-Group in Problem-Group-File with Machine-Plan-Ids:

IF all machine plans (identifed in the Proposed-Resolutions-List) have been marked as probed (in Plan-Database),

THEN

FOR EACH machine plan in Proposed-Resolutions-List:

Add any problems (in Conflict-Database) for this plan to Problem-List in Ranking-File record for this machine plan.

Determine ATC objections, using data on this machine plan, plan involved in problem (from Target-Problem-Id in Problem-Group), and on such factors as turbulent areas (in Atmospheric-Database).
Record ATC objections in Objection-List in Ranking-File record for this machine plan.

Store Objection-List in Resolutions-Database.

Send Objection-List-Notice.

Notes:

None.

Process Name: Rank Machine Plans

Process Number: 3.3.2

FOR EACH Problem-Group in Problem-Group-File in Resolutions-Database:

IF no entry in Ranking-File with a Machine-Plan-Id from Proposed-Resolutions-List has Machine-Plan-Rank set,

THEN

Retrieve Objection-List and Problem-List (from Ranking-File) for each machine plan in Proposed-Resolutions-List (in Problem-Group-File).

Rank machine plans using information from Objection-List and Problem-List and rules in Ranking-Rules-File (in Resolution-Goals-Database).

FOR EACH Machine-Plan-Id in Proposed-Resolutions-List:

Record rank in Machine-Plan-Rank in Ranking-File record for this Machine-Plan-Id.

Send Proposed-Resolutions-Notice.

Notes:

None.

3.4 Output Displays

Output Displays contains the processes that transfer the AERA-generated information to the portions of the AAS that control the display functions. The AAS is assumed to display the information in the manner desired by the controller.

This bubble will describe the interfaces between AERA and the other portions of the AAS in terms of the information that crosses the boundary.

There are two primary stimuli of display processing; that is, the controller and AERA. The controller can request that information be displayed to himself or another controller. These special requests will cause the processes in this bubble to forward the information one time. AERA will be continually attempting to generate information that should be displayed to the controller. When a notice is received that AERA has changed a database, these processes will forward all necessary information.

In addition, information requests from supervisors, the TMC, Flight Service Stations, or tower controllers could be passed to AERA through the AAS. The AAS is responsible for forwarding the requested information to the appropriate recipients.

3.4.1 Description by Levels

Output Displays

Diagram 5 (Figure 3-12), Output Displays, has been decomposed into five parts:

- Display Plan Data (Bubble 5.1)
- Display Controller Reminders (Bubble 5.2)
- Coordinate (Bubble 5.3)
- Data Link (Bubble 5.4)
- Display Workload Statistics (Bubble 5.5)

Bubbles 5.1, 5.3, 5.4, and 5.5 are initiated by special requests. Bubble 5.1 is also triggered by the completion of another AERA process. Bubble 5.2 is triggered periodically.

Diagram 5: Output Displays

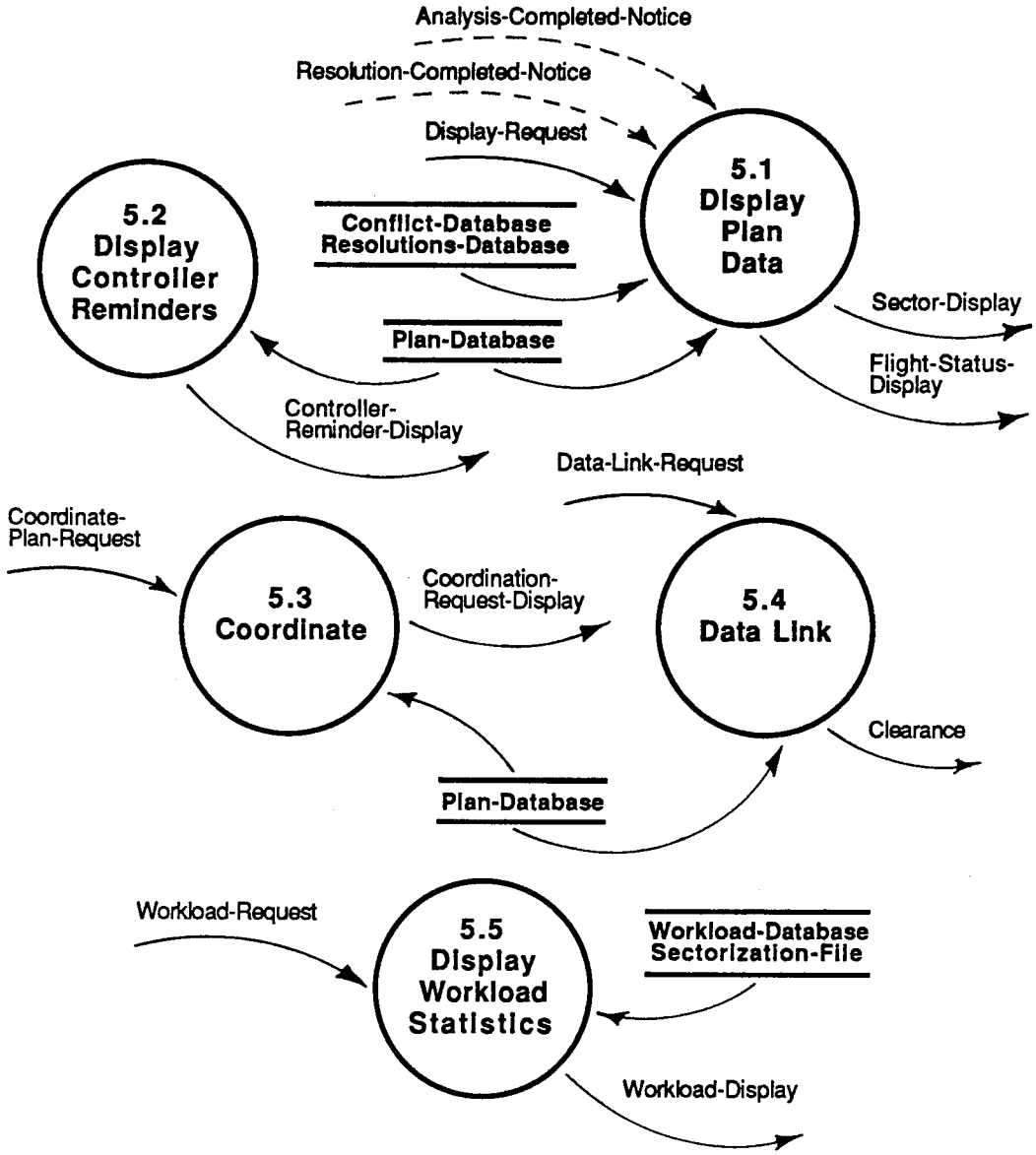


FIGURE 3-12
OUTPUT DISPLAYS

3.4.2 Minispecifications

The minispecifications for Bubble 5 follow. Notes for each minispecification provide additional guidelines and information.

Process Name: Display Plan Data

Process Number: 5.1

Information available:

- Plan information (Plan-Database)
- Probe results (Conflict-Database)
- Conformance monitoring results (Conflict-Database)
- Reconformance results (Plan-Database)
- Resolution results; machine plan and ranking information (Plan-Database and Resolutions-Database)
- Resolution request results (Resolution-Goals-Database)
- Resolution rationales (Resolutions-Database, Resolution-Goals-Database, and Resolution-Rules-Database)
- Reprobe plan information (Plan-Database)

Recipients (through AAS):

- Sector controllers
- Supervisors
- Traffic Management Coordinators
- Tower controllers
- Flight Service controllers
- Metering functions

Stimuli:

- Display request
- Aircraft conflict analysis notice
- Airspace conflict analysis notice
- Flow restriction analysis notice
- Nonconformance notice
- Reconformance notice
- Nonconformance update notice
- Machine resolution completed notice
- Requested resolution completed notice
- Proposed resolution notice

Notes:

1. The content and form of the messages which pass information for display have not been determined. Operational needs for displayed information are described in the AERA 2 Operational Description [5].

Process Name: Display Controller Reminders

Process Number: 5.2

Periodically do the following:

```
    FOR EACH record in Controller-Reminder-File (in Plan-Database)
        for which its Time is less than or equal to current time:

            CASE 1 (reminder is Deliver-Clearance-Reminder):

                Form and send Controller-Reminder-Display, using
                    Plan-Id and Controller-Reminder-Message from
                    this Controller-Reminder-File record.
                    * for display to current controller of plan *

            CASE 2 (reminder is Monitor-Maneuver-Reminder):

                Query tracking function for tracking history of
                    aircraft involved in plan with Plan-Id in
                    reminder record.

                IF tracking history shows that maneuver in Planned-
                    Clearance-Change in record has started,

                    THEN

                        Remove this controller reminder record.

                    OTHERWISE,

                        Form and send Controller-Reminder-Display,
                            using Plan-Id and Controller-Reminder-
                            Message from this Controller-Reminder-
                            File record.
                            * for display to current controller of
                            plan *

                        Remove this controller reminder record.
```

Notes:

None.

Process Name: Coordinate

Process Number: 5.3

```
IF there is already a pending plan (in Plan-Database) for
    aircraft of plan which input request identifies AND the request
    is not for an existing pending plan (that is, there is not a
    pending plan with same Plan-Number as input),

    THEN form and send Coordination-Request-Error.

    OTHERWISE,

        IF plan identified in input is in Plan-Database
            AND is of type 'Machine', 'Pending', or 'Trial'
            AND controller requesting coordination is current
            controller for indicated aircraft and owns indicated
            plan,

            THEN

                SELECT CASE based on Coordinate-Plan-Request type:

                    CASE 1 (input is List-Requested):

                        SELECT CASE based on current state of plan
                            to coordinate:

                            CASE 1 (plan has nominal path in Plan-
                                Database):

                                Set plan type to 'Pending'.
                                Mark plan (Action-Flag in Plan-File)
                                    for resynchronization.
                                Send Resynchronization-Notice.

                            CASE 2 (plan has no nominal path and is
                                in process of nominal path building):

                                Set plan type to 'Pending'.

                            CASE 3 (plan has no nominal path and has
                                errors preventing nominal path
                                building):
```

Form and send Coordination-Request-Error response.
Stop this process.

Determine sectors and/or TMC with which coordination must be done (rules applied by AERA, to generate list of locations; converted to list of sectors by AAS function, returning Coordinatees-List).

IF plan was forwarded from another sector,

THEN remove this sector from Coordinatees-List.

IF coordination is needed (list not empty),

THEN form and send Coordination-List response.

OTHERWISE, form and send Coordination-Not-Needed response.

CASE 2 (input is List-Included):

IF plan to coordinate was forwarded by another sector,

THEN form and send Forwarded-Plan-Being-Coordinated notice.

Record sectors with which to coordinate in Coordination-File (in Plan-Database).

Form and send Coordination-Request and Coordination-Begun response.

CASE 3 (input is No-List-Requested):

SELECT CASE based on current state of plan to coordinate:

CASE 1 (plan has nominal path in Plan-Database):

Set plan type to 'Pending'.
Mark plan (Action-Flag in Plan-File) for resynchronization.

Send Resynchronization-Notice.

CASE 2 (plan has no nominal path and is in process of nominal path building):

Set plan type to 'Pending'.

CASE 3 (plan has no nominal path and has errors preventing nominal path building):

Form and send Coordination-Request-Error response.
Stop this process.

Determine sectors and/or TMC with which coordination must be done (rules applied by AERA, to generate list of locations; converted to list of sectors by AAS function, returning Coordinatees-List).

IF plan was forwarded from another sector,

THEN remove this sector from Coordinatees-List.

IF coordination is needed (list not empty),

THEN

IF plan to coordinate was forwarded by another sector,

THEN form and send Forwarded-Plan-Being-Coordinated.

Record sectors with which to coordinate in Coordination-File (in Plan-Database).

Form and send Coordination-Request and Coordination-Begun response.

OTHERWISE, form and send Coordination-Not-Needed response.

```
OTHERWISE, * input plan is NOT in Plan-Database OR is not
    of type 'Machine', 'Pending', or 'Trial' OR
    controller requesting coordination is not both
    current and owning controller *

    IF plan identified in input is in Plan-Database
        AND is of type 'Machine', 'Pending', or 'Trial'
        AND controller requesting coordination owns plan
        to coordinate, but is NOT the current controller
        of aircraft in plan AND input is No-List-
        Requested,

        THEN

            SELECT CASE based on current state of plan
                to coordinate:

                CASE 1 (plan has nominal path in Plan-
                    Database):

                    Set plan type to 'Pending'.
                    Mark plan (Action-Flag in Plan-File)
                        for resynchronization.
                    Send Resynchronization-Notice.

                CASE 2 (plan has no nominal path and is
                    in process of nominal path building):

                    Set plan type to 'Pending'.

                CASE 3 (plan has no nominal path and has
                    errors preventing nominal path
                    building):

                    Form and send Coordination-Request-
                        Error response.
                    Stop this process.

            Record forwarding sector, receiving sector,
                and plan identifier in Forwarding-File
                (in Plan-Database).

            Transfer plan ownership to current
                controller.
            Form and send Forwarded-Plan-Request to
                current controller.
            Form and send Plan-Forwarded to requesting
                controller.
```

OTHERWISE, form and send Coordination-Request-Error.

Notes:

None.

Process Name: Data Link

Process Number: 5.4

Form and send Clearance, setting Clearance-Message by converting Planned-Clearance-Change list in Data-Link-Request into clearance language. * for transmission to aircraft identified by Aircraft-Id in input *

Notes:

None.

Process Name: Display Workload Statistics

Process Number: 5.5

Processing logic is provided by a part of the minispecifications for Bubble 1.2.2 in Section 3.1.2, "System-Level Design of AERA 1 in the Context of the AAS" [3] and for Bubble 1.2.2 in Section 2.4.2, "Automated En Route Air Traffic Control Algorithmic Specifications - AERA 1: Manage NAS Airspace" [7].

Notes:

None.

4. DATA DICTIONARY

A data dictionary is a repository of information about data. In this data dictionary, the data flows, control flows, files, and databases given in Section 3 are all defined. For each entity, the internal data storage is defined on a high level. Detailed data requirements are beyond the scope of this systems level document. The pound sign (#) is used to mark any data item whose definition is unchanged from the AERA 1 algorithmic specifications [7, Vol. 4]. No further breakdown is given for such a marked entry. Appendix A provides the definitions of format and structure which assisted in the construction of this data dictionary.

```
- A -

ACF-Handoff#

Action-Flag
    = Values:  Resynchronization
               Rebuild
               Extend-DNP
               Probed

Add-Metering-Assignment
    = Aircraft-Id + { Metering-Assignment }

AERA-Database
    = Airspace-Database + Conflict-Database +
      Feasibility-Rules-Database + Flow-Restriction-Database +
      Metering-Database + Plan-Database +
      Resolution-Goals-Database + Resolutions-Database +
      Sectorization-File + Workload-Database

AERA-Parameter-File#

Aircraft-Aircraft-Conflict-File#

Aircraft-Characteristics-Database#

Aircraft-Conflict-Analysis-Notice
    = * control flow *

Aircraft-Id#

Aircraft-Position#

Airspace-Added-Response
    = Airspace-Id

Airspace-Affected-Plans
    = { Airspace-Id + Aircraft-Id + Exit-Time }

Airspace-Change-Error-Response
    = Airspace-Id

Airspace-Change-Response
    = [ Airspace-Change-Error-Response | Airspace-Added-Response |
      Airspace-Changed-Response | Airspace-Deleted-Response ]

Airspace-Changed-Response
    = Airspace-Id
```

```
Airspace-Conflict-Analysis-Notice
    = * control flow *

Airspace-Conflict-File
    = Airspace-Violation-File + Airspace-Affected-Plans

Airspace-Database#

Airspace-Deleted-Response
    = Airspace-Id

Airspace-Id#

Airspace-Request#

Airspace-Violation-File#

Altitude-Deviation#

Amended-Plan-Entered-Response
    = Plan-Id

Amended-Plan-Error-Response
    = Plan-Id

Amended-Plan-Request-Response
    = [ Amended-Plan-Error-Response |
      Amended-Plan-Entered-Response ]

Analysis-Completed-Notice
    = [ Conformance-Analysis-Notice | Problem-Analysis-Notice ]

Atmospheric-Database
    = * called Atmospheric-Data-File in AERA 1 documents *

- B -

BAV-Entry-File#

BAV-Name#

- C -

Change-Metering-Assignment
    = Aircraft-Id + { Metering-Assignment }

Changed-Airspace-Notice
    = * control flow *
```

```
Changed-Environment-Notice
    = [ Changed-Airspace-Notice | Changed-Flow-Restriction-Notice
      | Changed-Metering-Notice ]

Changed-Flow-Restriction-Notice
    = * control flow *

Changed-Metering-Notice
    = * Control flow *

Changed-Plan-Entered-Notice
    = * control flow *

Clearance
    = Plan-Id + Clearance-Message

Clearance-Message
    = * clearance, expressed in operational terms *

Combination-Rules-Database
    = * criteria for defining related problems to form a problem
      set and rules for targeting one or more of the problems for
      resolution by APR *

Conflict-Database
    = Aircraft-Aircraft-Conflict-File + Airspace-Conflict-File +
      Flow-Restriction-Problem-File + Nonconformance-Problem-File

Conformance-Analysis-Notice
    = [ Nonconformance-Notice | Reconformance-Notice |
      Nonconformance-Update-Notice ]

Conformance-Parameter-File#

Controller-Aircraft-Problem-Set
    = Problem-Group-Id

Controller-Airspace-Problem-Set
    = Problem-Group-Id

Controller-Constraint
    = * information controller can specify to customize the
      output of APR, such as aircraft to maneuver and maneuver to
      be tried *

Controller-Flow-Restriction-Problem-Set
    = Problem-Group-Id
```

```
Controller-Nonconformance-Problem-Set
    = Problem-Group-Id

Controller-Partition-Set
    = { Problem-Id }

Controller-Problem-Group
    = { Problem-Id }

Controller-Problem-Group-List
    = { Controller-Problem-Group }

Controller-Problem-Set
    = [ Controller-Aircraft-Problem-Set |
      Controller-Airspace-Problem-Set |
      Controller-Nonconformance-Problem-Set |
      Controller-Flow-Restriction-Problem-Set ]

Controller-Reminder-Display
    = Plan-Id + Controller-Reminder-Message

Controller-Reminder-File
    = [ Deliver-Clearance-Reminder | Monitor-Maneuver-Reminder ]

Controller-Reminder-Message
    = Source + Planned-Clearance-Change

Controller-Request
    = [ New-Plan-Request | Plan-Amendment-Request |
      Resolution-Request | Trial-Plan-Request ]

Converted-Route#

Coordinate-Plan-Request
    = [ List-Requested | List-Included | No-List-Requested ]

Coordinatees-List
    = { Receiving-Sector }

Coordination-Begun
    = Plan-Id + Initiating-Sector

Coordination-File
    = { Plan-Id + Initiating-Sector + [ Receiving-Sector +
      Sector-Response | TMC-Response ] + Time-Out }

Coordination-List
    = Plan-Id + Initiating-Sector + Receiving-Sector-List
```

```
Coordination-Not-Needed
    = Plan-Id + Initiating-Sector

Coordination-Request
    = Plan-Id + Initiating-Sector + { Receiving-Sector }

Coordination-Request-Display
    = [ Coordination-Request-Error | Coordination-List |
      Coordination-Not-Needed | Coordination-Begun |
      Coordination-Request | Forwarded-Plan-Being-Coordinated |
      Forwarded-Plan-Request ]

Coordination-Request-Error
    = Plan-Id + Initiating-Sector

Coordination-Response
    = Plan-Id + [ Receiving-Sector + Sector-Response |
      Flow-Restriction-Id + TMC-Response ]

Coordination-Response-Summary
    = { Receiving-Sector + Sector-Response }

Current-Clearance#

Cusp-File#

Cusp-Type#

- D -

Data-Link-Request
    = Plan-Id + { Planned-Clearance-Change }

Delete-Metering-Assignment
    = Aircraft-Id

Deliver-Clearance-Reminder
    = Plan-Id + Time + Controller-Reminder-Message

Departure-Message
    = Aircraft-Id + Departure-Time

Departure-Time
    = * self-defining:  Time *

Display-Request
    = * request for display of AERA information *
```

```
DNP-Extension-Notice
    = * control flow *

- E -

Entered-Plan-Notice
    = [ Changed-Plan-Entered-Notice | New-Plan-Entered-Notice ]

Environment-Change-Response
    = [ Airspace-Change-Response |
      Flow-Restriction-Change-Response |
      Metering-Change-Response ]

Exception-File#

Exit-Time
    = * time at which aircraft exits from problem *

- F -

Feasibility-Rules-Database
    = * called Feasibility-Rules-File in AERA 1 documents *

Field-Change-List#

Filed-Plan#

Fix-Crossing-File#

Flight-Plan-Descriptors#

Flight-Status-Display
    = * AERA information on aircraft plans *

Flow-Exemption
    = Plan-Id + Flow-Restriction-Id

Flow-Restriction-Added-Response
    = Flow-Restriction-Id

Flow-Restriction-Affected-Plans
    = { Flow-Restriction-Id + Aircraft-Id + Exit-Time }

Flow-Restriction-Change-Error-Response
    = Flow-Restriction-Id
```

```
Flow-Restriction-Change-Response
    = [ Flow-Restriction-Change-Error-Response |
      Flow-Restriction-Added-Response |
      Flow-Restriction-Changed-Response |
      Flow-Restriction-Deleted-Response ]

Flow-Restriction-Changed-Response
    = Flow-Restriction-Id

Flow-Restriction-Database#

Flow-Restriction-Deleted-Response
    = Flow-Restriction-Id

Flow-Restriction-Id#

Flow-Restriction-Problem-Analysis-Notice
    = * control flow *

Flow-Restriction-Problem-File
    = Flow-Restriction-Violation-File +
      Flow-Restriction-Affected-Plans

Flow-Restriction-Request#

Flow-Restriction-Violation-File#

Forwarded-Plan-Being-Coordinated
    = Plan-Id + Initiating-Sector + Receiving-Sector

Forwarded-Plan-Request
    = Plan-Id + Receiving-Sector

Forwarding-File
    = { Plan-Id + Initiating-Sector + Receiving-Sector +
      Time-Out }

- G -

Group-List
    = { Problem-Id }

- H -

- I -

Initiating-Sector
    = * unique identifier for sector initiating coordination *
```

```
Initiator
    = Values:  Controller
               Machine

Input-Response
    = [ Environment-Change-Response | Plan-Request-Response |
      Reported-Coordination-Response | Sectorization-Response ]

- J -

- K -

- L -

Last-Update-Time#

Lateral-Deviation#

List-Included
    = Plan-Id + Initiating-Sector + { Receiving-Sector }

List-Requested
    = Plan-Id + Initiating-Sector

Location#

Longitudinal-Deviation#

- M -

Machine-Aircraft-Problem-Set
    = Problem-Group-Id

Machine-Airspace-Problem-Set
    = Problem-Group-Id

Machine-Flow-Restriction-Problem-Set
    = Problem-Group-Id

Machine-Nonconformance-Problem-Set
    = Problem-Group-Id

Machine-Partition-Set
    = { Problem-Id }

Machine-Plan-Aircraft-Analysis-Notice
    = * control flow *
```

```
Machine-Plan-Airspace-Analysis-Notice
    = * control flow *

Machine-Plan-Analysis-Notice
    = Machine-Plan-Aircraft-Analysis-Notice +
      Machine-Plan-Airspace-Analysis-Notice +
      Machine-Plan-FR-Analysis-Notice ]

Machine-Plan-FR-Analysis-Notice
    = * control flow *

Machine-Plan-Id
    = Plan-Id

Machine-Plan-Notice
    = * control flow *

Machine-Plan-Rank
    = * relative position of machine plan in list of machine
      plans *

Machine-Problem-Group
    = { Problem-Id }

Machine-Problem-Group-List
    = { Machine-Problem-Group }

Machine-Problem-Set
    = [ Machine-Aircraft-Problem-Set |
      Machine-Airspace-Problem-Set |
      Machine-Nonconformance-Problem-Set |
      Machine-Flow-Restriction-Problem-Set ]

Machine-Resolution-Completed-Notice
    = * control flow *

Maneuver-Envelope-File#

Maneuver-Type
    = * specific method of implementing a strategy, such as
      "direct to downstream fix" *

Metering-Applicability
    = Aircraft-Id

Metering-Assignment
    = Location + Time
```

```
Metering-Assignment-Added-Response
    = Aircraft-Id

Metering-Assignment-Changed-Response
    = Aircraft-Id

Metering-Assignment-Deleted-Response
    = Aircraft-Id

Metering-Assignment-Id
    = * Unique identifier for this metering flow restriction *

Metering-BAV-Correlations
    = { BAV-Name }

Metering-Change-Error-Response
    = Aircraft-Id

Metering-Change-Response
    = [ Metering-Change-Error-Response |
      Metering-Assignment-Added-Response |
      Metering-Assignment-Changed-Response |
      Metering-Assignment-Deleted-Response ]

Metering-Constraints
    = { Location + Time }
    * replaces Time-At-Fix-Or-Boundary flow restriction
      constraint type from AERA 1 *

Metering-Database
    = { Metering-Assignment-Id + Metering-Applicability +
      Metering-BAV-Correlations + Metering-Constraints }

Metering-Request
    = [ Add-Metering-Assignment | Change-Metering-Assignment |
      Delete-Metering-Assignment ]

Metering-Status#

Monitor-Maneuver-Reminder
    = Plan-Id + Time + Controller-Reminder-Message

- N -

New-Plan-Entered-Notice
    = * control flow *
```

```
New-Plan-Entered-Response
    = Plan-Id

New-Plan-Error-Response
    = Aircraft-Id

New-Plan-Request#

New-Plan-Request-Response
    = [ New-Plan-Error-Response | New-Plan-Entered-Response ]

No-List-Requested
    = Plan-Id + Initiating-Sector

Nominal-Path-Update-Notice
    = [ Resynchronization-Notice | DNP-Extension-Notice ]

Nonconformance-Notice
    = * control flow *

Nonconformance-Problem-File
    = { Plan-Id + Time + Aircraft-Position + Lateral-Deviation
      + Longitudinal-Deviation + Altitude-Deviation + Cusp-Type }

Nonconformance-Update-Notice
    = * control flow *

Nonresolvable-File
    = { Problem-Id + Rationale }

- O -

Objection-List
    = * list of ATC objections found with a machine plan, such as
      'additional sectors entered' or 'turbulence' *

Objection-List-Notice
    = * control flow *

Original-Flight-Plan#

- P -

Parameter-Values
    = * data which define a maneuver, such as start location and
      turn angle *
```

```
Path-Completed-Notice
    = * control flow *

Pilot-Amendment-Request
    = Plan-Id + Field-Change-List + Planned-Change-List

Pilot-Plan-Request
    = Aircraft-Id + Plan-Type + Route-String +
      Flight-Plan-Descriptors

Pilot-Request
    = [ Pilot-Amendment-Request | Pilot-Plan-Request ]

Plan-Amendment-Request
    = Plan-Id + Field-Change-List + Planned-Change-List

Plan-Database
    = Plan-File + BAV-Entry-File + Fix-Crossing-File +
      Planned-Action-File + Cusp-File + Maneuver-Envelope-File +
      Conformance-Parameter-File + Exception-File +
      Controller-Reminder-File + Coordination-File

Plan-File
    = { Plan-Id + Plan-Status + Last-Update-Time +
      ( Action-Flag ) + ( Original-Flight-Plan ) +
      Current-Clearance + Converted-Route + Metering-Status }

Plan-Forwarded
    = Plan-Id + Initiating-Sector

Plan-Id
    = Aircraft-Id + Plan-Number
    * Unique identifier for plan *

Plan-Number
    = * Unique identifier of plan among the plans for a given
      aircraft*

Plan-Request-Response
    = [ Amended-Plan-Request-Response |
      New-Plan-Request-Response | Resolution-Request-Response ]

Plan-Resolution-Request
    = Plan-Id + { Controller-Constraint }
```

```
Plan-Status
    = Values:  Current
               Pending
               Trial
               Trial-Reprobe
               Trial-LRA/RA
               Machine
               Dormant

Plan-Type#

Planned-Action-File#

Planned-Change-List#

Planned-Clearance-Change#

Position-Database#

Preferred-Maneuver-Parameter-File
    = * rules specifying preferred start and end locations and
      feasible parameter values *

Problem-Analysis-Notice
    = [ Aircraft-Conflict-Analysis-Notice +
      Airspace-Conflict-Analysis-Notice +
      Flow-Restriction-Problem-Analysis-Notice |
      Airspace-Conflict-Analysis-Notice |
      Flow-Restriction-Problem-Analysis-Notice ]

Problem-Group
    = Problem-Group-Id + Target-Problem-Id + Initiator +
      Group-List

Problem-Group-File
    = { Problem-Group + ( Proposed-Resolutions-List ) }

Problem-Group-Id
    = * Unique identifier for group of problems to be resolved *

Problem-Id
    = * Unique identifier for each problem detected *

Problem-List
    = { Problem-Id }
```

```
Problem-Resolution-Completed-Notice
    = [ Machine-Resolution-Completed-Notice |
      Requested-Resolution-Completed-Notice ]

Problem-Resolution-Request
    = Problem-Id + { Controller-Constraint }

Problem-Set
    = [ Controller-Problem-Set | Machine-Problem-Set |
      Replace-Plan-Set ]

Proposed-Resolutions-List
    = { Strategy + Maneuver-Type + [ Machine-Plan-Id |
      Rationale ] }

Proposed-Resolutions-Notice
    = * control flow *

- Q -

- R -

Ranking-File
    = { Machine-Plan-Id + Machine-Plan-Rank +
      [ Objection-List + Problem-List | Rationale ] +
      Replace-Machine-Plan-Time }

Ranking-Rules-File
    = * rules which specify the level of severity for each
      problem and ATC objection *

Rationale
    = * reason a strategy or maneuver was infeasible *

Receiving-Sector
    = * unique identifier for sector with which coordination is
      occurring *

Receiving-Sector-List
    = { Receiving-Sector }

Reconformance-Notice
    = * control flow *

Replace-Aircraft-Plan-Set
    = Problem-Group-Id + Machine-Plan-Id + Strategy +
      Maneuver-Type
```

```
Replace-Airspace-Plan-Set
    = Problem-Group-Id + Machine-Plan-Id + Strategy +
      Maneuver-Type

Replace-Flow-Restriction-Plan-Set
    = Problem-Group-Id + Machine-Plan-Id + Strategy +
      Maneuver-Type

Replace-Machine-Plan-Time
    = * self-defining:  Time *

Replace-Nonconformance-Plan-Set
    = Problem-Group-Id + Machine-Plan-Id + Maneuver-Type

Replace-Plan-Set
    = [ Replace-Aircraft-Plan-Set | Replace-Airspace-Plan-Set |
      Replace-Flow-Restriction-Plan-Set |
      Replace-Nonconformance-Plan-Set ]

Reported-Coordination-Response
    = Initiating-Sector + Plan-Id + Coordination-Response-Summary

Requested-Resolution-Completed-Notice
    = * control flow *

Resolution-Completed-Notice
    = [ Problem-Resolution-Completed-Notice |
      Proposed-Resolutions-Notice ]

Resolution-Goals-Database
    = Resolution-Request-File + Sector-Constraint-File +
      Ranking-Rules-File

Resolution-Request
    = [ Plan-Resolution-Request | Problem-Resolution-Request ]

Resolution-Request-Error-Response
    = [ Plan-Id | Problem-Id ]

Resolution-Request-File
    = { Resolution-Request + ( Resolution-Request-Result ) }

Resolution-Request-Notice
    = * control flow *

Resolution-Request-Received-Response
    = [ Plan-Id | Problem-Id ]
```

```
Resolution-Request-Response
    = [ Resolution-Request-Error-Response |
      Resolution-Request-Received-Response ]

Resolution-Request-Result
    = [ { Problem-Group-Id } | Rationale ]

Resolution-Rules-Database
    = Strategy-Maneuver-File + Preferred-Maneuver-Parameter-File
      + Combination-Rules-Database

Resolutions-Database
    = Problem-Group-File + Nonresolvable-File + Ranking-File

Resynchronization-Notice
    = * control flow *

Route-Database#

Route-String#

- S -

Sector-Constraint-File
    = * Constraints on APR, set by controller set-up of sector *

Sector-Display
    = * AERA information for display to sector controllers *

Sector-Response
    = Values:  Unable
               Approved
               No-Response

Sectorization-File#

Sectorization-Response
    = Values:  Sectorization-Request-Error
               Sectorization-Request-Completed

Sectorization-Request#

Source#

Strategy
    = * general plan of action, such as 'cut corner', intended to
      avoid a problem in an aircraft's route *
```

```
Strategy-Maneuver-File
    = { Strategy + Maneuver-Type }

- T -

Target-Problem-Id
    = Problem-Id

Time#

Time-Entered#

Time-Out
    = * time by which responses are expected *

TMC-Response
    = Values:  Approved
               Unable
               No-Response

Trial-Plan-Request#

- U -

- V -

- W -

Workload-Database#

Workload-Display
    = * called Displayable-Workload-Notice in AERA 1 documents *

Workload-Request#

- XYZ -
```

APPENDIX A

A GUIDE TO STRUCTURED SPECIFICATION

In this document we adopt the structured analysis conventions described by DeMarco in Structured Analysis and System Specification [8]. DeMarco's text deals mainly with those phases of system design and specification on the highest levels and does not address computer coding. The discipline of structured design does continue, though, into the lower levels of software design, and references are cited in DeMarco's book.

The conventions of structured analysis are few in number, but provide a powerful tool for the analyst to convey difficult subject matter in short space. DeMarco observes that most attempts to convey a design of a software system using text seem inadequate simply because the text cannot be constructed to satisfy both the analyst and the user who must understand and verify the design--the two do not see the same meaning in the same set of words. DeMarco goes on to describe a highly pictorial methodology for conveying design information.

A pictorial approach to system specification has the benefit that one can quickly grasp the major portions of the design without in-depth reading. To be sure, the design is further amplified by carefully structured language, but the basics of the design conveyed in pictures and diagrams are quickly grasped. In order to standardize the process--to create a language that both the analyst and the user can understand--DeMarco describes the Structured Analysis methodology.

The product of structured analysis is the Structured Specification. This Specification contains an analysis-phase system model portrayed using a set of diagrams which form function networks. The approach describes the data and the transformations used in processing the data. The diagrams are further amplified using a structured dictionary of data items and structured English to describe transforms, or processes. The Structured Specification is intended to facilitate a dialogue with the eventual user of the system. Proper use of the Structured Analysis techniques reduces redundancy and enhances maintainability.

The three components of the Structured Specification are:

- Data Flow Diagrams (DFDs)
- A Data Dictionary (DD)
- Minispecifications

Each component is described in detail below.

A.1 The Data Flow Diagram

DeMarco describes a Data Flow Diagram (DFD) as "a network representation of a system." The system being described can be any mix of manual and automated processes. The DFD is used in the structured specification as a partitioning tool. The mapping of data flows for a system indicates the major processes, or transformations, necessary to convert system input data to required output data.

A DFD may consist of

- Named vectors, either solid or dashed
- Process bubbles
- File lines
- Data source or sink boxes

A DFD gives the direction and content of data paths within the system. A solid named vector in a DFD is a data path for the information represented by the name attached to the vector. A convention introduced here, a dashed named vector is a control path for the process trigger represented by the name attached to the vector. In Figure A-1, the vectors named X and Y are data paths for respective data flows called X and Y.

Transformations of data are indicated in a DFD using process bubbles. Process P in Figure A-1 transforms Xs to Ys using information contained in the temporary depository of data, File F. The box labeled S in Figure A-1 is a data source (i.e., no named vectors terminate at the box). Likewise, a data sink can be illustrated using a box with no outgoing arrows. A box can represent both a data source and data sink. Using the four elements of a DFD, data can be described as emanating from data

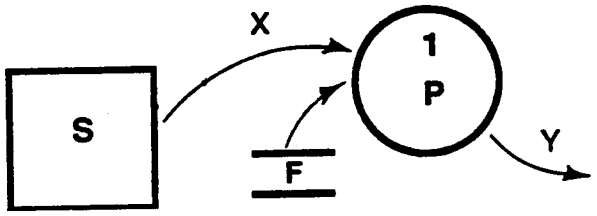


FIGURE A-1
SAMPLE DATA FLOW DIAGRAM

sources, ending in data sinks, being transformed through processes using file information, or storing file information as necessary. Figure A-1 represents an information pipeline through which data of known content flow.

Some notational conventions for DFDs include

- Data flow names are hyphenated using initial capitals
- Data flow names are selected to self-document the diagram when possible
- Data flow diagrams indicate net flows of data
- No procedural data-combining notation is used in the DFD
- A DFD is contained on one page

A Data Flow Diagram is maintained on a single page using the concept of "leveling." A leveled DFD portrays a top-down decomposition of a system in which further refinements to processes are contained on succeeding pages of diagrams or text. Figure A-2 shows the concept of a leveled data flow diagram. Process P is further described in Diagram 1 as a set of processes with respective flows. Using successive refinement of DFDs, a progressively more detailed picture is represented while allowing the user to stop at any level with a complete picture--although not the most detailed picture--of the system.

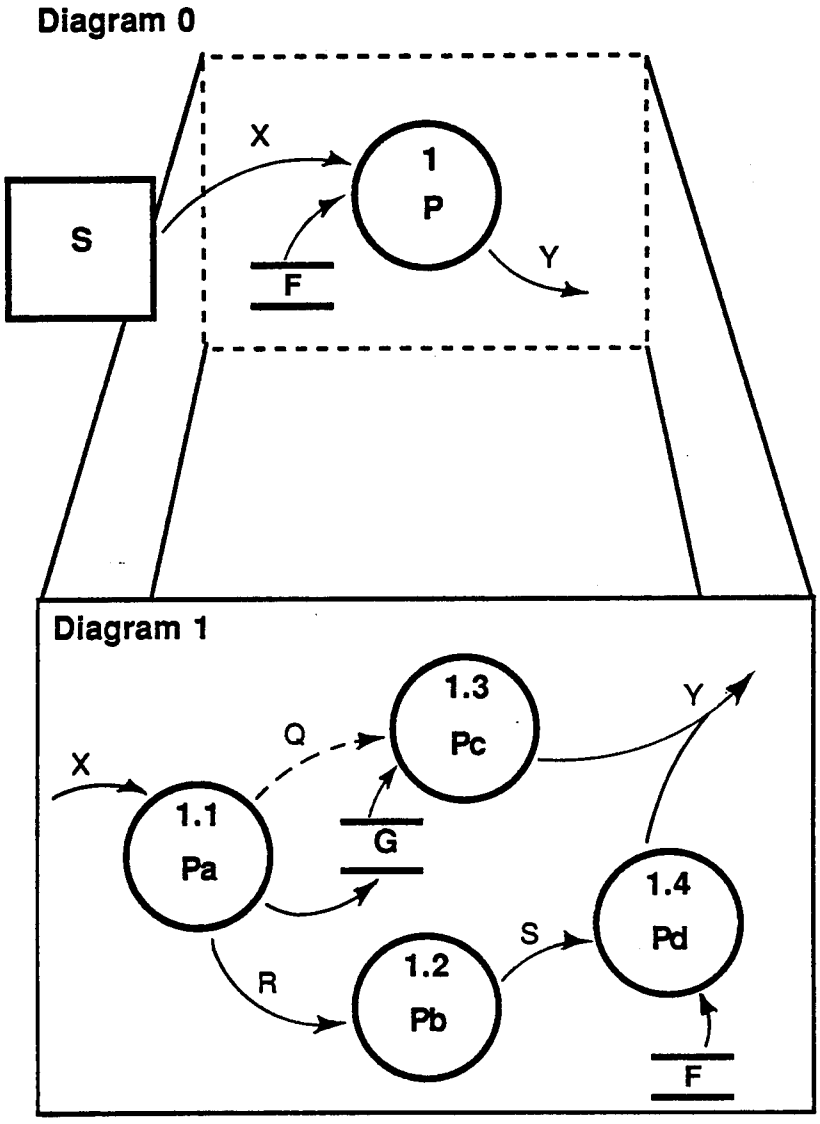


FIGURE A-2
A LEVELED DATA FLOW DIAGRAM

A set of leveled DFDs conserves the content of data flows. Figure A-2 shows this concept. The input and output streams of Diagram 1--called the "child" of Diagram 0--are exactly the same as the input and output to process P in Diagram 0--called the "parent" of Diagram 1. Data conservation, or balancing, may not be obvious, however, since the input to a child may be a named subset of the input of the parent process. A similar statement could be made concerning outputs.

Figure A-2 also shows an internal data file G, set by process Pa and used by process Pc. Process Pc is triggered by control flow Q from process Pa. Data flows R and S are internal to process P.

Last, Figure A-2 indicates a process numbering system. Although sequencing of processes within a diagram using consecutive numbers is arbitrary, the processes will always inherit, as a reference, the number of the parent process.

A.2 The Data Dictionary

The Data Dictionary is an integral part of the Structured Specification. It is simply a repository of information about data. Within the confines of the Data Dictionary, all named data flows in the DFDs are further described with information about the components of the data flow. The Data Dictionary also contains definitions of files and databases.

Files and databases are logical data stores. The usage is that a file consists of one or more stored data flows, whereas a database consists of files (and other databases).

The Data Dictionary, too, uses a set of notational conventions. These conventions include data aggregation and/or selection notations. The set of notations adopted for this specification are the same as those described by DeMarco:

= means IS EQUIVALENT TO

+ means AND

[a|b|c] means EITHER a OR b OR c

{ } means ITERATIONS OF the enclosed

( ) means an optional element

* offsets comments or remarks

The Data Dictionary accompanying the DFDs in Figure A-2 might include the entries:

```
X =   Time-of-Day +
      Temperature +
      Barometric-Pressure

Y =   Probability-of-Precipitation
```

File F may also be defined as

```
F =   { Time-of-Day +
        Temperature +
        Barometric-Pressure }
```

which is a file of iterations of the given elements.

The Data Dictionary may be commented as in

```
X =   Time-of-Day * Greenwich Mean Time * +
      Temperature * Fahrenheit * +
      Barometric-Pressure * inches of mercury *
```

According to DeMarco, the Data Dictionary should not contain a cross reference to those DFDs which contain the data item. Nor should data items within a data dictionary identify the other data items in which they are included. These conventions are adopted to enhance maintainability of the Data Dictionary.

A.3 Minispecifications

The Structured Analysis Methodology provides for a top-down decomposition of a system. Continued use of the methodology will ultimately lead the designer to the level of the functional primitive. A functional primitive is a process which needs no further data flow diagramming. It is an ending process.

Structured Analysis provides for a structured English description, or "minispecification" or "minispec," of a functional primitive. There must be such a description for each functional primitive. Processes which are further defined in succeeding DFDs are, by definition, already adequately defined. Each minispec describes the rules governing the process transformation of input data to output data. The emphasis is on the rules governing the transformation; implementation details are provided by software engineers.

The minispecification should be limited to about one page and contain no redundancy compared to the DFDs. Conventions of structured English vary from organization to organization, but usually include

- Use imperative English language verbs
- Use terms defined in the Data Dictionary
- Reserve certain key words for logic formulation such as
  - IF, THEN, OTHERWISE
  - SELECT, CASE
  - FOR EACH
  - AND, OR.

APPENDIX B

ACRONYMS

AAS	Advanced Automation System
ACF	Area Control Facility
ACCR	Aircraft Conflict Resolution
AERA	Automated En Route Air Traffic Control
APR	Automated Problem Resolution
ASCR	Airspace Conflict Resolution
ATC	Air Traffic Control
CAR	Controller-Assisted Resolution
DD	Data Dictionary
DFD	Data Flow Diagram
DNP	Detailed Nominal Path
FAA	Federal Aviation Administration
FRPR	Flow Restriction Problem Resolution
LRA	Limited Resolution Aid
NAS	National Airspace System
RA	Reconformance Aid
TMC	Traffic Management Coordinator

APPENDIX C

REFERENCES

1. U. S. Department of Transportation, Federal Aviation Administration, National Airspace System Plan: Facilities, Equipment and Associated Development, April 1985.

2. U. S. Department of Transportation, Federal Aviation Administration, Advanced Automation System: System Level Specification, FAA-ER-130-005F with SCN 003, July 1985.

3. J. P. Fernow et al., "System-Level Design of AERA 1 in the Context of the AAS," MTR-84W143, The MITRE Corporation, McLean, VA, September 1984.

4. C. G. Ball et al., "Draft Automated En Route ATC (AERA) 2 System Level Specification," WP-85W233, The MITRE Corporation, McLean, VA, September 1985.

5. C. G. Ball et al., "AERA 2 Operational Description," MTR-85W66, The MITRE Corporation, McLean, VA, July 1985.

6. W. C. Arthur et al., "Draft Functional Description of AERA 2 Automated Problem Resolution," WP-85W348, The MITRE Corporation, McLean, VA, September 1985.

7. J. P. Fernow et al., "Automated En Route Air Traffic Control Algorithmic Specifications--AERA 1," MTR-84W205, The MITRE Corporation, McLean, VA, November 1984.

8. T. DeMarco, Structured Analysis and System Specification, Yourdon Press, New York, NY, 1979.

9. A. H. Gisch et al., "AERA 2 Concept," WP-84W567, Rev. 1, The MITRE Corporation, McLean, VA, January 1985.

10. W. J. Swedish, "Extensions to AERA Applicability," MTR-85W78, The MITRE Corporation, McLean, VA, July 1985.

11. J. D. Reierson, "AERA Relationship to Traffic Flow Management," MTR-85W132, The MITRE Corporation, McLean, VA, August 1985.