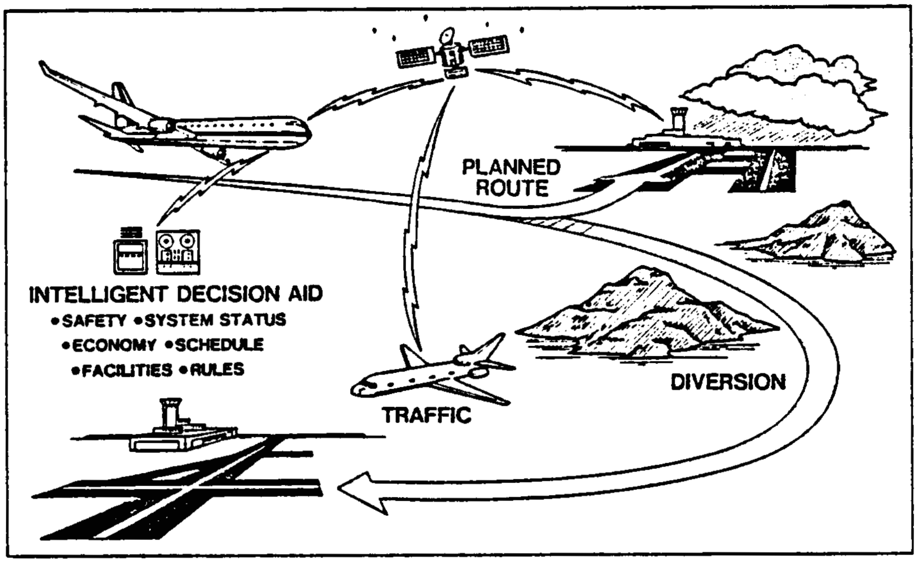
NASA Contractor Report 181820

"Diverter" AI Based Decision Aid



Phases I & II

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FOREWORD

This report discusses the feasibility of using artificial intelligence and algorithm based decision aides to assist pilots in evaluating and selecting route options dictated by in-flight diversions. The work reported on was performed by the Lockheed Aeronautical Systems Company-Georgia Division (LASC-Georgia) for the National Aeronautics and Space Administration (NASA) Langley Research Center (LaRC) at Hampton, Virginia. The project was funded by NASA under Contract Number NAS1-18029, Task 04. This report is also identified as LG88ER0116 for Lockheed internal control purposes.

Guidance for the program was provided by Cary R. Spitzer, NASA-Langley Technical Representative of the Contracting Officer, and George G. Steinmetz and Michael T. Palmer, NASA-Langley Technical Monitors. George A. Sexton directed the Lockheed effort, which was performed as part of a continuing preliminary design investigation of new aircraft concepts by the Aeronautical Systems Development Department, Charles F. Klusmann, Manager. Other Lockheed contributors were Scott J. Bayles, H. Kyle Collins, Jo Anne Evans, C. Tony Leavitt, Robert W. Patterson, Duane A. Schulke, and Deborah C. Williams.

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INTRODUCTION AND SUMMARY

New demands are being placed upon pilots to utilize airspace more effectively, to operate aircraft more efficiently, and to reduce in-flight delays while continuing to operate safely. At the same time, the amount of air traffic is increasing greatly with a relatively small increase in airport facilities. New technologies are being developed which, when properly applied, may help alleviate the overall problem. Artificial intelligence (AI) is one of those new technologies, and its application to airborne systems was the subject of this study. The specific application of AI addressed was its use in providing the pilot with all of the necessary information upon which to base decisions regarding in-flight diversions. Since the system provides information to the pilot to ensure that the aircraft maneuvers through the in-flight diversion to safely arrive at a destination, it was named "Diverter."

It was determined that a system to incorporate artificial intelligence into airborne flight management computers is feasible. The AI functions that would be most useful to the pilot are to perform situational assessment, evaluate systems status, evaluate outside influences on the contemplated rerouting, perform flight planning/replanning, and perform maneuver planning.

A study of the software architecture and software tools capable of demonstrating Diverter was also made. A skeletal planner known as the Knowledge Acquisition Development Tool (KADET), which is a combination script-based and rule-based system, was chosen and used to implement the system. A prototype system was developed which demonstrates advanced in-flight planning/replanning capability.

PROBLEM

Pilots of today's aircraft must obtain information pertinent to their proposed flight profile from a variety of sources. Through extensive preflight activities, they assimilate all necessary data and plan the flight, so that flying the flight plan can be executed in conjunction with other operational procedures. Currently, those flight plans are three dimensional (latitude, longitude and altitude). In the future, however, the fourth dimension (time) will be added to each steerpoint.

When an in-flight diversion is required, the data upon which to base decisions concerning diversions must now come from many sources, some of which are not readily available. In addition to knowing or obtaining the present position, fuel, and maintenance status of the aircraft, the pilot may need to consult aircraft handbooks, aircraft performance data, en route, terminal area, and instrument approach charts, company's flight operations, and air traffic controllers. Developing a new flight plan to make efficient use of manpower, fuel, and time, while satisfying all applicable constraints, can be time-consuming and labor intensive, particularly when the replanning is during an intensive flight phase. Frequently, there is inadequate time to obtain all data before initiating the diversion, so the pilot bases his decision upon the best information available, which is sometimes incomplete. A system is needed to quickly provide the pilot with complete and accurate information upon which to make decisions concerning in-flight diversions.

APPROACH

This program was divided into four phases: (1) Determination of feasibility and software tools, (2) Stand-alone demonstrations, (3) Evaluation in the Advanced Concepts Simulator, and (4) Validations in NASA's 737 Transport Systems Research Vehicle (TSRV) aircraft. This report covers the first two phases.

PHASE I

During Phase I, the feasibility of using artificial intelligence and algorithm based decision aids to assist the pilots in evaluating and selecting route options dictated by in-flight diversions was determined. The feasibility analysis consisted of a sequence of steps or activities. These activities focused analyses on the following:

- Diversion Classification
- Present Flight Replanning Procedures and Equipment
- Flight Management Computer Data Base
- Associated Ground Systems
- Time-Based Navigation
- Data Link Communications
- Diverter Functions
- Software Design and AI Issues

These analysis activities were not performed as discrete steps, but proceeded as an integrated and iterative process.

Through an extensive analysis of flight operations a set of diversion types was defined. The next step involved the detailed functional analysis of existing procedures and equipment used for executing diversions. This analysis identified current practices and needs which could be addressed by Diverter. The current Flight Management Computer (FMC) data base was found to be applicable to Diverter with the addition of aircraft system status and weather information.

Analyses also identified ground-based systems under development by the Federal Aviation Administration (FAA) with which Diverter must be compatible and complementary. A key issue to be considered by Diverter was the development of 4-D (i.e., time-based) navigation using sophisticated AI techniques. A key technology identified as having potential impact on Diverter was data link communications. Diverter must address issues associated with and be compatible with data links.

The integration of the available information resulted in the definition of a set of functions for Diverter. This set of functions is referenced against the current and future aviation environment as well as current and future communications and AI technologies. The development of the Diverter functions in conjunction with LASC-Georgia's extensive experience with AI resulted in the identification of critical AI technologies and capabilities needed for Diverter development.

DETERMINATION OF FEASIBILITY AND FUNCTIONAL REQUIREMENTS

Route replanning procedures for present aircraft operating in the current Air Traffic Control (ATC) environment were analyzed and used as the basis for beginning the study. In addition to conducting a literature review, airline pilots, airline training personnel, and air traffic control supervisors and controllers were interviewed. Operational procedures were observed at Atlanta Center, Atlanta Approach Control, and Atlanta-Hartsfield Tower. State-of-the-art equipment was operated in a B-767 flight simulator at the United Air Lines Training Center.

Diversions

Types of diversions were placed in six categories: different departure route, en route change to the same destination, delaying vectors, holding, different arrival route, and alternate destination. The causes for diversions were also placed into six categories: the first three are usually initiated exterior to the aircraft, the next two interior to the aircraft, and the last is initiated either way about equally.

a. Destination traffic is the most frequent cause for diversion because the number of aircraft arriving at busy terminals frequently exceeds the flow capacity. Arriving aircraft are placed in holding patterns or given delaying vectors.

b. Other en route traffic sometimes causes diversions because of conflicting routes of flight, crossing points or altitudes. The diversion could consist of a different departure route, route change to the same destination, or change of altitude or airspeed.

c. When the planned arrival airfield is closed or the arrival runway is closed or changed, the diversion may be to an alternate airfield, a different runway on the same airfield, or may be a delaying tactic such as holding, until the original destination runway is available.

d. An aircraft system malfunction sometimes causes a diversion to a suitable nearby airfield or to an airfield that has adequate repair facilities. Sometimes the aircraft establishes a holding pattern while diagnosing or correcting the malfunction, e.g., an unsafe landing gear indication.

e. Occasionally, pilots must divert their aircraft because a passenger has become very ill or unruly (up to the extreme of committing a hijacking). Usually this type of diversion would be to the nearest suitable airfield; however, in the case of hijacking, it could involve a variety of types of diversions.

f. Diversions due to adverse weather can be initiated by ATC or the pilot. They can involve any one or more of the types of diversions depending upon the kind and extent of the adverse weather.

Present Flight Replanning Procedures and Equipment

In present aircraft the pilot receives the initial indication of a possible diversion from the flight attendants for passengers, or from systems status displays for maintenance or nearby severe weather. Most frequently, however, the indication is received via voice communications from ATC or Company for the variety of other reasons to divert. When the pilot receives a change of ATC clearance, he evaluates it, then either accepts it, questions it, requests a modification to it, or rejects it. The decision is based upon the pilot's situational awareness, experience, intuition, and discussions with the Company's Flight Control, if appropriate. The route replanning may consist of following vectors provided by ATC, or the pilot may have to refer to on-board en route or terminal area charts. In aircraft equipped with a flight management computer (FMC), control/display unit (CDU), and navigation data base, the pilot can access required information through those systems. The data base typically contains all navigation aids in the area of operation (such as the US), all airways and named airway intersections, and all applicable airfields for large transport aircraft operations. Airfield data include runways, standard instrument departures (SID), transitions, standard arrival routes (STAR), instrument approaches and missed approaches. Some data bases also contain primary and alternate flight routes used by the Company. Aircraft performance data for climb, cruise, descent and landing are also included.

Aircraft with FMCs and CDUs provide the pilots with a convenient way of replanning for many types of diversions using 3-dimensional navigation. An alternate route can be built and stored in the computer, then executed with no delay. This is a convenient feature if there is a suspicion of a diversion. The alternate route can also be built in real-time, while proceeding along the primary route, then executed immediately. Alternate SIDs, STARs and transitions can be substituted directly into the flight plan from the data base, and either standard or non-standard holding patterns can easily be inserted. These present systems also provide the capability to fly a parallel course with offsets up to 20 nautical miles. This is sometimes convenient for avoiding weather or other traffic. There was no evidence of operational problems with the current FMC/CDU systems, although problems may have been present when those systems were first put into airline operation. This can probably be attributed to some modifications and debugging, and to considerably more training and by the pilots.

FMC Data Base Recommended for Diverter

Expanding the FMC data base to include additional pertinent information is one of the early steps in developing a Diverter system. Many categories of information that should be considered by the pilots prior to executing a diversion can be included. Figure 1 shows present categories and those recommended for the future. Most of the data are static enough in nature that only periodic updates would be required (e.g., each 28 days). The exceptions are: (1) current fuel and aircraft systems status, which must be sensed and updated continuously in real-time; and (2) current and forecast weather for the planned route, diversion route, planned destination, and alternate destination, which must be provided from a data base on the ground through data link.

Associated Ground Systems

The FAA, in its National Airspace System Plan, is working toward more automation in the air traffic control system and instituting a time-based navigation system (4-D Nav) to improve efficiency in the use of airspace. The airborne Diverter system complements many of the goals that FAA has established for ground systems which include: to detect potential traffic conflicts and provide resolutions; to implement Mode S data link and generate data link clearances, current weather and winds; and to provide en route metering from departure to arrival. The planned payoffs for automated en route air traffic control are capabilities to: (1) plan and monitor 4-D traffic flow, (2) permit aircraft to fly fuel efficient profiles, (3) increase safety, (4) increase National Airspace System capacity, and (5) increase controller productivity.

Time-Based Navigation

The Diverter system must be designed as an enhancement to current FMC to operate in a 4-D navigation environment. While the present FMC/CDU operate well in three dimensions, additional intelligence is required to add the dimension of time, particularly during an in-flight diversion. Conclusions drawn during the study indicate that 4-D navigation will be much more difficult to employ in terminal ATC areas than in center airspace, but it will be useful in both to enhance traffic flow. Until a solution is found to the problem of getting aircraft to the takeoff position in proper sequence and at precise times, 4-D ATC clearances will not be feasible until after the aircraft is airborne. There will also be a tradeoff in operating costs between the reduced delaying or holding time involved with 4-D and the less efficient engine operation caused by flying at non-optimum performance to meet time constraints.

Data Link Communications

Data link was another component which was discussed with ATC personnel and pilots. The advantages of data link are: (1) It will unload the voice communications system which is presently saturated, particularly in high volume terminal areas; and (2) systems can be designed so that direct communication between the aircraft computer and ground-based computers (such as ATC, Company, and weather service) can be accomplished. This could reduce workload considerably, and if hard copy printers are installed, pilots and/or controllers can obtain copies for reference, if desired.

There are several disadvantages of data link. The first is that the pilots will lose a certain amount of situational awareness concerning other air traffic that they now receive through voice communications. This includes trends or predictions on altitude and speed changes when they hear instructions being issued to aircraft that they are following.

PRESENT FMC DATA	ADDITIONAL DATA REQUIRED
NAV AIDS	FEDERAL AVIATION REGULATIONS
AIRFIELDS	WEATHER
COMPANY ROUTES	COMPANY RULES
A/C PERFORMANCE	OBSTACLES (ALT CONSTRAINTS)
FUEL	COMPANY PRIORITIES
A/C STATUS	SPECIAL USE AIRSPACE
	NOISE ABATEMENT AREAS
	SLOT TIMES

Figure 1. FMC Data Base for Diverter

Pilot reports on voice communications of unusual weather, such as storms, areas of turbulence, windshear, or icing along the planned route would also be lost. The second disadvantage is that see-and-avoid capabilities would be reduced over that for voice communications, if data link information is only presented on a head-down display. This disadvantage might be overcome in the future by converting some visual data link presentations to voice presentations on board the aircraft.

Concerns were expressed by both pilots and controllers that transmitting, receiving and interpreting data link messages would increase workload over voice command and possibly increase communications response time. This is of particular concern in the busy terminal areas. There was also concern that complete messages may not be received due to antenna location, weather phenomenon, or other reasons, and that neither the sender nor the receiver would immediately be aware of missing or incorrect data.

Diverter Functions

During Phase I it was determined that Diverter should operate as a flight manager by employing artificial intelligence to provide the pilot with decision aiding information, specifically as it related to in-flight diversions. Based upon the assumption that the prerequisites described earlier (expanded on-board data bases, time-based navigation, and FAA data link systems) will be available, candidate functions for Diverter were developed. The functions were placed into five categories as follows:

a. Perform situational assessment. At the time that a diversion is contemplated or directed, the aircraft's position, heading, airspeed, altitude, etc., must be known so that data can be applied in computation of the diversion.

b. Evaluate systems status. The maintenance status or present capability of the aircraft, engines, avionics systems, fuel, oxygen, etc., must be known and evaluated.

c. Evaluate influences on contemplated re-routing. Numerous factors external to the aircraft must be considered for safe, efficient operation. Weather along the proposed route must be suitable. Conflicts with other air traffic must be resolved. Federal Aviation Regulations must be complied with. Special Use Airspace must not be violated. Noise abatement procedures, company rules and priorities should be followed. And, slot times for arrival and other aircraft slot times should be considered. Weather and traffic information must be obtained in real-time, while the rest can reside in the on-board data base.

d. Perform flight planning/replanning. Diverter must evaluate a new route or destination provided by ATC with respect to time, situation, external influences, and systems status, as listed above; or it must plan for a new route or destination as a result of an on-board cause considering the same criteria. In either case, the results of the flight planning/replanning would be presented to the pilots to aid them in making a decision. Time-based navigation, or 4-D flight plans, will require a considerable increase in calculations over present 3-D navigation.

e. Perform maneuver planning. During the route replanning and execution of a diversion, Diverter must consider aircraft performance capability as it relates to the planned vertical profile, and must maneuver to avoid terrain, other traffic, and adverse weather. Aircraft performance and terrain/obstacle information can be part of the on-board data base; traffic and weather must be obtained in real-time.

The data flow for the Diverter system is shown in Figure 2. Data from those items listed as External Influences, Present Situation, Map (referring to where it may be displayed), Aircraft Performance, and Status will be available to Diverter either from a data base or real-time data link. A diversion may originate from an ATC instruction, an in-flight malfunction, a company directive, or a weather advisory. Diverter will consider all pertinent data and check or plan the new 4-D route and provide the pilot with information on it, including the effect on time constraints, available fuel, en route or destination weather and facilities/capabilities at the destination. The pilot can then approve and select the plan, or reject it, or modify it. In the latter case, Diverter will re-evaluate the flight plan as modified and notify the pilot of any discrepancies.

SOFTWARE DESIGN AND ARTIFICIAL INTELLIGENCE ISSUES

Early in the design process, it was important to define the software architecture and proper software tools that can support the Diverter system from an unsophisticated stand-alone demonstration through actual implementation in an aircraft. Part of this task was to determine the software design and artificial intelligence issues, and to recommend software tools to be used during later phases.

A comparison was made of the expert system building tools that are currently available. Through various ongoing AI projects at LASC-Georgia, a working knowledge has been gained of AI technologies, including those listed in the BBN/NASA report, "An Analysis of the Applications of AI to the Development of Intelligent Aids for Flight Crew Tasks." Intelligent systems have been developed at LASC-Georgia using several expert system development tools. These tools include: Automated Reasoning Tool (ART), Knowledge Engineering Environment (KEE), OPS5 (and other versions of OPS), S1, and the Lockheed Expert System (LES). Smaller programs are also being developed using the logic-based programming language PROLOG. Research was also done for the Metalevel Reasoning System (MRS) and SRL+ (now known as Knowledge Craft) tools. The capabilities of the knowledge representation schemes used by these development systems are basically quite similar for the purposes of this study.

In general, except for OPS5, all of these tools are very expensive and not very transportable; they provide most of the basic operations needed for developing large systems. For large planning systems (like Diverter), however, these rule-based systems are too cumbersome to be efficient (if they can be used successfully at all).

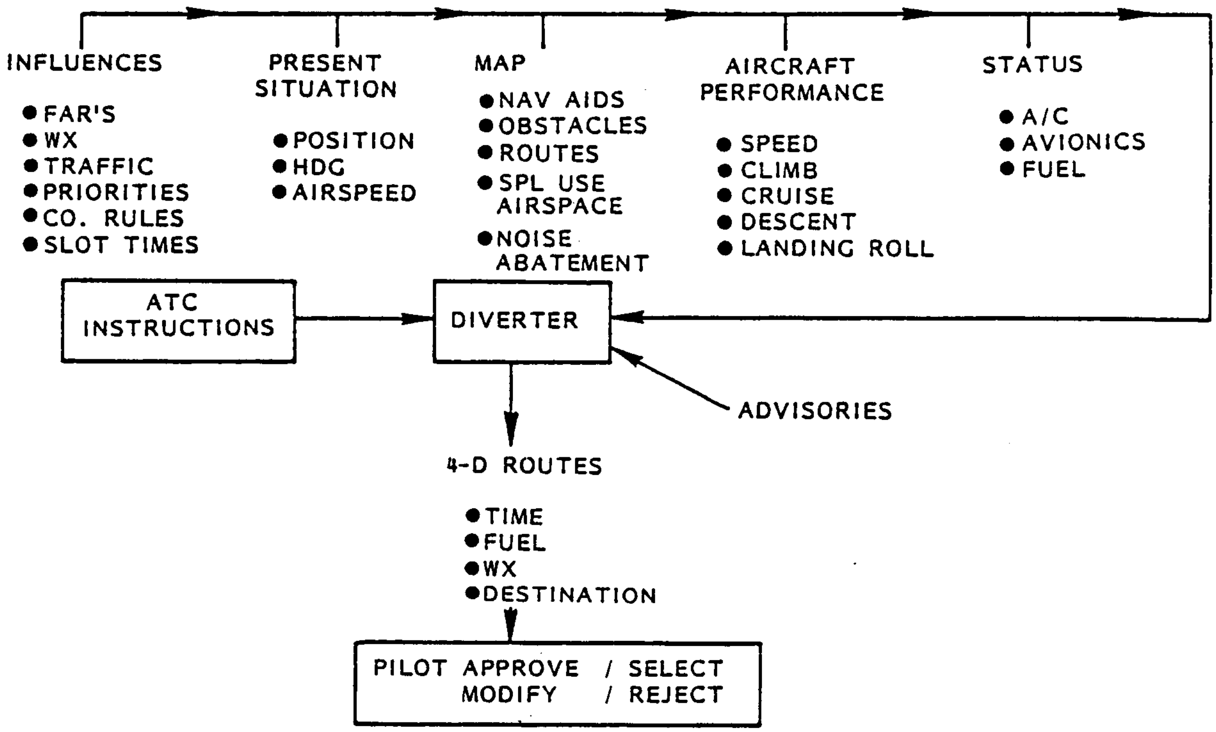

Figure 2. Diverter Data Flow

Rule-based systems were then compared to script-based systems. Script-based systems are constrained to structured sequences of events in a narrow knowledge or problem domain. It is also difficult to recognize when a script has failed or is working incorrectly. Rule-based systems, conversely, are more flexible and can handle both unrelated sets of information and unorganized or unexpected data. Rule-based systems also allow for the prediction of future events. It was determined that it would be much harder to implement Diverter using rule-based systems than using script-based planning systems. However, it was also determined that some kind of rule-based subsystem would be an excellent complement to the overall script-based planner. Using a script-based planner would provide a good representation of the well-defined "scripts" that normally take place during a Diverter mission, while the rules could handle the assertion of facts to any knowledge-base or blackboard, as well as handling the abnormal events that take place, possibly by executing a set of "subscripts."

Thus, a skeletal planner known as the Knowledge Acquisition Development Tool (KADET) was chosen. KADET is a planner that uses both script-based and rule-based systems and has the capability of executing in real time. KADET uses prior knowledge to construct scripts or skeletal plans. The details of these scripts/plans are then filled in as the system executes.

KADET's scripts/plans consist of a series of Plan Elements (PEs). The PEs are themselves made up of specific subscripts, and each now has its own blackboard. The blackboard contains assertions of facts with information including the certainty, source, and time of the assertion. There are a series of rule-based functions that work on these PEs. These rules are used to:

- o Initialize the PE
- o Specialize the PE to the specific domain
- o Determine if the PE is applicable to the current situation
- o Decompose the PE to satisfy each of its applicable subscripts
- o Establish the completion or failure of a script/plan
- o Execute a script/plan

KADET also has opportunistic rules, which allow higher priority items to be addressed immediately (e.g., a time-critical malfunction warning).

Valuable knowledge has been (and will continue to be) learned from direct involvement in the Pilot's Associate (PA) program. KADET is being used in the Tactics Planner, Mission Planner, and System Status modules within the PA. Diverter will apply "lessons learned" from the PA, not only with KADET but also with the concepts of conflict resolution and coordinating expert systems, which are directly applicable to the Diverter project.

PHASE II

During Phase II a prototype intelligent aid for diversion was developed. Phase II consisted of two major activities:

1. System Definition and Development
   a. Airfield Selection
   b. Route Selection
   c. System Functional Flow

2. Demonstration
   a. Hardware Configuration
   b. Scenarios
   c. Lessons Learned

Based on the information gathered in Phase I the system was defined and developed. Diverter was developed around two sequential decision processes: airfield selection followed by route selection. The overall system functional flow was designed around these two decision processes.

Demonstration of Diverter required the integration of AI technology with a standard aircraft simulation environment through the use of a complex system configuration. Once the hardware configuration was in place, several simulation scenarios were implemented. In the design, development, and demonstration process a number of valuable lessons were learned relating to hardware and software implementation, within the present AI architecture.

The conceptual architecture of the system is shown in Figure 3. This figure illustrates how the Diverter AI-based functional components combine to enhance the pilot's situational awareness and serve as an aid to the pilot's decision process. The figure also shows the necessary linkage of the Diverter system to the ATC environment as well as to other on-board intelligent aids. These would include systems based on NASA Langley's prototype on-board fault monitoring and diagnosis aid (FaultFinder), currently under development. The key functions of the Diverter architecture which have been implemented for this demonstration are:

- the generation of divert options
- the recommendation of diversion
- the flight replanner
- a preliminary explanation facility
- the initial message parser
- the capability for pilot to accept recommendation or select another option

SYSTEM DEFINITION AND DEVELOPMENT

Phase I of this program included an extensive analysis of the functional requirements of an intelligent diversion system. Phase I also examined the existing procedures and techniques used by pilots in diversion situations. Extensive data from the Federal Aviation Regulations (FARs), the Airman's Information Manual (AIM), and Air Traffic Procedures (ATP) were compiled for use in this project and are presented in Appendix A. Terrain and other obstacles within 35 nautical miles of the Denver airport (the diversion destination used in the prototype demonstration) were plotted, and rules to avoid those obstacles were developed and are presented in Appendix B. The data collected also included what information was used and what decisions were made by pilots

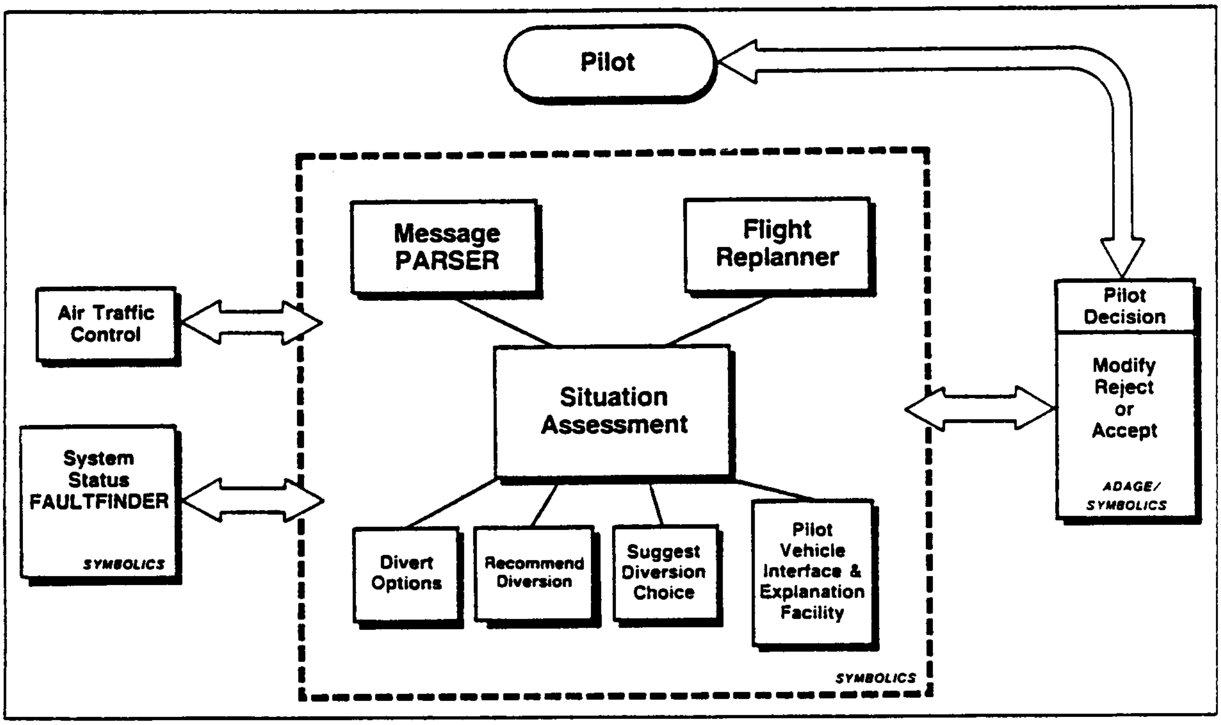

Figure 3. Conceptual Architecture of Diverter

within the constraints of the prescribed procedures. These analyses defined functions to which artificial intelligence technology could be applied with the most benefit.

The generic scenario for Diverter includes introduction of problem conditions requiring a diversion from the planned flight path. Diverter is capable of two modes of operation depending on the nature of the diversion. The modes available are: (a) Diverter evaluates a suggested diversion plan proposed by ATC and makes a recommendation to the pilot to accept/reject the plan; or (b) Diverter initiates a replanning procedure and then presents the recommendation to the pilot if the diversion is not initiated by ATC. The demonstration includes four different reasons for diversion: weather, cabin pressurization failure, engine failure, and a catastrophic emergency. Each of these situations has a different set of operational impacts as well as a different set of requirements to be addressed. The specific impacts and requirements of each situation were identified and defined through extensive discussion with the pilots.

Based on the functional analyses in Phase I in conjunction with known and available AI capabilities, the present system function was divided into two decision processes: (1) airfield selection; and (2) route selection. The solution for each of these decisions is based on the evaluation of a set of salient characteristics or attributes which effect the outcome of each question. These salient attributes were defined based on the knowledge acquisition process begun during Phase I. This process included in-depth interviews with domain experts who were civilian and military pilots and air traffic controllers, as well as examination of flight manuals, FAA regulations and company guidelines. Each attribute was assigned a numeric weight which reflects its relative importance and is used by Diverter in its computation/evaluation process. The correctness of the decisions and subsequent recommendations made by Diverter are dependent on the weightings. The attributes used by Diverter and their weightings (for the airspace used in the demonstration) are listed in Appendix C. This attribute information would be resident in the FMC for use by Diverter.

Airfield Selection

The first decision made by Diverter is airfield selection. Diverter chooses a set of alternate airfields based on their distance from the current location of the aircraft. This list of airfields is subjected to evaluation based on the weighted attributes. For this task Diverter employs an algorithmic search of a static data base. From this search procedure the best alternate is selected as the new destination. The attributes used in this evaluation procedure are listed below:

Airfield Decision Factors

- Safety
  - Weather
  - Crew Duty Time
  - Air Traffic
  - Aircraft Operations
  - Aircraft Maintenance Status

Airfield
  Airfield Conditions
  Navigation Aids Status
  Communications Status
  Special Operating Hours
  Parking Space Availability
  Maintenance Availability

Facilities
  Emergency Equipment
  Suitable Stairs
  Power Cart Availability
  Relief Crew Availability
  Transportation to Destination
  Hotel Accommodations

Passenger Comfort
  Cabin Altitude Descent Rate
  Turbulence
  Maneuvering

Schedule
  ATC En Route Vectors and Holding
  Delay in Terminal Area
  ATC, Gate, Taxi Delay
  Aircraft Turn Around Time
  Departure Delays
  Wind Effect

Economy
  Fuel
  Landing Fees
  Maintenance
  Crew

<u>Route Selection</u>

Diverter then must select a route to the new destination. Two methods were explored. The first employed a search using a relatively simple algorithm as done for airfield selection. In this case, the search and evaluation were based on a set of static attributes. The attributes that would be used by Diverter for this process are listed below.

Route Selection Factors

Safety
  Weather
  Air Traffic
  Aircraft Operations
  Aircraft Maintenance Status

Routing
  Approach Profile
  Restricted Areas
  Military Operation Areas
  Terrain/Obstacles
  Terminal Control Area Altitude/Route Restrictions

Schedule/Economy
  ATC En Route Vectoring/Holding
  Wind
  Meeting Slot Time
  Route/Approach/Descent Distance

Passenger Comfort
  Cabin Altitude Descent Rate
  Turbulence
  Maneuvering

The definition of alternate routes and the selection of a preferred route in a dynamic, real-time context is a complex problem. This problem cannot be solved adequately using simple strategies, such as those mentioned above, but requires special intelligent programming techniques in order to achieve a flexible, dynamic replanning capability. This programming problem is made more difficult by the need to provide the pilot with a query/explanation facility in order for him to understand and have confidence in the system's advice. Therefore a second more sophisticated replanning method was needed.

To inject the needed flexibility into the replanning process used by Diverter, an algorithm based on the A* search technique was developed. The A* algorithm searches all possible route segments from the aircraft's current location and finds the best possible (minimal "cost") route to the chosen destination based on the weighting scheme. The domain of this search is a map of all of the FAA defined flight segments to a specific airfield from the current location of the aircraft. A flight segment is a straight path between two FAA defined waypoints. This path can be defined for various altitude levels according to the airways depicted in the En Route Low Altitude and En Route High Altitude charts. "Costs" for the segments are determined based on the following factors:

- o Environment - This includes any weather problems that may be present and all ground based obstacles such as mountains, towers, etc.
- o Distance - This is raw distance in miles of that segment and the total distance of the path currently being considered.
- o Current Aircraft Status - For this phase we will only be concerned with an engine failure and a pressurization failure, in which case the maximum altitude for the aircraft is affected. An "extreme" emergency status is also implemented for this phase, which plans an immediate path to the nearest airfield staying within aircraft restraints such as maximum rate of descent and less than 1g turns.
- o Altitude - Based on aircraft status and environment, a low "cost" is given if the altitude of the segment is acceptable, and a very high "cost" is given if the segment's altitude is unacceptable.

System Functional Flow

The functional flow of the complete Diverter system is illustrated in Figure 4. All of the functions depicted in this chart are not currently implemented in the prototype. The functional flow reflects activity for a weather diversion, although Diverter is designed as a generic diversion aid for almost any situation. The prototype demonstration assumes that a diversion situation exists at the outset so that specific functions associated with the decision to divert are not currently used. The functions which have been implemented are indicated in Figure 4 by the highlighted boxes. The functional flow presented in this figure illustrates an implicit design criterion which places the pilot as the focal point and ultimate decision maker in the aircraft.

A brief description of the major functions follows. The numbers here correspond to the functional flow diagram.

1. Weather information is received by Diverter from ATC. In the operational system this information will be obtained via data link transmission.

2. Diverter currently displays the information on weather cell location, severity, and movement. The full system will also display expected delay time to destination based on the cell's rate of movement and weather avoidance rules.

3. Pilot forwards weather information to Company Control either by voice communication or by instructing Diverter to transmit using data link. In the prototype this function is simulated.

4. Diverter compiles a list of possible alternate airfields within a 200 mile range. The content of this list is based on runway length, aircraft configuration and status, and weather. Diverter then ranks the alternates on the basis of their distance from the current location of the aircraft. The completed system will use this information to formulate a recommendation to divert or not to divert.

5. The system can also display the alternates and a recommendation to divert.

6. Diverter computes a ranking of the alternate airfields based on the weightings of the individual attributes, e.g., safety, economy, fuel rules, etc. Diverter then presents the possible alternates and their rankings.

7. In the full system the pilot will be able to select a different range within which to make a selection.

8. The full system will also allow a company recommendation for an alternate or other possibility to be input.

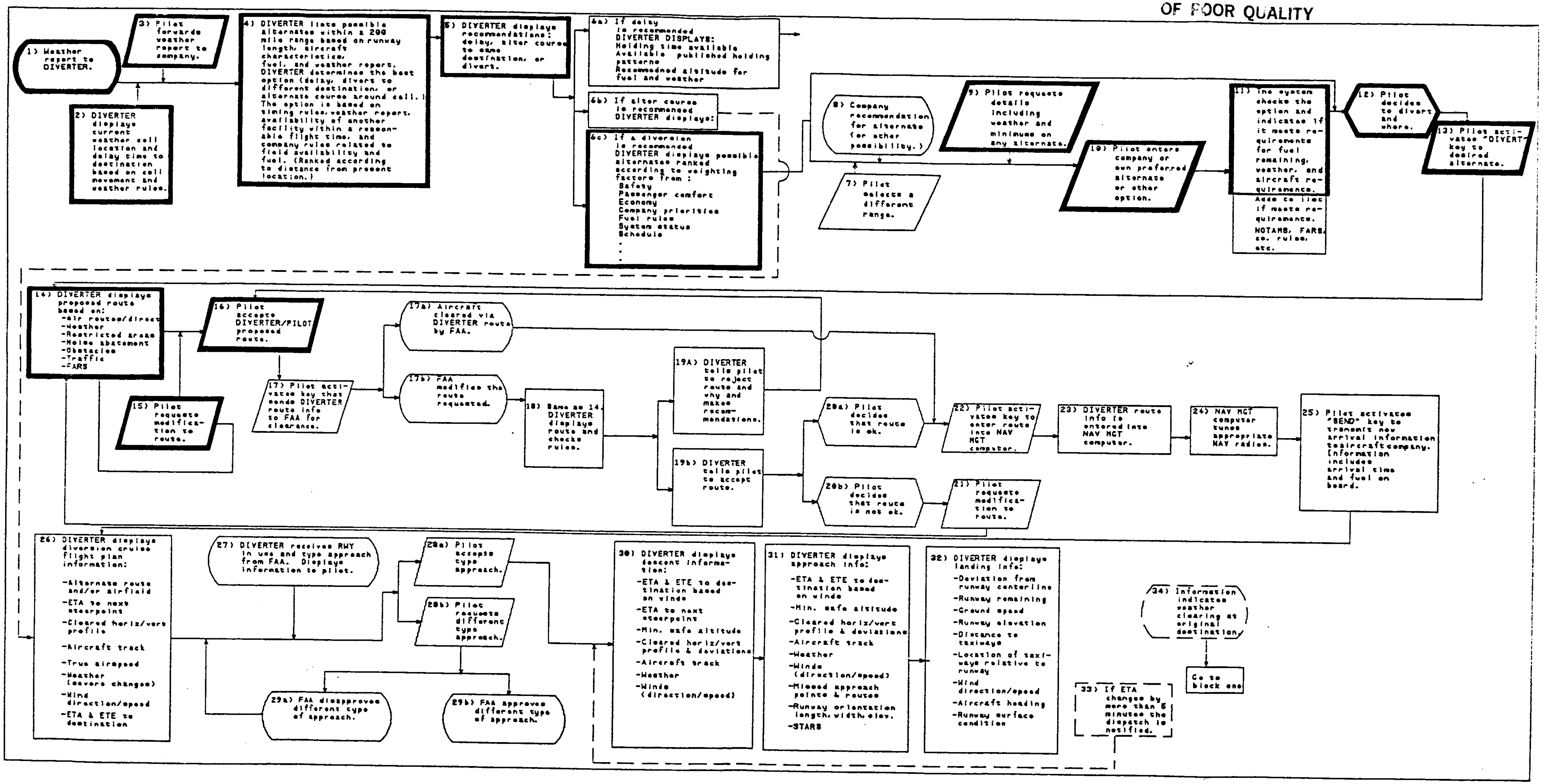

Figure 4. Functional Flow of Diverter

9. The pilot can then query the system for a detailed list of attributes of any of the alternate airfields. The pilot can ask for a side-by-side comparison listing of two of the alternates.

10. The pilot can then enter a different alternate airfield based on the company's or pilot's own preference.

11. Diverter will then indicate if the new alternate meets the requirements for fuel remaining, weather and aircraft requirements. The complete system will add the alternate to the list if it meets requirements (NOTAMS, FARS, company rules, etc.).

12. Pilot chooses the alternate to which he will divert.

13. The system will allow the pilot to activate Diverter to select a desired alternate and to develop a route to that alternate.

14. After the alternate is chosen Diverter develops and displays a list of alternate routes with numeric weights. The best route is indicated based on the relevant attributes of each route (e.g., environment, distance, aircraft status, altitude).

15. The pilot may then request modification to Diverter's route.

16. The pilot can then accept the Diverter's or his own proposed route.

The following functions illustrated in the flow chart have been defined for the fully functional system, but are not yet implemented.

- o If the pilot approves the Diverter recommendation, the route is submitted to ATC for approval. The alternate route is either cleared or modified by ATC.
- o If the route is modified, Diverter then presents the modified route to the pilot and evaluates the route for appropriateness. Diverter then makes a recommendation to the pilot to accept or reject the modified route.
- o Once a route is chosen and cleared by ATC, the pilot can then instruct Diverter to send the route information to the flight management computer (FMC). The FMC computer automatically tunes the navigation radios to the correct frequencies.
- o The pilot can then have Diverter notify, via data link, the company as to arrival information such as ETA and expected fuel needs.
- o Diverter displays the cruise flight plan information for the remainder of the diverted flight. This display will incorporate presently implemented and available information regarding the new route, waypoints, ETA to steerpoints, weather, and ETA to destination. Information on horizontal/vertical profiles will also be included as it is developed and implemented.

- o Diverter receives runway use and approach information via data link from ATC. The specified approach can be used by the pilot or the pilot can request an alternate. After an approach has been agreed upon, Diverter begins presenting descent, approach, and landing information.

DEMONSTRATION

Hardware Configuration

The Diverter prototype is operational and has been demonstrated in the Intelligent Systems Laboratory at LASC-Georgia. The system uses a Symbolics workstation for the intelligent software, interfaced with a VAX 11/780 which drives an Adage display system for presentation of Diverter information. This configuration is shown in Figure 5.

The input/output function for the demonstration was not implemented as a fully developed pilot-vehicle interface. The interface for the prototype was intended to provide a demonstration of capability and as such was relatively simple. For the prototype, text information, including explanation data, was presented via the Symbolics display screen. The map/navigation graphics were presented on a separate display driven by an Adage display system similar to those in NASA's Advanced Concepts Simulator (ACS). During Phase III the system is expected to interface with the Adage display systems and the control display units in the ACS which have touch-sensitive screens and multifunction keyboard input devices.

The interface from the Symbolics to the Adage displays was accomplished using Ethernet. The Symbolics information was transferred to the VAX using Chaosnet protocol. The information was then transferred to the VAX using Decnet protocol. The data was parsed and assembled into its correct form in the appropriate data base locations. The Adage display driver code then accessed these array locations to glean the appropriate display information.

A preliminary explanation capability was developed for this application. It allows the pilot to request more information about specific recommendations made by Diverter. The pilot can request Diverter to show a list of attributes for each alternate airfield or route. This information allows the pilot to review the rationale and to verify the recommendation provided by Diverter. In addition, the pilot may request a list of attributes for two of the alternate airfields or routes proposed by Diverter to allow a side-by-side comparison. This explanation facility, while effective, should be considered as a concept investigation tool rather than a final product.

Scenario

The demonstration was based on the following scenario. A commercial flight is en route from Los Angeles (LAX) to Colorado Springs (COS). A weather system develops over Colorado Springs requiring a diversion of the flight. As previously mentioned, the demonstration assumes immediately that a diversion is necessary because of the weather system. In the fully

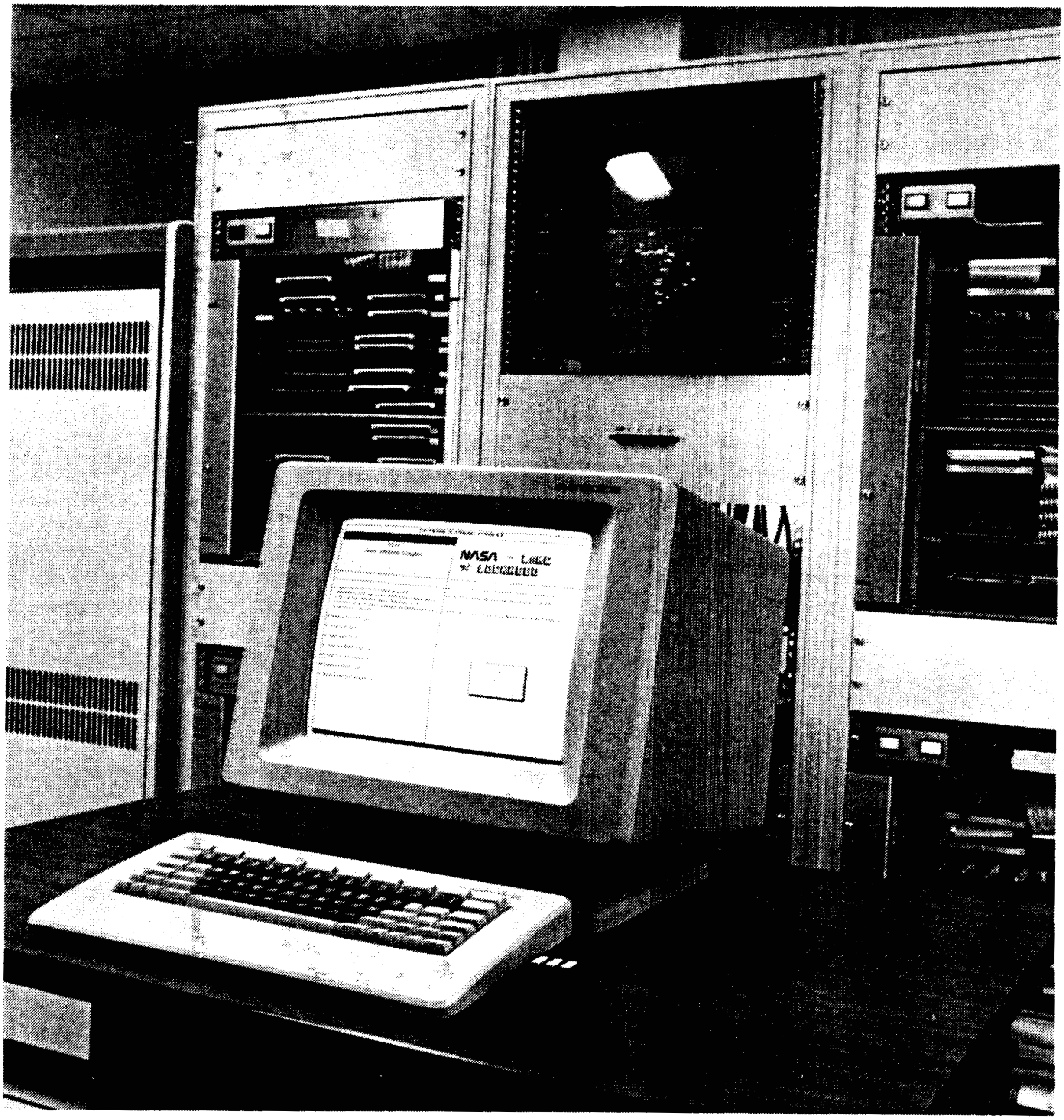

Figure 5. Lab Configuration for the Diverter Demonstration

functional Diverter the system will be able to evaluate the situation and decide if a diversion is required. For the demonstration, the data base was constrained to a small number of available or active airfields within a nominal 200 mile range. These constraints were intended to keep prototype development at a manageable level. An example display for a diversion, showing the active airfields with relative weights and Diverter's recommendations, is shown in Figure 6.

In addition to the weather situation, the demonstration includes several additional kinds of diversions: a diversion due to a pressurization failure; a diversion due to an engine failure; and a diversion due to a catastrophic emergency. The airfields are selected from the domain of airfields in the Denver area (restricted for the demonstration). The domain of the route search is a map of all FAA defined flight segments in the Denver area. A flight segment is a straight path between two FAA defined waypoints. This path can be defined for various altitude levels, according to the airway depicted in the En route Low Altitude and En route High Altitude charts. Weights for the segments are determined based on environment, distance, current aircraft status, and altitude. A sample of a variety of actual display screens from the demonstration are included as Appendix D.

Lessons Learned

During the development process of Diverter, a number of lessons were learned relating to the implementation of this type of AI architecture. Some of the most important items are presented below.

- o A planning system using 3-D arrays on the Symbolics is unacceptable for any reasonable search space. More research is needed in hardware used for this planning. For the segment data base we used, the A* algorithm worked very well. The problem involved is defining all the segments and calculating the weights in real time. Four factors were used with no trouble, but a larger subset of the factors from Appendix C, obtained dynamically, would be needed to realistically simulate the whole situation.
- o The demonstration was driven by software executed on the Symbolics. The navigational map displays used were the Adage displays currently used in the Advanced Concepts Flight Simulator (ACFS) at LASC-Georgia. In the absence of the hardware to simplify the transfer of data from a Symbolics to a VAX and eventually the Adage, we had to write our own software for the hardware we currently had.

  Strict use of a good Interface Control Document (ICD), as well as excellent software engineering practices with very skilled software engineers allowed very successful completion of this particular task. This difficult issue should be addressed carefully in future work. Items to be considered include language coordination between programs, common id names, message traffic, compatible transfer protocols, and timing for updates. The trade-offs between performing these tasks or buying expensive hardware (BUSLINK) to solve some of these problems, should be examined.

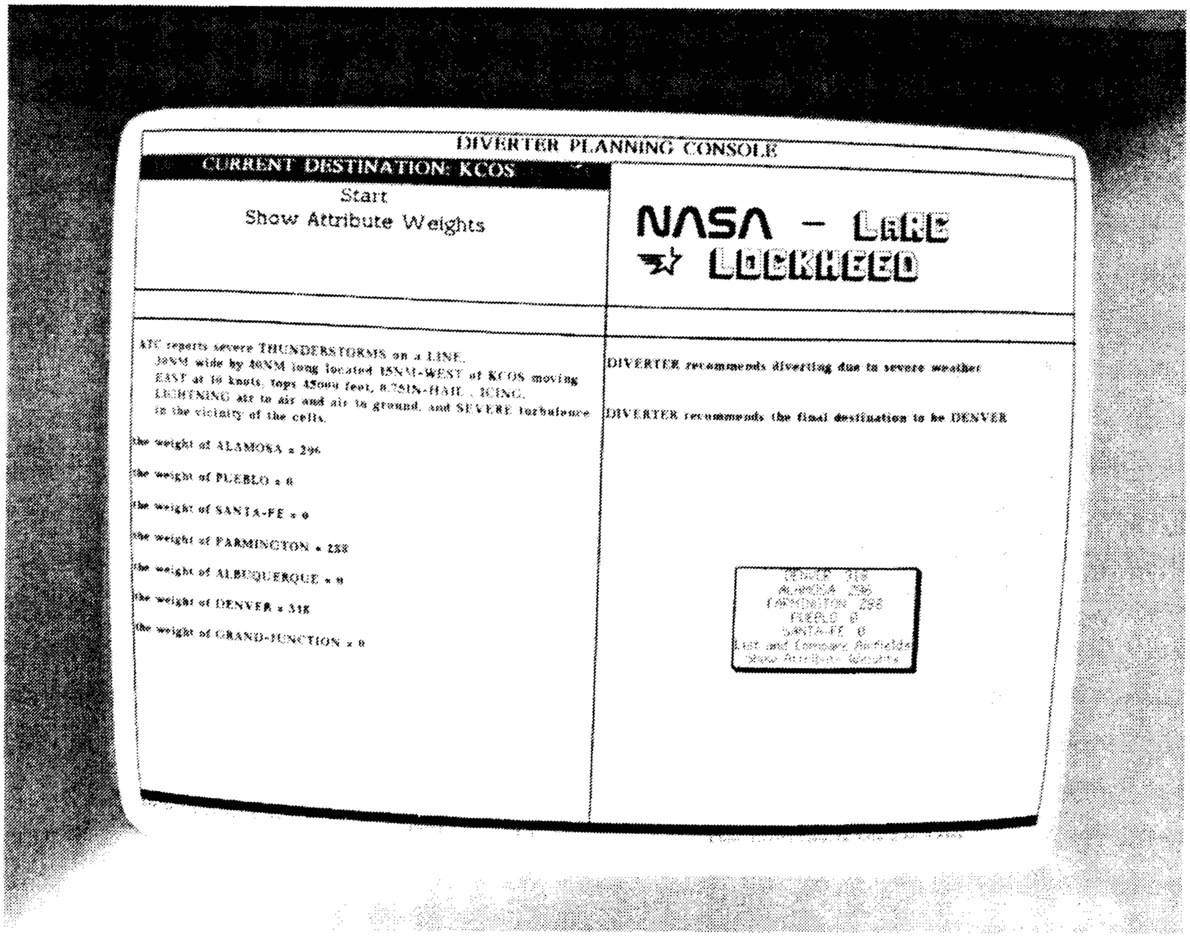

Figure 6. Diverter Display Example:
Alternate Airfields, Weights, and Recommendation

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- o The methods used for planning in Diverter, A*-type searches, do not produce a formal trace of rule firings or inferences that were made to arrive at the optimum route. The functions will not currently provide feedback as to why a segment was rejected or accepted but simply gives the path with the lowest "cost." To capture this kind of explanation of the decision process suitable for presentation to a pilot/user will be a difficult task.
- o Flavors and other object-oriented paradigms are excellent forms for representing data for the Diverter domain. Their flexibility and ease of manipulation are essential for the functions performed in this program. The sophisticated capability demonstrated in Diverter was made possible by the use of software tools such as Flavors which allow for dynamic data representation. Much of the capability of Diverter is related to the exploitation of a blackboard architecture developed with a script-based skeletal planner (KADET), described earlier. This architecture provided an efficient means of overall information management including module management, message passing, interface control as well as global and local data storage.
- o Driver software for the demonstration simulation must calculate much more than we anticipated. This will not be a problem in the future, since the ACS/ACFS already performs these functions, but the time and subset of tasks needed to develop a driver on the Symbolics was underestimated.
- o The Diverter Manager module was an integration strongpoint. This module, by using blackboards and strong ICDs, coordinated the other modules very efficiently. Problems were encountered during integration, but approximately 80% of them were anticipated and solutions developed.

CONCLUSIONS AND RECOMMENDATIONS

Artificial intelligence technology can provide pilots with information on which to base decisions concerning many flight management activities including in-flight planning and replanning. Diverter demonstrates the capability of an intelligent flight management system. This system can rapidly assimilate information from aircraft sensors and systems, a large on-board data base, real-time inputs from the pilot, or data link from the ground. Diverter evaluates this information to develop planning/replanning guidance for presentation to the pilot. The functions of Diverter are to perform situation assessment, to evaluate influences of current system status, evaluate "influences" on rerouting, to perform flight planning and replanning, and to present this information, and additional explanatory information when necessary, to the pilot.

Future work on Diverter should address two major areas. The first area involves the development and evaluation of a viable, operationally capable pilot-vehicle interface (PVI). This PVI is expected to present text and graphic information, including explanations, and allow pilot input through the multifunction control display unit (CDU) of the FMC or through other means (such as voice input) in the ACS. Route information in graphics format will be presented on the navigation/map display. The PVI should also provide an expanded and refined explanation capability. The explanations provided should be flexible enough to provide the pilot with information in the appropriate quantity and format for a given situation. Full implementation of a PVI will necessarily require a careful evaluation process to ensure a maximally effective interface.

The second area involves transporting the stand-alone prototype into a full simulation environment such as the ACS at NASA LaRC. This will allow for testing of the capabilities and limitations of the system in a fully dynamic environment. Once the simulator work is completed, efforts can then proceed to place Diverter into an operational environment such as NASA's Boeing 737 Transport Systems Research Vehicle (TSRV).

APPENDIX A

Compilation of Relevant Operation Rules and Regulations

This appendix summarizes the set of aircraft operation rules and regulations relevant for use in Diverter. These rules were extracted from Federal Aviation Regulations (FARs), Airman Information Manual (AIM) and Air Traffic Procedure (ATP) documents. Each rule is referenced for the appropriate source document.

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Goal: Aircraft Separation
Category 1: Departures
Category 2: En Route
Category 3: Arrivals (This is the category considered in this Appendix)
Subcategories: Normal IFR
Weather Effects
VFR
Radio Outage
Emergency
Aircraft Performance
Type of Approach
Runway Conditions and Wake Turbulence
Fuel Dumping

Goals: Noise Abatement, Terrain Avoidance, Fuel Conservation, Weather Avoidance, and Schedule Compliance.

Assumptions:

(1) Pilot is in a radar environment inside a terminal control area and will remain there.
(2) There is a control tower in operation.
(3) Pilot has all necessary equipment and it is in good operation order except when specified.
(4) No missed approach procedures are considered.
(5) Landing is made at a civil airport (military minima differ somewhat).
(6) Separation standards for helicopters are not considered.
(7) Separation minima are included as well as other factors that may affect separation between aircraft.

Other information that may be required:

Traffic Pattern Information
Current Notams and PIREP Information
MVA's (Minimum Vectoring Altitudes)
Wind Direction and Velocity on Active Runway
Approach Chart Information - Length of runway; MDAs; MSAs; notes and specifications; minimum, maximum, and mandatory altitudes.

Goal: Aircraft Separation

Category 1: Departures

Category 2: En Route

*Category 3: Arrivals
Subcategories: Normal IFR
Weather Effects
VFR
Radio Outage
Emergency
Acft Performance
Type of Approach
Runway Conditions & Wake Turbulence
Fuel Dumping

Goal: Noise Abatement

Goal: Terrain Avoidance

Goal: Fuel Conservation

Goal: Weather Avoidance

Goal: Schedule Compliance

*This is the category considered in this first draft.

Assumptions:

(1) Pilot is in a radar environment inside a terminal control area and will remain there.
(2) There is a control tower in operation.
(3) Pilot has all necessary equipment and it is in good operating order except when specified.
(4) No missed approach procedures are considered.
(5) Landing is made at a civil airport (military minima differ somewhat).
(6) Separation standards for helicopters are not considered.
(7) Separation minima are included as well as other factors that may affect separation between acft.

Computer may also need other information:

Traffic Pattern Information
Current Notams and PIREP Info
MVA's (Minimum Vectoring Altitudes)
Wind Direction and Velocity on Active Runway
Approach Chart Info - Length of runway; MDA's; MSA's; notes and specifications; minimum, maximum, and mandatory altitudes.

Standard IFR

AIM PP272 FAR 91.70(a)	1)	If aircraft altitude $<$ 10,000 ft then if distance from airport $>$ 20 miles then aircraft speed $\geq$ 210 kts and $\leq$ 250 kts else if distance from airport $<$ 20 miles then if aircraft is turbine-powered then speed $\geq$ 170 kts and $\leq$ 250 kts else speed $\geq$ 150 kts and $\leq$ 250 kts.
AIM 271c	2)	If aircraft are at the same altitude then if acft are $\leq$ 40 miles from the radar antenna site then 3 miles radar separation must exist between them else 5 miles radar separation must exist between them.
AIM 371	3)	If a procedure turn is required on the IAP then the procedure turn distance shall be made within the turn distance specified on the IAP and the acft altitude shall not be below the minimum altitude specified.
AIM 371	4)	If a holding pattern is specified by the IAP then the holding maneuver must be executed within the published leg length or 1 minute time limitation.
AIM 364b	5)	If acft is cleared for an IAP then the acft altitude must be $\geq$ minimum altitude for that procedure and $\leq$ the maximum altitude or $=$ mandatory altitude.
AIM 364b,c, d	6)	If a vector to the approach is provided by ATC then the acfts altitude must be $\geq$ minimum safe altitude (MSA) and minimum vectoring altitude (MVA).
FAR 91.87d	7)	If acft is turbine-powered or a large acft then the minimum altitude will be $\geq$ 1,500 ft above the surface of the airport until further descent is required for safe landing.
AIM 84	8)	If below 18,000 ft MSL then if magnetic course is 0 degrees and $<$ 179 degrees, then correct altitude $=$ odd thousands, MSL else if magnetic course is $>$ 180 degrees and $<$ 359 degrees then correct altitude $=$ even thousands, MSL.

ATP 5-115	9)	If one acft is arriving and another acft is departing on a parallel runway and the departure course diverges by $\geq$ 30 degrees from the missed approach course, then if runway thresholds are staggered and the arriving acft is approaching the nearer runway and the center lines are $\geq$ 1000 ft apart and the landing thresholds are staggered at least 500 ft for each 100 ft less than 2,500 the centerlines are separated or if the arriving acft is approaching the further runway, then
		if the runway centerline separation $\geq$ 2,500 ft by at least 100 ft for each 500 ft the landing thresholds are staggered then
		simultaneous operations are approved.

ATP 5-115 10) If nonintersecting runways diverge by $\geq$ 15 degrees and runway edges do not touch, then simultaneous operations are approved.

ATP 5-120 11) If an acft is vectored to intercept the final approach course, then the acft must intercept the final approach course no closer than the FAF and if for a precision approach, then acft alt $\leq$ glideslope/glidepath or if for a nonprecision approach, then at an altitude that will allow descent in accordance with the published procedure.

ATP 5-121 12) If an acft is vectored to a final approach course then if the distance from interception point to the approach gate $<$ 2 miles the maximum intercept angle = 20 degrees else if distance $\geq$ 2 miles then the maximum intercept angle = 30 degrees.

ATP 6-51 13) If IFR acft are not separated laterally or by radar minima then 1000 feet vertical separation is required.

AIM 552 14) If an acft is a heavy jet and is flying behind another heavy jet at the same altitude, then 4 miles separation is required.

15) If an acft is a small/large acft flying behind a heavy jet then 5 miles separation is required.

Weather Effects

FAR 135.225 (a),(b) 1) If an instrument approach procedure is to be executed then weather conditions must be at or above IFR landing minimums for that airport and for that procedure.

FAR 135.225 (c) 2) If pilot has begun the final approach segment of an instrument approach and conditions go below minimum after the acft is on ILS final approach and has passed the FAF or acft is on an ASR or PAR final approach and has turned over to final approach controller or if acft is on a final approach using a VOR/NDB procedure and has passed the FAF or has completed the procedure turn and is established inbound on the final approach course within the distance prescribed in the procedure then
if at MDA or DH the weather conditions are $\geq$ minimums prescribed for the procedure then continue approach and land.

FAR 91.116 3) If approach is not Category II or Category III and the RVR is not reported, then

if ground visibility = 1/4 stat. mi. then RVR = 1600 ft
or if ground visibility = 1/2 stat mi. then RVR = 2400 ft
or if ground visibility = 5/8 stat. mi. then RVR = 3200 ft
or if ground visibility = 3/4 stat. mi. then RVR = 4000 ft
or if ground visibility = 7/8 stat. mi. then RVR = 4500 ft
or if ground visibility = 1 stat. mi. then RVR = 5000 ft
or if ground visibility = 1.25 stat. mi. then RVR = 6000 ft.

AIM 381b. 4) If the final approach course of the IAP is within 30 degrees of the runway alignment and normal descent can be made from the IFR altitude on the IAP to the runway then straight in weather minimums are published on the IAP.

5) If normal rate of descent or runway alignment factor of 30 degrees is exceeded, then use the circling minimum and if pilot has runway in sight and has sufficient time to make a normal approach, then the pilot should make a straight-in approach without circling when cleared by ATC.

6) If weather conditions are minimum and circling is required then maneuver the shortest path to the base or downwind leg and make standard left turns unless otherwise cleared by ATC.

AIM 385 7) If ground visibility < 1 stat. mi. then contact approach is not permissible.

AIM 410	8)	If ceiling < 500 ft above MVA and visibility < 3 mi. and acft cannot remain in VFR conditions, then visual approach is not permissible.
AIM 512(f)	9)	If the approach is nonprecision, then the minimum RVR = 2400 ft.
	10)	If the approach is Category I, then the minimum RVR = 1800 ft. or if the approach is Category II then the minimum RVR = 1200 ft. or if the approach is Category IIIa then the minimum RVR = 700 ft. or if the approach is Category IIIb then the minimum RVR = 150 ft or if the approach is Category IIIc then the minimum RVR = 0 ft.
AIM 526 (a)	11)	If a thunderstorm is approaching head-on then acft should not land.
	12)	If a thunderstorm is overhead then the acft should not fly under it.
	13)	If a thunderstorm is identified as severe then the acft should avoid it by 20 miles.
	14)	If the area has 6/10 thunderstorm coverage then entire area should be avoided.
	15)	If acft enters a thunderstorm then fly the straightest path possible.

VFR

FAR 91.105 (a) 1) If VFR and < 10,000 ft AGL then flight visibility ≥ 3 stat. mi. and distance from clouds = 500 ft below, 1000 ft above, and 2,000 ft horizontal.

2) If acft is operating special VFR then ground visibility = 1 stat. mi. and acft must remain clear of clouds and ceiling must be ≥ 1000 ft.

3) If acft is operating VFR > 3,000 ft AGL then altitude on course of 0 degrees through 179 degrees = any odd thousand ft MSL plus 500 ft or if course is 180 degrees through 359 degrees from altitude = any even thousand ft MSL plus 500 ft.

AIM 98 4) If within the TCA then VFR ON TOP is not allowed.

AIM 165c(6) 5) If acft is within the TCA then vertical separation from IFR acft = 500 ft or at least 1 1/2 miles radar separation.

ATP 3-92,93 6) If conditions are VFR or visual separation is applied and simultaneous operations are being conducted on parallel runways then

if acft is a light, single engine prop then 300 ft must exist between runway centerlines
else if acft is twin engine prop then 500 ft must exist between runway centerlines
else 700 ft must exist between centerlines.

ATP 7-43 8) If acft is operating Special VFR then acft altitude must be at least 500 ft below IFR traffic and not below the MSA.

ATP 7-92b 9) If acft is VFR then 500 ft must exist between it and all other traffic except for heavy jet where more separation should exist.

ATP 7-92c 10) If a Category I or II aircraft is VFR then 1 1/2 mi. must exist between it and other IFR/VFR acft of the same type and between it and Category III IFR/VFR acft only if they are on parallel courses.

Radio Outage

FAR 91.127 1) If clearance limit is a fix from which approach begins then if EFC was issued then begin approach at EFC time else begin approach at ETA.

2) If clearance limit is not a fix from which approach begins then if EFC was issued then depart limit at EFC time else proceed to fix from which approach begins and begin approach at ETA time.

c(4) 3) If holding instructions were issued then if EFC was issued then leave holding fix at EFC time else if EAC was issued then leave holding fix at EAC time.

c(5) 4) If EAC time is received then maintain en route altitude until EAC time else maintain altitude until ETA time.

AIM 205 5) If receiver is inoperative then the following ATC light signals may be used:

steady green = cleared to land
flashing green = return for landing
steady red = give way to other acft & continue circling
flashing red = unsafe, do not land
alternating red & green = exercise extreme caution.

Emergency

AIM 364c

1) If approach is NDB or VOR and acft is $\leq$ 25 miles from the navaid then use the published minimum safe altitude on approach procedure chart.

2) If distress or urgency condition is declared then Direction Finding Instrument Approach procedure may be used.

Aircraft Performance

AIM Glossary	1)	If acft's max. T.O. weight $\geq$ 300,000 lbs then acft is categorized as heavy.
	2)	If acft's max. T.O. weight > 12,500 and < 300,000 lbs then acft is large.
	3)	If acft's max. T.O. weight $\leq$ 12,500 lbs then acft is small.
ATP 5-72e	4)	If small acft is landing behind large acft then 4 miles must exist between them when large acft is over landing threshold.
	5)	If small acft is landing behind heavy acft then 6 miles must exist between them when heavy acft is over landing threshold.
	6)	If parallel runways are < 2,500 ft apart then the above minima also apply.
ATP 6-64	7)	If a small acft is making a timed approach behind a heavy acft then 3 minutes or 6 miles must exist between them.
	8)	If conditions are VFR or visual separation is applied and simultaneous operations are being conducted on parallel runways then if acft is a light single engine prop then 300 ft must exist between runway centerlines else if acft is a twin engine prop then 500 ft must exist between runway centerlines else 700 ft must exist between centerlines.
AIM PP272	9)	If ATC issues speed < minimum safe speed of aircraft then pilot should fly speed = minimum safe speed and advise ATC.
FAR 97.3	10)	If acft is Category A then landing speed < 91 kts else if acft is Category B then landing speed $\geq$ 91 kts and < 121 kts else if acft is Category C then landing speed $\geq$ 121 kts and < 141 kts else if acft is Category D then landing speed $\geq$ 141 kts and < 166 kts else if acft is Category E then landing speed $\geq$ 166 kts

Types of Approaches:

AIM 376 1) If parallel ILS/MLS approaches are being conducted on parallel runways $\geq$ 2,500 ft apart then
if acft are on adjacent localizer courses then minimum separation between successive acft is 2 miles
else if acft are on the same localizer course then minimum separation is 3 miles
else if acft are making turn on to localizer course then 1000 ft vertical or 3 miles radar separation must exist

AIM 12i 2) If approach is ILS and Category I then
if there is no touchdown zone and centerline lighting then
minimum DH $\geq$ 200 ft and min. RVR $\geq$ 2,400 ft else
if Category IA or IB or IC then
DH $\geq$ 200 ft and RVR $\geq$ 1800 ft else if Category ID then DH $\geq$ 200 ft and RVR $\geq$ 2000 ft

3) If approach is ILS and Category II then
DH $\geq$ 100 ft and RVR $\geq$ 1200 ft

4) If approach is ILS and Category III A then
DH = no minimum and RVR $\geq$ 700 ft
else if approach is ILS and Category IIIB then
DH = no minimum and RVR $\geq$ 150 ft
else if approach is ILS and Category IIIC then
DH = no minimum and RVR = no minimum

AIM 375 5) If simultaneous ILS approaches are being conducted on parallel runways $\geq$ 4,300 ft apart then acft are laterally separated by a 2000 ft no transgression zone.

AIM 383 6) If pilot is conducting a visual approach and has the other acft in sight then there are no separation minima.

ATP 6-64 7) If successive timed approaches are being conducted then if a small acft follows a heavy acft then 3 mins. or 6 miles radar separation must exist else 2 mins. or 5 miles.

ATP 7-35 8) If a contact approach is being conducted then acft must be cleared at or below an altitude that is at least 1000 ft below IFR traffic, but above the MSA.

ATP 7-34 9) If CVFP approach is being conducted and the pilot has the other acft in sight then there are no separation minima.

Runway Conditions:

AIM 552	1)	If a small acft is landing behind a heavy jet then 6 miles separation is required.
	2)	If a small acft is landing behind a large acft then 4 miles separation is required.
AIM 545(b)	3)	If acft is landing after a large/heavy aircraft executes a low approach, missed approach, or touch-and-go then at least 2 minutes should pass before landing.
AIM 226b	4)	If wind velocity $\geq$ 5 kts then runway most nearly aligned with wind is preferred else "calm wind" runway is preferred.
AIM 228a	5)	If braking action is good then land else if braking action is fair then use caution else if braking action is poor or nil use extreme caution or don't land.
AIM 523	6)	If reported wind shear conditions are hazardous for acft type then don't land.

Fuel Dumping:

ATP 8-53

1) If acft is dumping fuel then separate other IFR acft from it by 1000 ft above it or 2000 ft below it or 5 miles radar separation or 5 miles lateral separation.

2) If acft is dumping fuel then separate VFR acft from it by 5 miles.

APPENDIX B

Terrain Avoidance Rules for Denver Area.

This appendix lists the terrain avoidance rules for aircraft within 35 nautical miles of Denver VORTAC.

TERRAIN AVOIDANCE

(Terrain avoidance is for aircraft within 35 NM of Denver VORTAC.)

Assumptions:

(1) Aircraft is under radar control.
(2) Rules: a) in non-mountainous areas the MVA must be 1000 ft. above highest obstacle.
b) in mountainous areas MVA must be 2000 ft. above highest obstacle.
c) or MVA must be ≥ an established MSA.
(3) Aircraft has ground tracking capability such as INS or RNAV so that its position from the Denver VORTAC can be computer at any time, as well as latitudinal and longitudinal coordinates.

If aircraft is within 25 NM of the airport, then:

(1) If aircraft position is between 0° - 165° radial of the Denver VORTAC the NVA ≥ 8100 MSL.
(2) If aircraft position is between 90° - 180° radial of the Denver VORTAC then the MVA ≥ 10500 MSL.
(3) If aircraft position is between 170° - 325° radial of the Denver VORTAC then the MVA ≥ 12600 MSL.
(4) If aircraft position is between 325° - 340° radial of the Denver VORTAC then the MVA ≥ 10500 MSL.
(5) If aircraft position is between 340° - 360° radial of the Denver VORTAC then the MVA ≥ 8100 MSL.

If aircraft is outside 25 NM of the airport then:

(1) If aircraft position is between 0° - 90° radial of the Denver VORTAC then the MVA ≥ 6200 MSL.
(2) If aircraft position is between 90° - 180° radial of the Denver VORTAC then the MVA ≥ 8500 MSL.
(3) If aircraft position is between 180° - 270° radial of the Denver VORTAC then the MVA ≥ 14300 MSL.
(4) If aircraft position is between 270° - 360° radial of the Denver VORTAC then the MVA ≥ 14700 MSL.

APPROACH CONTROL AIRSPACE

(Approach control airspace is for aircraft within 20 NM of Denver TACAN. These specifications assure aircraft is within Terminal Control Area.)

(1) If aircraft position is from 5° to 10° of Denver TACAN then
   - a) If aircraft is within 10 DME of Denver TACAN then altitude $\geq$ ground and $\leq$ 11000 MSL.
   - b) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
   - c) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude $\geq$ 9000 MSL and $\leq$ 11000 MSL.

(2) If aircraft position is from 5° to 10° radial of Denver TACAN then
   - a) If aircraft is within 10 DME of Denver TACAN then altitude $\geq$ ground and $\leq$ 11000 MSL.
   - b) If aircraft is from 10 DME to 16 DME of Denver TACAN then if aircraft $\leq$ $104^\circ47'$ longitude then altitude $\geq$ 8000 MSL and $\geq$ 11000 MSL.
   - c) If aircraft is from 16 DME to 20 DME of Denver TACAN then if aircraft $\leq$ $104^\circ47'$ longitude then altitude $\geq$ 10000 MSL and $\leq$ 11000 MSL else altitude $\geq$ 9000 MSL and $\leq$ 11000 MSL.

(3) If aircraft position is from 10° to 20° radial of Denver TACAN then
   - a) If aircraft is within 10 DME of Denver TACAN then if aircraft is $\leq$ $104^\circ48'$ longitude then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL else altitude $\geq$ ground and $\leq$ 11000 MSL.
   - b) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
   - c) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude $\geq$ 10000 MSL and $\leq$ 11000 MSL.

(4) If aircraft position is from 20° to 30° radial of Denver TACAN then
   - a) If aircraft is within 7 DME of Denver TACAN then altitude $\geq$ ground and $\leq$ 11000 MSL.
   - b) If aircraft is from 7 DME to 10 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
   - c) If aircraft is from 10 DME to 16 DME of Denver TACAN then if aircraft $\leq$ $104^\circ47'$ longitude then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL else altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
   - d) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude $\geq$ 10000 MSL and $\leq$ 11000 MSL.

(5) If aircraft position is from 30° to 50° radial of Denver TACAN then
   - a) If aircraft is within 7 DME of Denver TACAN then altitude $\geq$ ground and $\leq$ 11000 MSL.

b) If aircraft is from 7 DME to 10 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.
d) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude $\geq$ 10000 MSL and $\leq$ 11000 MSL.

(6) If aircraft position is from 50^{o} to 60^{o} radial of Denver TACAN then
a) If aircraft is within 7 DME of Denver TACAN then if aircraft is $\leq$ $104^{o}47'$ longitude then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL else altitude $\geq$ ground and $\leq$ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.
d) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude $\geq$ 10000 MSL and $\leq$ 11000 MSL.

(7) If aircraft position is from 60^{o} to 70^{o} radial of Denver TACAN then
a) If aircraft is within 7 DME of Denver TACAN then if aircraft is > $39^{o}49'$ latitude then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL else altitude $\geq$ ground and $\leq$ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.
d) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude $\geq$ 10000 MSL and $\leq$ 11000 MSL.

(8) If aircraft position is from 70^{o} to 80^{o} radial of Denver TACAN then
a) If aircraft is within 7 DME of Denver TACAN then altitude $\geq$ ground and $\leq$ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN then if aircraft is > $39^{o}50'$ latitude then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL else altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
d) If aircraft is from 16 DME to 20 DME of Denver TACAN then if aircraft is > $39^{o}50'$ latitude then altitude $\geq$ 10000 MSL and $\leq$ 11000 MSL else altitude $\geq$ 9000 MSL and $\leq$ 11000 MSL.

(9) If aircraft position is from 80^{o} to 90^{o} radial of Denver TACAN then
a) If aircraft is within 7 DME of Denver TACAN then altitude $\geq$ ground and $\leq$ 11000 MSL.
b) If aircraft is from 7 DME to 16 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.

c) If aircraft is from 16 DME to 20 DME of Denver TACAN then if aircraft is $\geq$ $39^{\circ}44'$ latitude then altitude $\geq$ 9000 MSL and $\leq$ 11000 MSL else altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.

(10) If aircraft position is from 90° to 100° radial of the Denver TACAN then
a) If aircraft is within 7 DME of Denver TACAN then altitude $\geq$ ground and $\leq$ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then if aircraft is $\leq$ $39^{\circ}44'$ latitude then altitude $\geq$ 7500 MSL and $\leq$ 11000 MSL else altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN then if aircraft is $>$ $39^{\circ}44'$ latitude then altitude_ 9000 MSL and $\leq$ 11000 MSL else altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.

(11) If aircraft position is from 100° to 110° radial of Denver TACAN then
a) If aircraft is within 7 DME of Denver TACAN then is aircraft is $\leq 39^{\circ}44'$ latitude then altitude $\geq$ 7500 MSL and $\leq$ 11000 MSL else altitude $\geq$ ground and $\leq$ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then is aircraft is $\leq$ $39^{\circ}44'$ latitude then altitude $\geq$ 7500 MSL and $\leq$ 11000 MSL else altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude $\geq$ 7500 MSL and $\leq$ 11000 MSL.
d) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.

(12) If aircraft position is from 110° to 120° radial of Denver TACAN then
a) If aircraft is within 7 DME of Denver TACAN then if aircraft is $\leq$ $39^{\circ}44'$ latitude then altitude $\geq$ 7500 MSL and $\leq$ 11000 MSL else altitude $\geq$ ground and $\leq$ 11000 MSL.
b) If aircraft is from 7 DME to 16 DME of Denver TACAN then altitude $\geq$ 7500 MSL and $\leq$ 11000 MSL.
c) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.

(13) If aircraft position is from 120° to 130° radial of Denver TACAN then
a) If aircraft is within 7 DME of Denver TACAN then if aircraft is $\leq$ $39^{\circ}44'$ latitude altitude and $\leq$ $104^{\circ}48'$longitude then altitude $\geq$ 7500 MSL and $\leq$ 11000 MSL else altitude $\geq$ ground and $\leq$ 11000 MSL.
b) If aircraft is from 7 DME to 16 DME of Denver TACAN then altitude $\geq$ 7500 MSL and $\leq$ MSL.
c) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.

(14) If aircraft position is from 130° to 140° radial of Denver TACAN then

a) If aircraft is within 7 DME of Denver TACAN then if aircraft is ≤ 104°44' longitude then altitude ≥ 7500 MSL and ≤ 11000 MSL else altitude ≥ ground and ≤ 11000 MSL.
b) If aircraft is from 7 DME to 16 DME of Denver TACAN then altitude ≥ 7500 MSL and ≤ 11000 MSL.
c) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude ≥ 8000 MSL and ≤ 11000 MSL.

(15) If aircraft position is from 140° to 150° radial of Denver TACAN then

a) If aircraft is within 7 DME of Denver TACAN then if aircraft is ≤ 104°48' longitude then altitude ≥ 8000 MSL and ≤ 11000 MSL else altitude ≥ ground and ≤ 11000 MSL.
b) If aircraft is from 7 DME to 16 DME of Denver TACAN then altitude ≥ 7500 MSL and ≤ 11000 MSL.
c) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude ≥ 8000 MSL and ≤ 11000 MSL.

(16) If aircraft position is from 150° to 160° radial of Denver TACAN then

a) If aircraft if within 7 DME of Denver TACAN then altitude ≥ ground and ≤ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then if aircraft is > 39°36' latitude then altitude ≥ 7500 MSL and ≤ 11000 MSL else altitude ≥ 8000 MSL and ≤ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude ≥ 8000 MSL and ≤ 11000 MSL.
d) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude ≥ 10000 MSL and ≤ 11000 MSL.

(17) If aircraft position is 160° to 170° radial of Denver TACAN then

a) If aircraft is within 7 DME of Denver TACAN then altitude ≥ ground and ≤ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then if aircraft is > 39°36' latitude then altitude ≥ 7500 MSL and ≤ 11000 MSL else altitude ≥ 8000 MSL and ≤ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude ≥ 8000 MSL and ≤ 11000 MSL.
d) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude ≥ 10000 MSL and ≤ 11000 MSL.

(18) If aircraft position is from 170° to 180° radial of Denver TACAN then

a) If aircraft is within 7 DME of Denver TACAN then altitude ≥ ground and ≤ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then if aircraft is > 39°36' latitude then altitude ≥ 7500 MSL and ≤ 11000 MSL else altitude ≥ 8000 MSL and ≤ 11000 MSL.

c) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.
d) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude $\geq$ 10000 MSL and $\leq$ 11000 MSL.

(19) If aircraft position is from 180° to 190° radial of Denver TACAN then
 a) If aircraft is within 7 DME of Denver TACAN then altitude $\geq$ ground and $\leq$ 11000 MSL.
 b) If aircraft is from 7 DME to 10 DME of Denver TACAN then if aircraft is $\leq$ 104°59' longitude then altitude $\geq$ 7500 MSL and $\leq$ 11000 MSL else altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
 c) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.
 d) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude $\geq$ 10000 MSL and $\leq$ 11000 MSL.

(20) If aircraft position is from 190° to 200° radial of Denver TACAN then
 a) If aircraft is within 7 DME of Denver TACAN then if aircraft is $\leq$ 104°59' longitude then altitude $\geq$ ground and $\leq$ 11000 MSL else altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
 b) If aircraft is from 7 DME to 10 DME of Denver TACAN then if aircraft is $\leq$ 104°59' longitude then altitude $\geq$ 7500 MSL and $\leq$ 11000 MSL else if aircraft is . 104°59' longitude and >39°36' latitude then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL else altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.
 c) If aircraft is from 10 DME to 16 DME from Denver TACAN then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.
 d) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude $\geq$ 10000 MSL and $\leq$ 11000 MSL.

(21) If aircraft position is from 200° to 210° radial of Denver TACAN then
 a) If aircraft is within 7 DME of Denver TACAN then if aircraft is $\leq$ 39°42' latitude and > 104°59' longitude then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL else altitude $\geq$ ground and $\leq$ 11000 MSL.
 b) If aircraft is from 7 DME to 10 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
 c) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.
 d) If aircraft is from 16 DME to 20 DME of Denver TACAN and aircraft is $\leq$ 105°11' then altitude $\geq$ 10000 MSL and $\leq$ 11000 MSL.

(22) If aircraft position is from 210° to 220° radial of the Denver TACAN then
 a) If aircraft is within 7 DME of Denver TACAN then if aircraft is $\leq$ 39°42' latitude then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL else altitude $\geq$ ground and $\leq$ 11000 MSL.

b) If aircraft is from 7 DME to 10 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN and aircraft is $\leq$ 105°11' longitude then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.
d) If aircraft is from 16 DME to 20 DME of Denver TACAN and aircraft is $\leq$ 105°11' longitude then altitude $\geq$ 10000 MSL and $\leq$ 11000 MSL.

(23) If aircraft position is from 220° to 230° radial of Denver TACAN then
a) If aircraft is within 7 DME of Denver TACAN then if aircraft is > 39°42' latitude then altitude $\geq$ ground and $\leq$ 11000 MSL else altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN and $\leq$ 105°11' longitude then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.

(24) If aircraft position is from 230° to 270° radial of Denver TACAN then
a) If aircraft is within 7 DME of Denver TACAN then altitude $\geq$ ground and $\leq$ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN and $\leq$ 105°11' longitude then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.

(25) If aircraft position is from 270° to 280° radial of Denver TACAN then
a) If aircraft is within 7 DME of Denver TACAN then if aircraft is > 39°49' latitude then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL else altitude $\geq$ ground and $\leq$ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN and $\leq$ 105°11' longitude then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.

(26) If aircraft position is from 280° to 290° radial of Denver TACAN then
a) If aircraft is within 7 DME of Denver TACAN then if aircraft is > 39°49' latitude and > 104°57' longitude then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL else altitude $\geq$ ground and $\leq$ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN and altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN and $\leq$ 104°57' longitude then altitude $\geq$ 8000 MSL and $\leq$ 11000 MSL.
d) If aircraft is from 16 DME to 20 DME of Denver TACAN and 105°11' longitude then altitude $\geq$ 10000 MSL and $\leq$ 11000 MSL.

(27) If aircraft position is from 290° to 300° radial of Denver TACAN then

a) If aircraft is within 7 DME of Denver TACAN then if aircraft ≤ 104°57' longitude then altitude ≥ ground and ≤ 11000 MSL else altitude ≥ 7000 MSL and ≤ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then altitude ≥ 7000 MSL and ≤ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude ≥ 8000 MSL and ≤ 11000 MSL.
d) If aircraft is from 16 DME to 20 DME of Denver TACAN and ≤ 105°11' longitude then altitude ≥ 10000 MSL and ≤ 11000 MSL.

(28) If aircraft position is from 300° to 320° radial of Denver TACAN then

a) If aircraft is within 7 DME of Denver TACAN then if aircraft is ≤ 104°57' longitude then altitude ≥ ground and ≤ 11000 MSL else altitude ≥ 7000 MSL and ≤ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then altitude ≥ 7000 MSL and ≤ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude ≥ 8000 MSL and ≤ 11000 MSL.
d) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude ≥ 10000 MSL and ≤ 11000 MSL.

(29) If aircraft position is from 320° to 330° radial of Denver TACAN then

a) If aircraft is within 7 DME of Denver TACAN then altitude ≥ ground and ≤ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then altitude ≥ 7000 MSL and ≤ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN then if aircraft is ≤ 104°57' longitude then altitude ≥ 7000 MSL and ≤ 11000 MSL else altitude ≥ 8000 MSL and ≤ 11000 MSL.
d) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude ≥ 10000 MSL and ≤ 11000 MSL.

(30) If aircraft position is from 330° to 340° radial of Denver TACAN then

a) If aircraft is within 7 DME of Denver TACAN then altitude ≥ ground and ≤ 11000 MSL.
b) If aircraft is from 7 DME to 10 DME of Denver TACAN then if aircraft is ≤ 104°54' longitude then altitude ≥ ground and ≤ 11000 MSL else altitude ≥ 7000 MSL and ≤ 11000 MSL.
c) If aircraft is from 10 DME to 16 DME of Denver TACAN then if aircraft is ≤ 104°57' longitude then altitude ≥ 7000 MSL and ≤ 11000 MSL else altitude ≥ 8000 MSL and ≤ 11000 MSL.
d) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude ≥ 10000 MSL and ≤ 11000 MSL.

(31) If aircraft position is from 340° to 350° radial of Denver TACAN then

a) If aircraft is within 10 DME of Denver TACAN then altitude $\geq$ ground and $\leq$ 11000 MSL.

b) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.

c) If aircraft is from 16 DME to 20 DME of Denver TACAN then if aircraft is $\leq$ $104^{\circ}56'$ longitude then altitude $\geq$ 9000 MSL and $\leq$ 11000 MSL else altitude $\geq$ 10000 MSL and $\leq$ 11000 MSL.

(32) If aircraft position is from 350° to 360° radial of Denver TACAN then

a) If aircraft is within 10 DME of Denver TACAN then altitude $\geq$ ground and $\leq$ 11000 MSL.

b) If aircraft is from 10 DME to 16 DME of Denver TACAN then altitude $\geq$ 7000 MSL and $\leq$ 11000 MSL.

c) If aircraft is from 16 DME to 20 DME of Denver TACAN then altitude $\geq$ 9000 MSL and $\leq$ 11000 MSL.

TERRAIN AVOIDANCE (IN CLOSE PROXIMITY OF DENVER AIRPORT)

(Terrain avoidance is for aircraft within 2 1/2 NM from centerline of RWY 26L and RWY 35R and within 10 NM of both ends of RWY 26L and RWY 35R.)

(1) If aircraft position is $\leq$ 105°07'30" longitude and $\geq$ 104°38' longitude and $\leq$ 39°48' latitude and $\geq$ 39°43' latitude then:

- (a) If aircraft is $\leq$ 3 NM from 39°43' latitude and 105°08' longitude then altitude $\geq$ 6900 MSL else
- (b) If aircraft is $\leq$ 3 NM from 39°47'30" latitude and 105°01 longitude then altitude $\geq$6600 MSL else
- (c) If aircraft is $\leq$ NM from 39°45' latitude and 105°oo' longitude then altitude $\geq$ 6900 MSL else
- (d) If aircraft is $\leq$ 3 NM from 39°50' latitude and 104°57' longitude then altitude $\geq$ 6600 MSL else
- (e) If aircraft is $\leq$ 3 NM from 39°49' latitude and 104°56' longitude then altitude $\geq$ 6500 MSL else
- (f) If aircraft is $\leq$ 3 NM from 39°47' latitude and 104°56' longitude then altitude $\geq$ 6600 MSL else
- (g) If aircraft is $\leq$ 3 NM from 39°45' latitude and 104°59' longitude then altitude $\geq$ 7000 MSL else
- (h) If aircraft is $\leq$ 3 NM from 39°44' latitude and 104°42' longitude then altitude $\geq$ 6900 MSL else altitude $\geq$ ground.

(2) If aircraft position is $\leq$ 39°54' latitude and . 39°36' latitude and $\leq$ 104°56' longitude and $\geq$ 104°49' longitude then:

- (a) If aircraft is $\leq$ 3 NM from 39°48' latitude and 104°56' longitude then altitude $\geq$ 6500 MSL else
- (b) If aircraft is $\leq$ 3 NM from 39°54' latitude and 104°54' longitude then altitude $\geq$ 6600 MSL else
- (c) If aircraft is $\leq$ 3 NM from 39°57' latitude and 104°51' longitude then altitude $\geq$ 6400 MSL else
- (d) If aircraft is $\leq$ 3 NM from 39°40' latitude and 104°53' longitude then altitude $\geq$ 6900 MSL else
- (e) If aircraft is $\leq$ 3 NM from 39°39' latitude and 104°53' longitude then altitude $\geq$ 6800 MSL else
- (f) If aircraft is $\leq$ 3 NM from 39°38' latitude and 104°54' longitude then altitude $\geq$ 7000 MSL else
- (g) If aircraft is $\leq$ 3 NM from 39°37' latitude and 104°53' longitude then altitude $\geq$ 6900 MSL else
- (h) If aircraft is $\leq$ 3 NM from 39°40'30" latitude and 104°56' longitude then altitude $\geq$ 6800 MSL else
- (i) If aircraft is $\leq$ 3 NM from 39°39' latitude and 104°49' longitude then altitude $\geq$ 7100 MSL else altitude $\geq$ ground.

APPENDIX C

Attribute Data Base with Weightings

This appendix lists the attributes relevant for airfield and route selection. Also included, are the applicability of each attribute for the sample of airfields used in the Diverter demonstration and the weights assigned to each attribute.

DIVERTER

KEY TO DATA BASE AND WEIGHTING FACTORS

o For the data bases:

If the block is blank, we have not yet determined how to assign weighting factors, or it is not a factor for a diversion.

O Indicates that the particular factor will not have an impact on DIVERTER'S recommendations.

X Indicates that the factor will be a factor in DIVERTER'S recommendation.

o For weighting factors:

\- Indicates that any of the assigned numbers in the stipulated range can be assigned (e.g., for a 1 -10 from 1 to 10 can be assigned)

/ For yes/no questions, a yes answer receives the higher value (e.g., OPERATE > MIN ENROUTE ALTITUDE? 1/10. If yes the assigned value = 10, if no the assigned value is 1). Also, where three specific numbers have been stipulated (e.g., 1/5/10) only one of the three numbers can be assigned.

o Any issue under safety factors or NOTAMS which is assigned a value of 1, eliminates that airfield from consideration.

o An assigned value of 1 for severe turbulence under passenger comfort eliminates the airfield from consideration.

o Weighting factors for destination selection:

Safety	= 10
Airfield Status/Facilities	= 10
Economy	= 6
Schedule	= 5
Passenger Comfort	= 4

o Weighting factors for route selection:

Safety	= 10
Routing	= 7
Schedule/Economy	= 6
Passenger Comfort	= 4

OPERATIONAL PRIORITIES (GLOBAL) (Page 1 of 2)

1. SAFETY

   Weather

   Crew Duty Time

   Air Traffic

   A/C Operations

   A/C Maintenance Status

2. AIRFIELD

   NOTAMS

      Airfield Conditions

      Navigation Aids Status

      Communications Status

      Special Operating Hours

      Parking Space Availability

      Maintenance Availability

   Facilities

      Fire and Emergency Equipment

      Suitable Stairs

      Power Cart Availability

      Relief Crew Availability

      Transportation to Passenger Destination

      Hotel Accommodations

OPERATIONAL PRIORITIES (GLOBAL) (Page 2 of 2)

3. PASSENGER COMFORT

   Pressurization Control

   Weather (turbulence)

   A/C Maneuvering

4. SCHEDULE

   ATC Enroute Vectors and Holding

   Delay in Terminal Area

   ATC Gate Taxi Delays

   A/C Turn Around Time

   Departure Delays (ATC Clearances/Traffic) From New Destination

   Wind Effects

5. ECONOMY

   Fuel

   Landing Fees

   Maintenance

   Crew

SAFETY FACTORS (OTHER THAN NOTAMS)DATABASE

	ALS	PUB	SAF	FMN	ABQ	DEN	GJT
WEATHER MINIMUMS	O	O	X	X	X	X	X
CREW DUTY TIME	O	O	O	O	X	O	O
AIR TRAFFIC							
ENROUTE	O	X	O	O	O	X	O
APPROACH	O	O	O	X	O	X	O
RUNWAY	O	O	O	O	O	O	O
AIRCRAFT OPERATIONS							
AIRSPEED LIMITS	O	O	O	O	O	O	O
SEVERE TURBULENCE	O	X	O	O	O	O	O
STRUCTURAL LIMITS	O	O	O	O	O	O	O
ICING CONDITIONS	O	X	X	O	O	X	X
MEA	O	O	O	O	O	O	O
AIRCRAFT MAINTENANCE							
MEL	O	X	X	O	O	X	O
SAFETY WRITEUP	O	O	O	O	O	O	O

SAFETY FACTOR WEIGHTING (Page 1 of 2)

		ALS	PUB	SAF	FMN	ABQ	DEN	GJT
APPROACH MINIMUMS Below = 1 Meets = 8 Exceeds = 10	1/8/10	10	10	8	8	1	8	8
CREW DUTY TIME (CDT) CDT + 30 - 60 minutes = 4 CDT + < 30 minutes = 6 Can Be Met = 10	4/6/10	10	10	10	10	6	10	10
CONFLICTING ENROUTE TRAFFIC Some = 7 None = 10	7/10	10	7	10	10	10	7	10
CONFLICTING APPROACH TRAFFIC Some = 7 None = 10	7/10	10	10	10	7	10	7	10
CONFLICTING RUNWAY TRAFFIC Some = 2 None = 10	2/10	10	10	10	10	10	10	10
STAY WITHIN A/S LIMITS	1/10	10	10	10	10	10	10	10
NO SEVERE TURBULENCE	1/10	10	1	10	10	10	10	10

SAFETY FACTOR WEIGHTING (page 2 of 2)

		ALS	PUB	SAF	FMN	ABQ	DEN	GJT
WITHIN STRUCTURAL LIMITATIONS	1/10	10	10	10	10	10	10	10
ICING CONDITIONS	1 - 10	10	2	5	10	10	8	8
OPERATE > MIN ENROUTE ALTITUDE	1/10	10	10	10	10	10	10	10
REQ. A/C APP/LDG EQUIP OPER	1/5/10	10	5	5	10	10	5	10

Icing conditions:

Exceeds A/C parameters = 1
Heavy = 2
Moderate = 5
Light = 8
None = 10

Req. A/C App/Ldg Equip Oper:

None = 1
Some = 5
All = 10

AIRFIELD DATA BASE (NOTAMS) (Page 1 of 2)

	ALS	PUB	SAF	FMN	ABQ	DEN	GJT
AIRFIELD CONDITIONS							
Runway	X	O	X	X	O	O	X
Taxiway	O	O	O	X	O	O	O
Lighting (night)	O	O	O	O	O	O	X
Lighting (day, weather)	O	O	O	O	O	O	X
NAVIGATION AIDS STATUS							
ILS (scheduled maintenance)	O	O	X	X	O	O	X
VOR	O	O	X	O	O	O	O
DME	O	X	O	X	O	O	O
Marker Beacon	O	O	O	X	X	O	X
Approach Control Radar	X	O	X	O	O	O	O
COMMUNICATIONS STATUS							
Approach Control	X	O	O	O	O	O	O
Tower	O	O	O	O	O	O	O
Ground Control	O	O	O	X	O	O	O

AIRFIELD DATA BASE (FACILITIES) (Page 2 of 2)

	ALS	PUB	SAF	FMN	ABQ	DEN	GJT
SPECIAL OPERATING HOURS							
Airfield Closures	O	O	O	X	O	O	X
PARKING SPACE	O	O	O	O	O	O	O
MAINTENANCE	X	O	X	O	O	O	O
FACILITIES							
FIRE AND EMERGENCY EQUIPMENT	O	O	O	O	O	O	O
SUITABLE STAIRS	X	X	X	X	X	O	X
POWER CART	X	X	X	X	O	O	X
RELIEF CREW	X	X	X	X	O	O	X
PASSENGER TRANSPORTATION	X	X	X	X	O	O	X
HOTEL ACCOMMODATIONS	X	X	O	X	O	O	O

AIRFIELD WEIGHTING FACTORS (NOTAMS) (Page 1 of 3)

AIRFIELD CONDITIONS		ALS	PUB	SAF	FMN	ABQ	DEN	GJT
LENGTH OF OPEN RUNWAY	1 - 10	10	10	8	10	10	10	10
< 5,000' = 1 5,000' = 5 6,000' = 6 7,000' = 8 > 8,000' = 10								
RUNWAY CLOSED/OPEN	1/10	10	10	10	10	10	10	1
RUNWAY CONDITION	1 - 10	10	10	7	5	10	10	10
Ice = 1 Slush = 5 Wet or Snow = 7 Dry = 10								
TAXIWAY								
Open to gate	2/10	10	10	10	2	10	10	10
GATE AVAILABILITY								
Not Available = 2 Available after 30 min = 4 Remote stairs available = 5 Available < 30 minutes = 6 Available = 10	2-10	10	10	10	10	10	10	10
LIGHT (NIGHT)	2/10	10	10	10	10	10	10	2
LIGHT (day or weather)	2/10	10	10	10	10	10	10	2

AIRFIELD WEIGHTING FACTORS (Page 2 of 3)

		ALS	PUB	SAF	FMN	ABQ	DEN	GJT
NAVIGATION AIDS STATUS								
INSTRUMENT APPROACH AIDS OK (weather)	1 - 10	10	7	1	5	8	10	6

1 = ILS & VOR out
5 = ILS, DME, & marker beacon out
6 = ILS & marker beacon out
7 = DME out
8 = Marker beacon out
10 = All operational

		ALS	PUB	SAF	FMN	ABQ	DEN	GJT
APPROACH CONTROL RADAR OK	5/10	5	10	5	10	10	10	10
COMMUNICATIONS STATUS								
APPROACH CONTROL COMM OK	5/10	5	10	10	10	10	10	10
TOWER COMM OK	5/10	10	10	10	10	10	10	10
GROUND CONTROL COMM OK	5/10	10	10	10	5	10	10	10
SPECIAL OPERATING HOURS	1 - 10	10	10	10	6	10	10	1

Closed ETA +- 60 minutes = 1
Closed ETA +- 30 minutes = 4
Closed ETA +- 10 minutes = 6
Closed at ETA + 0 to 10 minutes = 9
No special operating hours = 10

		ALS	PUB	SAF	FMN	ABQ	DEN	GJT
PARKING SPACE AVAILABLE	4/8	8	8	8	8	8	8	8

AIRFIELD WEIGHTING FACTORS (Page 3 of 3)

FACILITIES

		ALS	PUB	SAF	FMN	ABQ	DEN	GJT
MAINTENANCE/PARTS None = 2 Non-company = 4 Company = 7	2/4/7	2	4	4	4	4	7	4
FIRE AND EMERGENCY EQUIPMENT	1/10	10	10	10	10	10	10	10
SUITABLE STAIRS	2/8	2	8	2	8	8	8	8
POWER CART AVAILABLE	2/4	4	4	4	4	4	4	4
RELIEF CREW AVAILABLE (If req.)	4/6	4	4	4	4	6	6	4
TRANSPORTATION TO PASSENGER DESTINATION Surface = 2 Other = 4 Company Air = 7	2/4/7	2	4	4	4	7	7	4
HOTEL ACCOMMODATIONS AVAILABLE IF > 6 HOUR LAYOVER	3/7	3	3	7	3	7	7	7

PASSENGER COMFORT DATA BASE

	ALS	PUB	SAF	FMN	ABQ	DEN	GJT
CABIN ALTITUDE RATE OF DESCENT	X	X	O	O	O	O	O
TURBULENCE	O	X	O	O	O	X	X
MANEUVERING	X	O	O	O	O	O	O

PASSENGER COMFORT WEIGHTING

		ALS	PUB	SAF	FMN	ABQ	DEN	GJT
CABIN ALTITUDE RATE OF DESCENT	1/3/4	1	3	4	4	4	4	4
> 2,000'/min	= 1							
500 - 2,000'/min	= 3							
< 500'/min	= 4							
TURBULENCE	1 - 4	4	1	4	4	4	3	3
Severe	= 1							
Moderate	= 2							
Light	= 3							
None	= 4							
MANEUVERING								
Gs	1 - 4	1	4	4	4	4	4	4
1G +- .7G	= 1							
1G +-.2 to -.7G	= 2							
1G +-.1 to -.2G	= 3							
< 1G	= 4							
Bank Angle	3/4	3	4	4	4	4	4	4
30-60 degree bank	= 3							
< 30 degree bank	= 4							
No large power changes required	2/4	2	4	4	4	4	4	4

SCHEDULE FACTORS DATA BASE

	ALS	PUB	SAF	FMN	ABQ	DEN	GJT
ATC ENROUTE VECTORS/ DIVERSIONS/HOLDING	O	O	O	O	O	X	O
DELAY IN TERMINAL AREA	O	X	O	O	X	O	O
ATC TAXI DELAYS TO GATE	O	O	O	O	O	O	O
A/C TURN AROUND TIME AT GATE	X	O	X	X	O	O	O
DPT. DELAYS - ATC CLEARANCES/TRAFFIC	O	O	O	O	O	X	O
ENROUTE WIND TO NEW DESTINATION	O	O	O	O	O	O	O

SCHEDULE FACTOR WEIGHTING (Page 1 of 2)

		ALS	PUB	SAF	FMN	ABQ	DEN	GJT
ATC ENROUTE VECTORS/HOLDING	1/3/5	5	5	5	5	5	3	5
> 20 minutes = 1 10 - 20 minutes = 3 0 - 10 minutes = 5								
DELAY IN TERMINAL AREA	1/4/5	5	1	5	5	4	5	5
> 30 minutes = 1 10 - 30 minutes = 4 0 - 10 minutes = 5								
ATC GATE TAXI DELAYS	1/3/5	5	5	5	5	5	5	5
> 15 minutes = 1 1 - 15 minutes = 3 0 minutes = 5								
A/C TURN AROUND TIME	1 - 5	1	5	3	3	5	5	5
> 60 minutes = 1 30 - 60 minutes = 3 < 30 minutes = 4 None = 5								
DEPARTURE DELAYS FROM NEW DEST (ATC CLEARANCES/TRAFFIC)	2 - 5	5	5	5	5	5	4	5
> 30 minutes = 2 10 - 30 minutes = 3 < 10 minutes = 4 None = 5								

SCHEDULE FACTOR WEIGHTING (Page 2 of 2)

		ALS	PUB	SAF	FMN	ABQ	DEN	GJT
WIND EFFECTS	1 - 5	5	5	5	5	5	5	5

> - 9 = 1
- 60 to - 90 = 2
- 30 to - 60 = 3
> - 30 = 4
None = 5

ECONOMY FACTORS DATA BASE

	ALS	PUB	SAF	FMN	ABQ	DEN	GJT
FUEL USE	O	O	X	X	X	O	X
LANDING FEES	X	X	X	O	X	X	O
MAINTENANCE	X	X	X	X	X	O	X
CREW COST	O	O	X	X	X	X	X

ECONOMY FACTOR WEIGHTING

		ALS	PUB	SAF	FMN	ABQ	DEN	GJT
FUEL USE BASED ON DISTANCE/ ENROUTE TRAFFIC DELAYS (to diversion point + next dest)	1 - 6	6	6	5	5	1	6	5

> 5,000 pounds = 1
2,000 - 5,000 pounds = 3
1,000 - 2,000 pounds = 5
< 1,000 pounds = 6

LANDING FEES	2/4/6	4	4	4	6	2	2	6

> $500 = 2
$100 - $500 = 4
< 100 = 6

SCHEDULED MAINTENANCE	1/4/6	6	6	4	4	4	6	6

> $5000 = 1
$1000 - $5000 = 4
< $1000 = 6

UNSCHEDULED MAINTENANCE	2/4/6	2	4	4	2	4	6	2

None = 2
Non-company = 4
Company = 6

CREW DUTY TIME	3/5/6	6	6	3	5	3	5	5

More than 30 minutes > original = 1
10 - 30 minutes > than original = 3
Equal to original destination = 5
10 - 30 minutes < than original = 6

PROPOSED ALTERNATE ROUTE SELECTION FACTORS DATA BASE

	1	2	3	4	5
SAFETY					
WEATHER	X	X	X	X	O
AIR TRAFFIC	X	X	X	X	X
A/C OPERATIONS	O	O	O	O	O
A/C MAINTENANCE STATUS	O	O	X	X	X
PASSENGER COMFORT					
CABIN ALTITUDE DESCENT RATE	O	O	O	O	O
TURBULENCE	O	X	X	O	O
MANEUVERING	O	X	X	O	O
SCHEDULE/ECONOMY					
ATC ENROUTE VECTORING/HOLDING	O	O	X	O	O
WIND	O	O	O	O	X
MEETING SLOT TIME	O	X	X	X	X
ROUTE + APPROACH DESCENT DISTANCE	O	O	X	X	X

PROPOSED ALTERNATE ROUTE SELECTION FACTORS DATA BASE

	1	2	3	4	5
ROUTING					
APPROACH PROFILE	O	X	X	X	X
RESTRICTED AREAS	X	X	X	X	X
MILITARY OPERATION AREAS	O	X	O	O	O
TERRAIN/OBSTACLES	O	O	O	O	O
TERMINAL CONTROL AREA ALTITUDE/ROUTE RESTRICTIONS	X	O	O	O	X

ROUTE SELECTION WEIGHTING (Sheet 1 of 4)

		1	2	3	4	5
SAFETY						
ENROUTE WEATHER	1 - 10	7	7	5	7	10

Severe = 1
Moderate = 5
Light = 7
None =10

		1	2	3	4	5
No Enroute Traffic Conflicts	6/10	10	10	6	10	10
No Approach Traffic Conflicts	6/10	10	10	10	10	6
Conflicting Runway Traffic	7/10	7	7	10	7	10
AIRCRAFT OPERATIONS						
Stays within A/S limits	1/10	10	10	10	10	10
Within A/C icing parameters	1/10	10	10	10	10	10
Operates above MEA	1/10	10	10	10	10	10
A/C MAINTENANCE STATUS	1/6/10	10	10	6	6	6

Causes route to be unsafe = 1
Causes some problems with route = 6
Does not affect route =10

ROUTE SELECTION WEIGHTING (Sheet 2 of 4)

		1	2	3	4	5
PASSENGER COMFORT						
CABIN ALTITUDE DESCENT RATE	1/3/4	4	4	4	4	4
> 2,000'/min = 1						
500-2,000'/min = 3						
< 500'/min = 4						
TURBULENCE	1 - 4	4	3	1	4	4
Severe = 1						
Moderate = 2						
Light = 3						
None = 4						
MANEUVERING						
Gs	1 - 4	4	3	3	4	4
1G +- .7G	= 1					
1G +- .2 to - .7G	= 2					
1G +- .1 to - .2G	= 3					
< 1G	= 4					
Bank angle	3/4	4	4	4	4	4
30 - 60 degree bank	= 3					
< 30 degree bank angle	= 4					
SCHEDULE/ECONOMY						
ATC ENROUTE VECTORING/ HOLDING/DELAYS	1/3/5	5	5	3	5	5
> 40 minutes	= 1					
20 - 40 minutes	= 3					
< 20 minutes	= 5					

ROUTE SELECTION WEIGHTING (Sheet 3 of 4)

		1	2	3	4	5
WIND EFFECTS ON COST	1/3/5	5	5	5	5	3
MEETING SLOT TIME	3/4/5	5	4	4	4	3
ROUTE + APPROACH DESCENT DISTANCE	3/4/5	5	5	3	3	3
INSTRUMENT APPROACH PROFILE	2/4/6	6	4	4	4	4
RESTRICTED AREAS	3/4/5	4	4	3	4	4

WIND EFFECTS ON COST 1/3/5

- Original cost + > $200 = 1
- Original cost + < $200 = 3
- < original destination costs = 5

MEETING SLOT TIME 3/4/5

- +- 5 minutes = 3
- +- 2 minutes = 4
- +- 5 seconds = 5

ROUTE + APPROACH DESCENT DISTANCE 3/4/5

- > 50 additional miles = 3
- = shortest + up to 50 miles = 4
- < shortest = 5

ROUTING

INSTRUMENT APPROACH PROFILE 2/4/6

- Entire instrument appraoch = 2
- Procedure turn/track = 4
- Enroute descent to straight in = 6

RESTRICTED AREAS 3/4/5

- Additional time > 5 minutes = 3
- Additional time < 5 minutes = 4
- No additional time required = 5

ROUTE SELECTION WEIGHTING (Sheet 4 of 4)

		1	2	3	4	5
MILITARY OPERATION AREAS	3/4/5	5	4	5	5	5
Additional time > 5 minutes = 3 Additional time < 5 minutes = 4 No additional time required = 5						
NO CLIMB REQUIRED FOR TERRAIN/OBSTACLE CONFLICTS						
NON-EMERGENCY	6/10	10	10	10	10	10
EMERGENCY	1/10	10	10	10	10	10
TERMINAL CONTROL AREA ALTITUDE/ROUTE RESTRICTIONS	2/4/6	4	6	6	6	2
No descent until 5-10 min out = 2 No descent until 2-5 min out = 4 Descent unrestricted = 6						

DIVERSION FOR LOSS OF PRESSURIZATION

PROPOSED ALTERNATE ROUTE SELECTION FACTORS DATA BASE

	1	2	3	4
SAFETY				
WEATHER	X	X	X	O
AIR TRAFFIC	X	X	X	X
A/C OPERATIONS	X	O	O	O
A/C MAINTENANCE STATUS	X	O	X	X
PASSENGER COMFORT				
CABIN ALTITUDE DESCENT RATE	X	X	X	X
TURBULENCE	O	X	X	O
MANEUVERING	O	X	X	O
SCHEDULE/ECONOMY				
ATC ENROUTE VECTORING/HOLDING	O	O	X	O
WIND	O	O	O	X
MEETING SLOT TIME	X	O	O	X
ROUTE + APPROACH DESCENT DISTANCE	X	O	X	X

PROPOSED ALTERNATE ROUTE SELECTION FACTORS DATA BASE

	1	2	3	4
ROUTING				
APPROACH PROFILE	O	X	X	X
RESTRICTED AREAS	X	X	X	X
MILITARY OPERATION AREAS	O	X	O	O
TERRAIN/OBSTACLES	X	O	O	O
TERMINAL CONTROL AREA ALTITUDE/ROUTE RESTRICTIONS	X	O	O	O

ROUTE SELECTION WEIGHTING (Sheet 1 of 4)

		1	2	3	4
SAFETY					
ENROUTE WEATHER	1 - 10	7	1	1	7
Severe = 1 Moderate = 5 Light = 7 None =10					
No Enroute Traffic Conflicts	6/10	10	10	6	10
No Approach Traffic Conflicts	6/10	10	10	10	6
Conflicting Runway Traffic	7/10	7	7	10	7
AIRCRAFT OPERATIONS					
Stays within A/S limits	1/10	10	10	10	10
Within A/C icing parameters	1/10	10	10	10	10
Operates above MEA	1/10	1	10	10	10
A/C MAINTENANCE STATUS	1/6/10	1	10	6	6

Causes route to be unsafe = 1
Causes some problems with route = 6
Does not affect route =10

ROUTE SELECTION WEIGHTING (Sheet 2 of 4)

		1	2	3	4
PASSENGER COMFORT					
CABIN ALTITUDE DESCENT RATE	1/3/4	1	1	1	1
> 2,000'/min	= 1				
500 - 2,000'/min	= 3				
< 500'/min	= 4				
TURBULENCE	1 - 4	3	1	2	3
Severe	= 1				
Moderate	= 2				
Light	= 3				
None	= 4				
MANEUVERING					
Gs	1 - 4	4	4	4	4
1G +- .7G	= 1				
1G +- .2 to - .7G	= 2				
1G +- .1 to - .2G	= 3				
< 1G	= 4				
Bank angle	3/4	4	4	4	4
30 - 60 degree bank	= 3				
< 30 degree bank angle	= 4				
SCHEDULE/ECONOMY					
ATC ENROUTE VECTORING/ HOLDING/DELAYS	1/3/5	5	5	3	5
> 40 minutes	= 1				
20 - 40 minutes	= 3				
< 20 minutes	= 5				

ROUTE SELECTION WEIGHTING (Sheet 3 of 4)

Criterion	Scale	1	2	3	4
WIND EFFECTS ON COST	1/3/5	5	5	5	3
Original cost + > $200 = 1					
Original cost + < $200 = 3					
< original destination costs = 5					
MEETING SLOT TIME	3/4/5	4	5	5	4
+- 5 minutes = 3					
+- 2 minutes = 4					
+- 5 seconds = 5					
ROUTE + APPROACH DESCENT DISTANCE	3/4/5	4	5	3	3
> 50 additional miles = 3					
= shortest + up to 50 miles = 4					
< shortest = 5					
ROUTING					
INSTRUMENT APPROACH PROFILE	2/4/6	6	4	4	4
Entire instrument appraoch = 2					
Procedure turn/track = 4					
Enroute descent to straight in = 6					
RESTRICTED AREAS	3/4/5	4	4	3	4
Additional time > 5 minutes = 3					
Additional time < 5 minutes = 4					
No additional time required = 5					

ROUTE SELECTION WEIGHTING (Sheet 4 of 4)

		1	2	3	4
MILITARY OPERATION AREAS	3/4/5	5	4	5	5

Additional time > 5 minutes = 3
Additional time < 5 minutes = 4
No additional time required = 5

		1	2	3	4
NO CLIMB REQUIRED FOR TERRAIN/OBSTACLE CONFLICTS					
NON-EMERGENCY	6/10	6	10	10	10
EMERGENCY	1/10	1	10	10	10
TERMINAL CONTROL AREA ALTITUDE/ROUTE RESTRICTIONS	2/4/6	4	6	6	6

No descent until 5-10 min out = 2
No descent until 2 - 5 min out = 4
Descent unrestricted = 6

DIVERSION FOR LOSS OF ENGINE POWER

PROPOSED ALTERNATE ROUTE SELECTION FACTORS DATA BASE

	1	2	3	4	5
SAFETY					
WEATHER	X	X	X	X	O
AIR TRAFFIC	X	X	X	X	X
A/C OPERATIONS	O	O	O	O	O
A/C MAINTENANCE STATUS	X	X	X	X	X
PASSENGER COMFORT					
CABIN ALTITUDE DESCENT RATE	O	O	O	O	O
TURBULENCE	O	X	X	X	O
MANEUVERING	O	O	O	O	O
SCHEDULE/ECONOMY					
ATC ENROUTE VECTORING/HOLDING	O	O	X	O	O
WIND	O	O	O	X	O
MEETING SLOT TIME	X	X	X	X	O
ROUTE + APPROACH DESCENT DISTANCE	X	X	X	X	O

PROPOSED ALTERNATE ROUTE SELECTION FACTORS DATA BASE

	1	2	3	4	5
ROUTING					
APPROACH PROFILE	X	X	X	X	O
RESTRICTED AREAS	X	X	X	X	O
MILITARY OPERATION AREAS	O	O	O	O	O
TERRAIN/OBSTACLES	O	O	O	O	O
TERMINAL CONTROL AREA ALTITUDE/ROUTE RESTRICTIONS	X	X	X	O	X

ROUTE SELECTION WEIGHTING (Sheet 1 of 4)

		1	2	3	4	5
SAFETY						
ENROUTE WEATHER	1 - 10	7	5	1	7	10
No Enroute Traffic Conflicts	6/10	10	10	6	10	10
No Approach Traffic Conflicts	6/10	10	10	10	10	6
Conflicting Runway Traffic	7/10	7	7	10	7	10
AIRCRAFT OPERATIONS						
Stays within A/S limits	1/10	10	10	10	10	10
Within A/C icing parameters	1/10	10	10	10	10	10
Operates above MEA	1/10	10	10	10	10	10
A/C MAINTENANCE STATUS	1/6/10	6	6	6	6	6

Enroute weather:

Severe = 1
Moderate = 5
Light = 7
None =10

A/C maintenance status:

Causes route to be unsafe = 1
Causes some problems with route = 6
Does not affect route =10

ROUTE SELECTION WEIGHTING (Sheet 2 of 4)

		1	2	3	4	5
PASSENGER COMFORT						
CABIN ALTITUDE DESCENT RATE	1/3/4	4	4	4	4	4
> 2,000'/min	= 1					
500 - 2,000'/min	= 3					
< 500'/min	= 4					
TURBULENCE	1 - 4	3	2	1	3	4
Severe	= 1					
Moderate	= 2					
Light	= 3					
None	= 4					
MANEUVERING						
Gs	1 - 4	4	4	4	4	4
1G +- .7G	= 1					
1G +- .2 to - .7G	= 2					
1G +- .1 to - .2G	= 3					
< 1G	= 4					
Bank angle	3/4	4	4	4	4	4
30 - 60 degree bank	= 3					
< 30 degree bank angle	= 4					
SCHEDULE/ECONOMY						
ATC ENROUTE VECTORING/ HOLDING/DELAYS	1/3/5	5	5	3	5	5
> 40 minutes	= 1					
20 - 40 minutes	= 3					
< 20 minutes	= 5					

ROUTE SELECTION WEIGHTING (Sheet 3 of 4)

		1	2	3	4	5
WIND EFFECTS ON COST	1/3/5	5	5	5	3	5
Original cost + > $200	= 1					
Original cost + < $200	= 3					
< original destination costs	= 5					
MEETING SLOT TIME	3/4/5	3	4	4	4	5
+- 5 minutes	= 3					
+- 2 minutes	= 4					
+- 5 seconds	= 5					
ROUTE + APPROACH DESCENT DISTANCE	3/4/5	3	3	3	3	5
> 50 additional miles	= 3					
= shortest + up to 50 miles	= 4					
< shortest	= 5					

ROUTING

		1	2	3	4	5
INSTRUMENT APPROACH PROFILE	2/4/6	4	4	4	4	6
Entire instrument appraoch	= 2					
Procedure turn/track	= 4					
Enroute descent to straight in	= 6					
RESTRICTED AREAS	3/4/5	4	4	3	4	5
Additional time > 5 minutes	= 3					
Additional time < 5 minutes	= 4					
No additional time required	= 5					

ROUTE SELECTION WEIGHTING (Sheet 4 of 4)

		1	2	3	4	5
MILITARY OPERATION AREAS	3/4/5	5	5	5	5	5

Additional time > 5 minutes = 3
Additional time < 5 minutes = 4
No additional time required = 5

		1	2	3	4	5
NO CLIMB REQUIRED FOR TERRAIN/OBSTACLE CONFLICTS						
NON-EMERGENCY	6/10	10	10	10	10	10
EMERGENCY	1/10	10	10	10	10	10
TERMINAL CONTROL AREA ALTITUDE/ROUTE RESTRICTIONS	2/4/6	2	4	4	6	4

No descent until 5-10 min out = 2
No descent until 2 - 5 min out = 4
Descent unrestricted = 6

NAVIGATION POINTS FOR DIVERTER

INTERSECTIONS

GOSIP	3738N 10434W
SHREW	3910N 10540W
BYSON	3922N 10532W
KINGO	3757N 10336W
JACOX	3929N 10454W
GANDI	3945N 10453W
ACREE	3852N 10604W
PYNON	3831N 10435W
MIDAY	3834N 10440W
PETEY	3841N 10440W
RAMAH	3910N 10401W
FRIHO	3525N 10640W
AWASH	3513N 10659W
BATTZ	3852N 10818W
LOMMA	3916N 10847W
RESER	3654N 10727W

POAKE	3554N 10600W
BOBOW	3546N 10607W
VIGIL	3755N 10427W
CHILT	3910N 10505W
SILOW	3925N 10501W
ENGLE	3938N 10456W
CURLY	3524N 10708W
CABZO	3528N 10714W
BRAZO	3649N 10639W
TURLY	3648N 10747W
NAMBE	3548N 10601W
PEDRA	3526N 10657W
ZIASE	3529N 10636W
BLOOM	3749N 10359W
STAXX	3759N 10408W
ORWAY	3816N 10403W
BLOKE	3725N 10530W
COMBO	3525N 10601W

DANNE	3736N 10600W
AYNES	3821N 10414W
ALS 003/17	3738N 10542W
ALS 322/11	3731N 10555W
PUB 178/10	3806N 10427W

NAVIGATION AIDES (TACAN/VOR)

MTJ	3830N 10754W
DRO	3709N 10746W
CIM	3630N 10453W
TBE	3716N 10336W
OTO	3504N 10556W
TXC	3932N 10313W
ABQ	3503N 10648W
JNC	3904N 10848W
TAS	3637N 10554W
COS	3857N 10438W
FMN	3645N 10806W
ALS	3721N 10549W

C-2

LAA	3812N 10242W
HGO	3849N 10337W
SAF	3533N 10604W
PUB	3818N 10425W
DEN	3953N 10452W
IOC	3926N 10420W
HBU	3828N 10702W

AIRFIELDS

KALS	3726N 10552W
KABQ	3512N 10640W
KDEN	3946N 10453W
KFMN	3644N 10814W
KGTJ	3907N 10831W
KPUB	3817N 10430W
KSAF	3537N 10605W

DIVERTER ROUTES FOR WEATHER DIVERSION

Basic Flight Plan - LAX to COS

FROM	VIA	TO	MH/DIST(NM)	ALT
LAX	J-60	HEC	031/85	FL290
HEC	J-6	EED	076/98	FL330
EED	J-6	DRK	077/99	FL330
DRK	J-10	FMN	045/247	FL330
FMN	J-44	ALS	057/115	FL330
ALS	DIR	GOSIP	041/60	FL210
GOSIP	V-83	PUB	358/41	18000
PUB	R-309	PYNON	309/16	14000
PYNON	R-309	MIDAY	309/5.6	10000
MIDAY	LOC	PETEY	348/6.7	9000
PETEY	ILS	KCOS	348/6.0	6172
			579.3	

WEATHER DIVERT TO DENVER ROUTE 1

FROM	VIA	TO	MH/DIST(NM)	ALT
ALS	J-44	SHREW	350/109	FL240
SHREW	J-44	BYSON	033/17	17000
BYSON	DIR	JACOX	073/24	10000
JACOX	LOC	GANDI	351/15.9	7500
GANDI	ILS	KDEN	351/6.7	5333
			163.6	

WEATHER DIVERT TO DENVER ROUTE 2

FROM	VIA	TO	MH/DIST(NM)	ALT
ALS	R-341	ACREE	341/94	FL260
ACREE	J-10	SHREW	033/22	FL210
SHREW	J-44	BYSON	033/17	17000
BYSON	DIR	JACOX	073/24	10000
JACOX	LOC	GANDI	351/15.9	7500
GANDI	ILS	KDEN	351/6.7	5333
			179.6	

WEATHER DIVERT TO DENVER ROUTE 3

FROM	VIA	TO	MH/DIST(NM)	ALT
ALS	J-206	HBU	306/88	FL310
HBU	J-10	ACREE	046/55	FL250
ACREE	J-10	SHREW	033/22	FL210
SHREW	J-44	BYSON	033/17	17000
BYSON	DIR	JACOX	073/24	10000
JACOX	LOC	GANDI	351/15.9	7500
GANDI	ILS	KDEN	351/6.7	5333
			228.6	

WEATHER DIVERT TO DENVER ROUTE 4

FROM	VIA	TO	MH/DIST(NM)	ALT
ALS	J-102	LAA	057/157	FL330
LAA	J-168	HGO	298/58	FL260
HGO	J-168	RAMAH	306/27	FL180
RAMAH	J-168	IOC	306/23	FL180
IOC	R-253	JACOX	253/26.2	10000
JACOX	LOC	GANDI	351/15.9	7500
GANDI	ILS	KDEN	351/6.7	5333
			319.8	

WEATHER DIVERT TO DENVER ROUTE 5

FROM	VIA	TO	MH/DIST(NM)	ALT
ALS	J-102	LAA	057/157	FL330
LAA	J-168	HGO	298/58	FL260
HGO	J-168	RAMAH	306/27	FL180
RAMAH	J-168	IOC	306/23	FL180
IOC	R-286	GANDI	286/31	7500
GANDI	ILS	KDEN	351/6.7	5333
			302.7	

WEATHER DIVERT TO ABQ

ALS	J-13	FRIHO	187/121	FL310
FRIHO	DIR	AWASH	230/20	FL210
AWASH	DIR	ABQ	136/16	10000
ABQ	ILS	KABQ	074/10	5352
			166	

WEATHER DIVERT TO GJT

ALS	J-206	HBU	306/88	FL310
HBU	V-484	BATTZ	280/64	14000
BATTZ	V-484	JNC	280/26	10000
JNC	V-187	LOMMA	341/13	8000
LOMMA	ILS	KGJT	112/16	4858
			207	

WEATHER DIVERT TO FMN

ALS	J-44/V-210	RESER	240/84	15000
RESER	V-210	FMN	240/31	8000
FMN	ILS	KFMN	255/6	5503
			181	

DIVERT FOR WEATHER TO KSAF

ALS	V-83	TAS	173/45	FL250
TAS	V-83	NAMBE	174/49	11000
NAMBE	V-83	SAF	174/15	9000
SAF	DIR	COMBO	152/13	9000
COMBO	DIR	SAF	332/8	7800
SAF	DIR	KSAF	332/4.2	6344
			134.2	

DIVERT FOR WEATHER TO KPUB

ALS	V-83	GOSIP	061/60	FL180
GOSIP	V-83	VIGIL	358/19	13000
VIGIL	V-83	PUB 178/10	358/12	11000
PUB 178/10	ARC	AYNES	VAR/20	7000
AYNES	DIR	PUB	244/10	5500
PUB	DIR	KPUB	244/2.1	4726
			123.1	

DIVERT FOR WEATHER TO KALS

ALS	DIR	ALS 003/17	003/17	15000
ALS 003/17	ARC	DANNE	VAR/12	10000
DANNE	DIR	ALS 322/11	142/6	9000
ALS 322/11	DIR	KALS	142/5.2	7535
			40.2	

DIVERT FOR PRESSURE LOSS TO DENVER

Route 1

FROM	VIA	TO	MH/DIST (NM)	ALT
ALS	V-484	HBU	326-276/96	15000
HBU	V-95	CHILT	050/99	17000
CHILT	V-89	SILOW	005/15	12000
SILOW	DIR	JACOX	073/6.8	10000
JACOX	LOC	GANDI	351/15.9	7500
GANDI	ILS	KDEN	351/6.2	5333
			238.9	

Route 2

FROM	VIA	TO	MH/DIST (NM)	ALT
ALS	V-83	GOSIP	061/60	14000
GOSIP	V-19	PUB	358/41	9000
PUB	V-19	IOC	351/69	9000
IOC	DIR	ENGLE	275/26	9000
ENGLE	LOC	GANDI	351/5.7	7500
GANDI	ILS	KDEN	351/6.2	5333
			207.9	

Route 3

FROM	VIA	TO	MH/DIST (NM)	ALT
ALS	V-83	GOSIP	061/60	14000
GOSIP	V-83	PUB	358/41	10000
PUB	V-81	COS	333/40	10000
COS	V-83	IOC	012/33	10000
IOC	DIR	ENGLE	275/26	9000
ENGLE	LOC	GANDI	351/5.7	7500
GANDI	ILS	KDEN	351/6.2	5333
			211.9	

Route 4

FROM	VIA	TO	MH/DIST (NM)	ALT
ALS	V-210	GOSIP	061/60	14000
GOSIP	V-210	KINGO	058/51	12000
KINGO	V-169	HGO	347/53	9000
HGO	V-366	IOC	306/50	9000
IOC	DIR	ENGLE	275/26	9000
ENGLE	LOC	GANDI	351/5.7	7500
GANDI	ILS	KDEN	351/6.2	5333
			251.9	

DIVERT FOR PRESSURE LOSS TO ABQ

Route 1

ALS	V-210	FMN	240/115	15000
FMN	V-187	AWASH	134/104	11000
AWASH	V-187	ABQ	136/16	8000
ABQ	ILS	KABQ	077/9.8	5352
			244.8	

Route 2

ALS	V-83	TAS	173/45	12000
TAS	V-83	SAF	174/64	11000
SAF	DIR	AWASH	238/49	9000
AWASH	DIR	ABQ	136/16	8000
ABQ	ILS	KABQ	077/9.8	5352
			183.8	

Route 3

ALS	V-83	TAS	173/45	12000
TAS	V-83	SAF	174/64	11000
SAF	DIR	CURLY	249/51	9000
CURLY	V-187	AWASH	136/10	9000
AWASH	V-187	ABQ	136/16	8000
ABQ	ILS	KABQ	077/9.8	5352
			195.8	

DIVERT FOR PRESSURE LOSS TO KGTJ

Route 1

ALS	V-484	HBU	326-276/96	15000
HBU	V-26	MTJ	261/40	13000
MTJ	V-26	JNC	295/54	11000
JNC	V-187	LOMMA	341/13	9000
LOMMA	ILS	KGTJ	112/17.1	4858
			220.1	

Route 2

ALS	V-484	HBU	326-276/96	15000
HBU	V-484	JNC	280/90	14000
JNC	V-187	LOMMA	341/13	9000
LOMMA	ILS	KGTJ	112/17.1	4858
			216.1	

Route 3

ALS	V-210	FMN	240/115	15000
FMN	V-187	JNC	333/142	15000
JNC	V-187	LOMMA	341/13	9000
LOMMA	ILS	KGTJ	112/17.1	4858
			287.1	

DIVERT FOR PRESSURE LOSS TO KFMN

Route 1

ALS	V-210	RESER	240/84	15000
RESER	V-210	FMN	237/31	9000
FMN	ILS	KFMN	256/5.9	5503
			120.9	

Route 2

ALS	V-484	HBU	326-276/96	15000
HBU	V-95	DRO	190/85	17000
DRO	DIR	TURLY	170/24	10000
TURLY	V-368	FMN	252/16	9000
FMN	ILS	KFMN	256/5.9	5503
			226.9	

Route 3

ALS	V-368	BRAZO	218/51	13000
BRAZO	V-368	TURLY	252/54	13000
TURLY	V-368	FMN	252/16	9000
FMN	ILS	KFMN	256/5.9	5503
			126.9	

DIVERT FOR PRESSURE LOSS TO KSAF

Route 1

ALS	V-83	TAS	173/45	12000
TAS	V-83	NAMBE	174/49	11000
NAMBE	V-83	SAF	174/15	9000
SAF	DIR	COMBO	152/13	9000
COMBO	DIR	SAF	332/8	7800
SAF	DIR	KSAF	332/4.2	6344
			134.2	

Route 2

ALS	V-210	FMN	240/115	15000
FMN	V-187	CABZO	134/88	11000
CABZO	V-62	ZIASE	075/26	10000
ZIASE	V-62	SAF	075/27	9000
SAF	DIR	COMBO	152/13	9000
COMBO	DIR	SAF	332/8	7800
SAF	DIR	KSAF	332/4.2	6344
			283.2	

Route 3

ALS	V-368	FMN	219-252/121	13000
FMN	V-68	PEDRA	114-152/81	13000
PEDRA	V-62	ZIASE	075/17	10000
ZIASE	V-62	SAF	075/27	9000
SAF	DIR	COMBO	152/13	9000
COMBO	DIR	SAF	332/8	7800
SAF	DIR	KSAF	332/4.2	6344
			271.2	

DIVERT FOR PRESSURE LOSS TO KPUB

Route 1

ALS	V-83	GOSIP	061/60	14000
GOSIP	V-83	VIGIL	358/19	9000
VIGIL	V-83	PUB 178/10	358/12	7000
PUB 178/10	ARC	AYNES	VAR/20	7000
AYNES	DIR	PUB	244/10	5500
PUB	DIR	KPUB	244/2.1	4726
			123.1	

DIVERT FOR PRESSURE LOSS TO KALS

ALS	DIR	ALS 003/17	003/17	15000
ALS 003/17	ARC	DANNE	VAR/12	10000
DANNE	DIR	ALS 322/11	142/6	9000
ALS 322/11	DIR	KALS	142/5.2	7535
			40.2	

DIVERTER ROUTES FOR ENGINE POWER LOSS

DIVERT TO DENVER

Route 1

ALS	V-484	HBU	326-276/96	16000
HBU	V-95	CHILT	050/99	16000
CHILT	V-89	SILOW	005/15	12000
SILOW	DIR	JACOX	073/6.8	10000
JACOX	LOC	GANDI	351/15.9	7500
GANDI	ILS	KDEN	351/6.2	5333
			238.9	

Route 2

ALS	V-83	GOSIP	061/60	17000
GOSIP	V-19	PUB	358/41	16000
PUB	V-19	IOC	351/69	16000
IOC	DIR	ENGLE	275/26	9000
ENGLE	LOC	GANDI	351/5.7	7500
GANDI	ILS	KDEN	351/6.2	5333
			207.9	

Route 3

ALS	V-83	GOSIP	061/60	17000
GOSIP	V-83	PUB	358/41	16000
PUB	V-81	COS	333/40	16000
COS	V-83	IOC	012/33	16000
IOC	DIR	ENGLE	275/26	9000
ENGLE	LOC	GANDI	351/5.7	7500
GANDI	ILS	KDEN	351/6.2	5333
			211.9	

Route 4

ALS	V-210	GOSIP	061/60	17000
GOSIP	V-210	KINGO	058/51	16000
KINGO	V-169	HGO	347/53	16000
HGO	V-366	IOC	306/50	16000
IOC	DIR	ENGLE	275/26	9000
ENGLE	LOC	GANDI	351/5.7	7500
GANDI	ILS	KDEN	351/6.2	5333
			251.9	

Route 5

ALS	DIR	JACOX	005/135	10000
JACOX	LOC	GANDI	351/15.9	7500
GANDI	ILS	KDEN	351/6.2	5333
			157.1	

DIVERT TO ABQ

Route 1

ALS	V-210	FMN	240/115	16000
FMN	V-187	AWASH	134/104	11000
AWASH	V-187	ABQ	136/16	8000
ABQ	ILS	KABQ	077/9.8	5352
			244.8	

Route 2

ALS	V-83	TAS	173/45	17000
TAS	V-83	SAF	174/64	11000
SAF	DIR	AWASH	238/49	9000
AWASH	DIR	ABQ	136/16	8000
ABQ	ILS	KABQ	077/9.8	5352
			183.8	

Route 3

ALS	V-83	TAS	173/45	17000
TAS	V-83	SAF	174/64	11000
SAF	DIR	CURLY	249/51	9000
CURLY	V-187	AWASH	136/10	9000
AWASH	V-187	ABQ	136/16	8000
ABQ	ILS	KABQ	077/9.8	5352
			195.8	

DIVERT TO KGTJ

Route 1

ALS	V-484	HBU	326-276/96	16000
HBU	V-26	MTJ	261/40	16000
MTJ	V-26	JNC	295/54	11000
JNC	V-187	LOMMA	341/13	9000
LOMMA	ILS	KGTJ	112/17.1	4858
			220.1	

Route 2

ALS	V-484	HBU	326-276/96	16000
HBU	V-484	JNC	280/90	16000
JNC	V-187	LOMMA	341/13	9000
LOMMA	ILS	KGTJ	112/17.1	4858
			216.1	

Route 3

ALS	V-210	FMN	240/115	16000
FMN	V-187	JNC	333/142	16000
JNC	V-187	LOMMA	341/13	9000
LOMMA	ILS	KGTJ	112/17.1	4858
			287.1	

DIVERT TO KFMN

Route 1

ALS	V-210	RESER	240/84	16000
RESER	V-210	FMN	237/31	9000
FMN	ILS	KFMN	256/5.9	5503
			120.9	

Route 2

ALS	V-484	HBU	326-276/96	16000
HBU	V-95	DRO	190/85	16000
DRO	DIR	TURLY	170/24	10000
TURLY	V-368	FMN	252/16	9000
FMN	ILS	KFMN	256/5.9	5503
			226.9	

Route 3

ALS	V-368	BRAZO	218/51	16000
BRAZO	V-368	TURLY	252/54	16000
TURLY	V-368	FMN	252/16	9000
FMN	ILS	KFMN	256/5.9	5503
			126.9	

DIVERT TO KSAF

Route 1

ALS	V-83	TAS	173/45	FL210
TAS	V-83	NAMBE	174/49	11000
NAMBE	V-83	SAF	174/15	9000
SAF	DIR	COMBO	152/13	9000
COMBO	DIR	SAF	332/8	7800
SAF	DIR	KSAF	332/4.2	6344
			134.2	

Route 2

ALS	V-210	FMN	240/115	16000
FMN	V-187	CABZO	134/88	16000
CABZO	V-62	ZIASE	075/26	10000
ZIASE	V-62	SAF	075/27	9000
SAF	DIR	COMBO	152/13	9000
COMBO	DIR	SAF	332/8	7800
SAF	DIR	KSAF	332/4.2	6344
			283.2	

Route 3

ALS	V-368	FMN	219-252/121	16000
FMN	V-68	PEDRA	114-152/81	16000
PEDRA	V-62	ZIASE	075/17	16000
ZIASE	V-62	SAF	075/27	9000
SAF	DIR	COMBO	152/13	9000
COMBO	DIR	SAF	332/8	7800
SAF	DIR	KSAF	332/4.2	6344
			271.2	

DIVERT TO KPUB

Route 1

ALS	V-83	GOSIP	061/60	16000
GOSIP	V-83	VIGIL	358/19	9000
VIGIL	V-83	PUB 178/10	358/12	7000
PUB 178/10	ARC	AYNES	VAR/20	7000
AYNES	DIR	PUB	244/10	5500
PUB	DIR	KPUB	244/2.1	4726
			123.1	

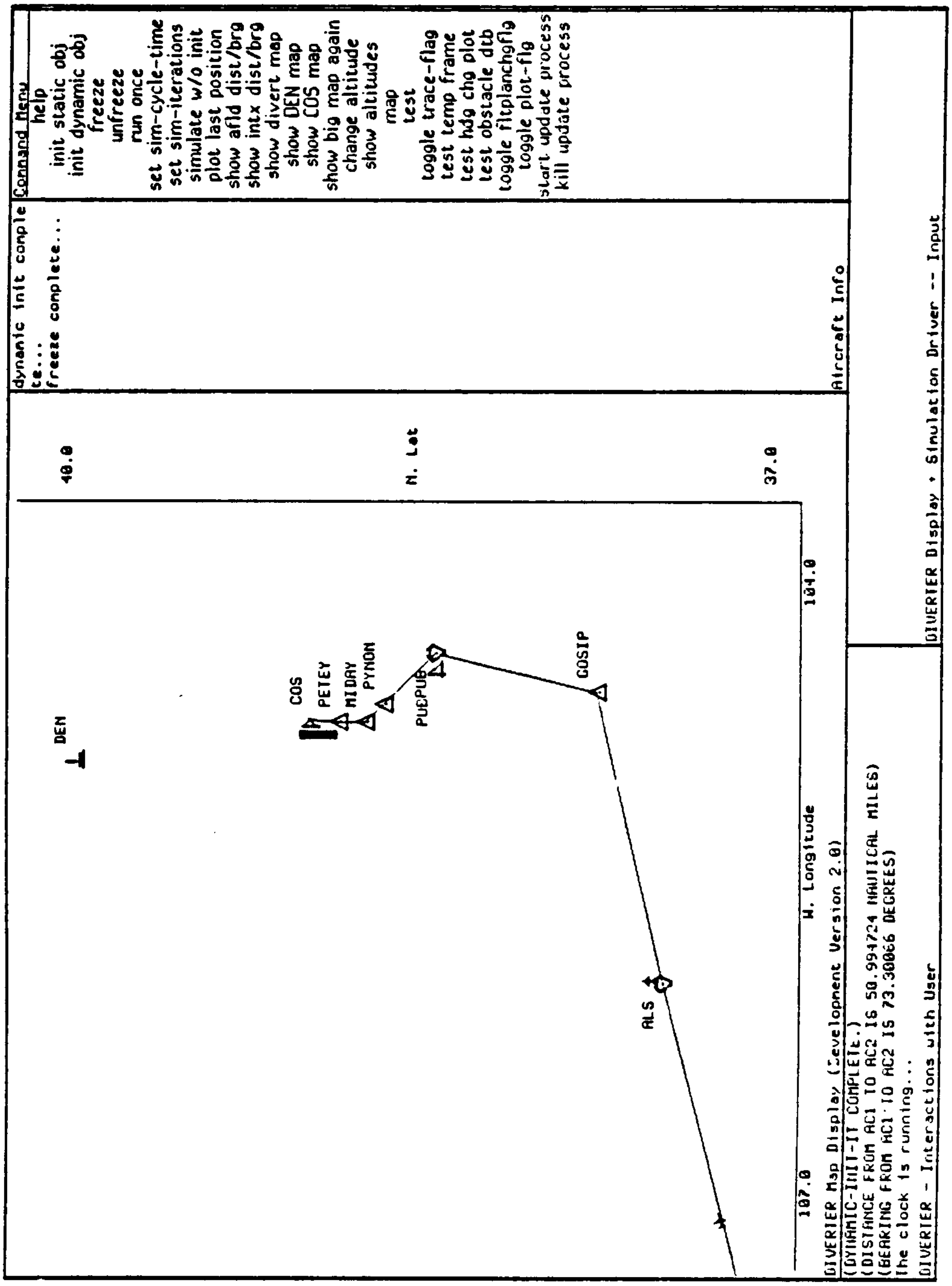
DIVERT KALS

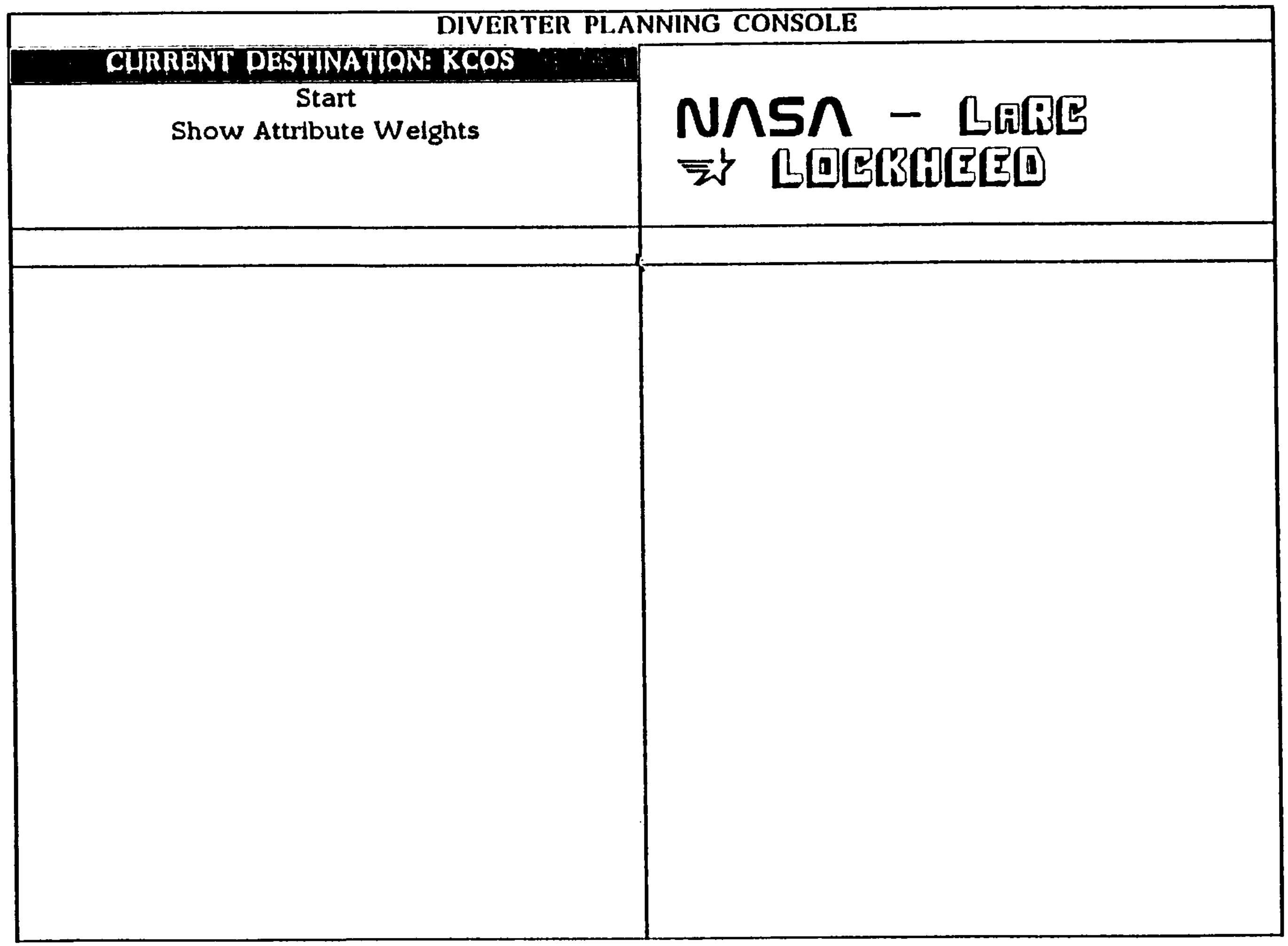
ALS	DIR	ALS 003/17	003/17	17000
ALS 003/17	ARC	DANNE	VAR/12	10000
DANNE	DIR	ALS 322/11	142/6	9000
ALS 322/11	DIR	KALS	142/5.2	7535
			40.2	

APPENDIX D

Sample Diverter Display Screen Images

This appendix contains a sample of display screen images taken from the Diverter demonstration showing the type and format of information presented in the demonstration.


Command Menu
help
init static obj
init dynamic obj
freeze
unfreeze
run once
set sim-cycle-time
set sim-iterations
simulate w/o init
plot last position
show afld dist/brg
show intx dist/brg
show divert map
show DEN map
show COS map
show big map again
change altitude
show altitudes
map
test
toggle trace-flag
test temp frame
test hdg chg plot
test obstacle dtb
toggle fltplanchgflg
toggle plot-flg
start update process
kill update process
dynamic init comple te...
freeze complete...
Aircraft Info
40.0
N. Lat
37.0
104.0
107.0
W. Longitude
DEN
COS
PETEY
MIDAY
PYNON
PUEPUB
COSIP
ALS
DIVERIER Map Display (Development Version 2.0)
(DYNAMIC-INIT-IT COMPLETE.)
(DISTANCE FROM AC1 TO AC2 IS 50.994724 NAUTICAL MILES)
(BEARING FROM AC1 TO AC2 IS 73.30066 DEGREES)
The clock is running...
DIVERIER - Interactions with User
DIVERIER Display + Simulation Driver -- Input


DIVERTER PLANNING CONSOLE
CURRENT DESTINATION: KCOS
Start
Show Attribute Weights
NASA - LaRC
LOCKHEED

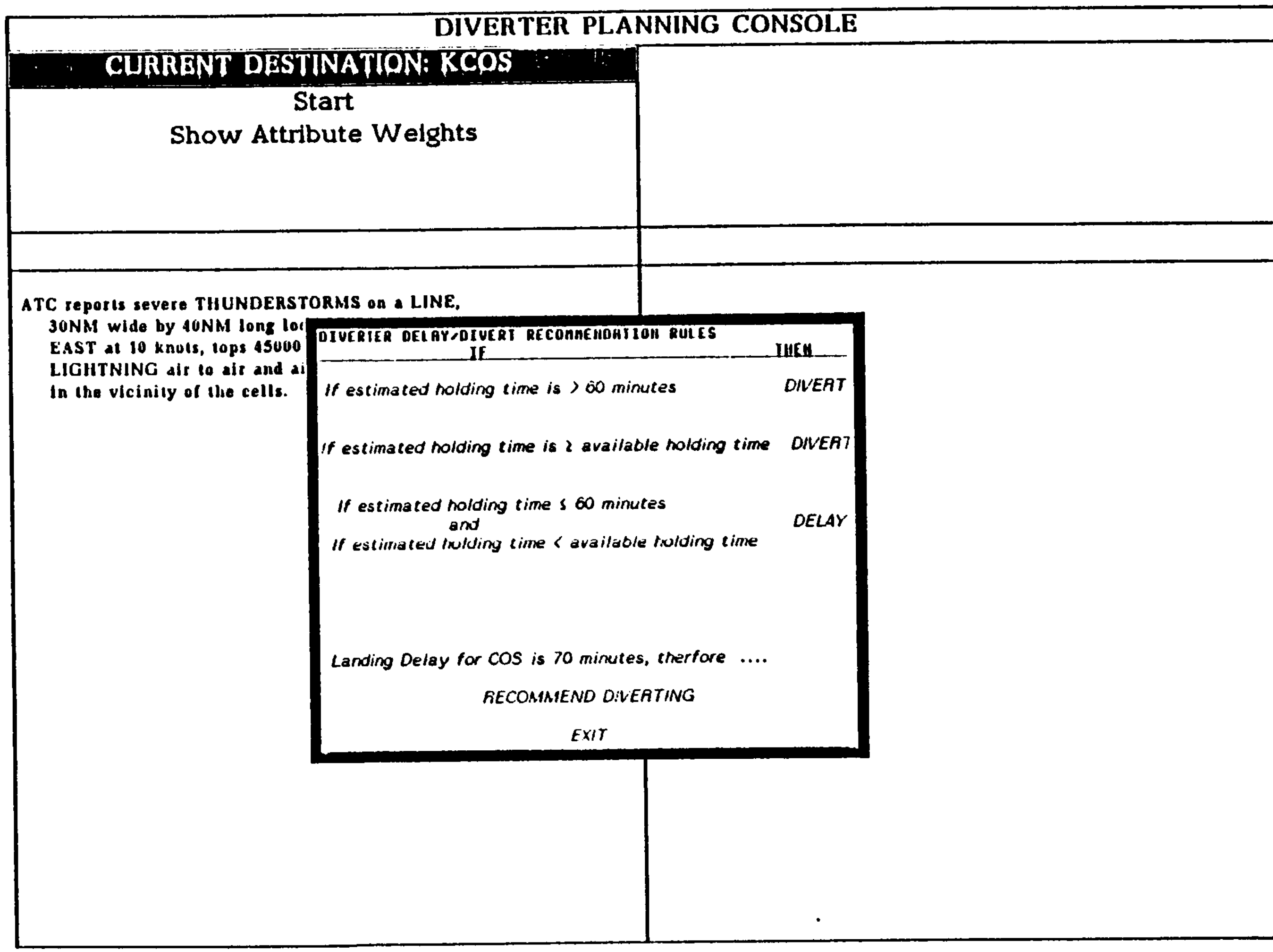
DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: KCOS

Start

Show Attribute Weights

ATC reports severe THUNDERSTORMS on a LINE,
30NM wide by 40NM long located 15NM-WEST of KCOS moving EAST at 10 knots, tops 45000 feet, 0.75IN-HAIL , ICING, LIGHTNING air to air and air to ground, and SEVERE turbulence in the vicinity of the cells.



DIVERTER PLANNING CONSOLE
CURRENT DESTINATION: KCOS
Start
Show Attribute Weights
ATC reports severe THUNDERSTORMS on a LINE,
30NM wide by 40NM long lo
EAST at 10 knots, tops 45000
LIGHTNING air to air and ai
in the vicinity of the cells.
DIVERTER DELAY/DIVERT RECOMMENDATION RULES
IF
THEN
If estimated holding time is > 60 minutes
DIVERT
If estimated holding time is ≥ available holding time
DIVERT
If estimated holding time ≤ 60 minutes
and
If estimated holding time < available holding time
DELAY
Landing Delay for COS is 70 minutes, therfore ....
RECOMMEND DIVERTING
EXIT

DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: KCOS

Start

Show Attribute Weights

ATC reports severe THUNDERSTORMS on a LINE, 30NM wide by 40NM long located 15NM-WEST of KCOS moving EAST at 10 knots, tops 45000 feet, 0.75IN-HAIL , ICING, LIGHTNING air to air and air to ground, and SEVERE turbulence in the vicinity of the cells.

the weight of ALAMOSA = 296

the weight of PUEBLO = 0

the weight of SANTA-FE = 0

the weight of FARMINGTON = 288

the weight of ALBUQUERQUE = 0

the weight of DENVER = 318

the weight of GRAND-JUNCTION = 0

DIVERTER recommends diverting due to severe weather

DIVERTER recommends the final destination to be DENVER

DENVER 318
ALAMOSA 296
FARMINGTON 288
PUEBLO 0
SANTA-FE 0
List and Compare Airfields
Show Attribute Weights

DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: KCOS

AIRFIELDS

1. DENVER 318
2. ALAMOSA 296
3. FARMINGTON 288
4. PUEBLO 0
5. SANTA-FE 0

Exit

DENVER

ATTRIBUTES FOR DENVER

WEATHER FOR DENVER

"10BKN30OVC4H 300//05 2995 66F"

SAFETY ATTRIBUTES FOR DENVER

DENVER meets approach minimum standards
DENVER safety crew duty time can be met
DENVER enroute traffic has some conflicts
DENVER approach traffic has some conflicts
DENVER runway traffic has no conflicts
DENVER within airspeed safety limits
DENVER no severe turbulence
DENVER is within structural limits
DENVER route would cause light icing
DENVER allows the airplane to be above minimum enroute altitude
DENVER has some aircraft approach landing equipment inoperative

AIRFIELD STATUS ATTRIBUTES FOR DENVER

DENVER has a runway of 8,000 feet or greater
DENVER airport is open
DENVER has a dry runway
DENVER taxiways open
MORE

DENVER

ATTRIBUTES FOR DENVER

DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: KCOS

AIRFIELDS

1. DENVER 318
2. ALAMOSA 296
3. FARMINGTON 288
4. PUEBLO 0
5. SANTA-FE 0

Exit

DENVER

DENVER has an available gate
DENVER has adequate lighting at night
DENVER has instrument condition lighting
DENVER all instrument approach aids operational
DENVER has approach control radar
DENVER has approach control communications
DENVER has tower control communications
DENVER has ground control communications
DENVER has no special operating hours
DENVER has parking space readily available

DENVER meets approach minimum standards
DENVER safety crew duty time can be met
DENVER enroute traffic has some conflicts
DENVER approach traffic has some conflicts
DENVER runway traffic has no conflicts
DENVER within airspeed safety limits
DENVER no severe turbulence
DENVER is within structural limits
DENVER route would cause light icing
DENVER allows the airplane to be above minimum enroute altitude
DENVER has some aircraft approach landing equipment inoperative

AIRFIELD STATUS ATTRIBUTES FOR DENVER

DENVER has a runway of 8,000 feet or greater
DENVER airport is open
DENVER has a dry runway
DENVER taxiways open

DENVER

ATTRIBUTES FOR DENVER

FACILITIES ATTRIBUTES FOR DENVER

DENVER has company parts and maintenance available
DENVER has fire and emergency equipment available
DENVER has suitable stairs readily available
DENVER has power cart readily available
DENVER has relief crew available if required
DENVER has company air transportation to passenger destination
DENVER has good hotel accomodations if greater than a 6 hour layove
r

PASSENGER COMFORT ATTRIBUTES FOR DENVER

DENVER cabin altitude descent rate less than 500 ft/min
DENVER has light turbulence
DENVER route would not require any maneuver above 1 G
DENVER route would require less than a 30 degree bank angle
DENVER route would not require any large power changes

SCHEDULE ATTRIBUTES FOR DENVER

DENVER requires holding pattern of 10 - 20 minutes
DENVER has terminal delay of between 0 and 10 minutes
DENVER has no gate taxi delay
DENVER has no turn around delay
DENVER has departure delays between 0 and 10 minutes
MORE

DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: KCOS

LOCKHEED
NASA – LaRC

AIRFIELDS

1. DENVER 318
2. ALAMOSA 296
3. FARMINGTON 288
4. PUEBLO 0
5. SANTA-FE 0

Exit

FARMINGTON

ATTRIBUTES FOR FARMINGTON

WEATHER FOR FARMINGTON

"10BKN25OVC15 290//10 3008 68F"

SAFETY ATTRIBUTES FOR FARMINGTON

FARMINGTON meets approach minimum standards
FARMINGTON safety crew duty time can be met
FARMINGTON enroute traffic has no conflicts
FARMINGTON approach traffic has some conflicts
FARMINGTON runway traffic has no conflicts
FARMINGTON within airspeed safety limits
FARMINGTON no severe turbulence
FARMINGTON is within structural limits
FARMINGTON route would not cause any icing
FARMINGTON allows the airplane to be above minimum enroute altit
ude
FARMINGTON has all aircraft required landing equipment

AIRFIELD STATUS ATTRIBUTES FOR FARMINGTON

FARMINGTON has a runway of 8,000 feet or greater
FARMINGTON airport is open
FARMINGTON has a slush on the runway
MORE

FARMINGTON

ATTRIBUTES FOR FARMINGTON

DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: KCOS

LOCKHEED
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AIRFIELDS

1. DENVER 318
2. ALAMOSA 296
3. FARMINGTON 288
4. PUEBLO 0
5. SANTA-FE 0

Exit

FARMINGTON

FARMINGTON taxiway to gate closed
FARMINGTON has an available gate
FARMINGTON has adequate lighting at night
FARMINGTON has instrument condition lighting
FARMINGTON ILS, DME, & marker beacon out
FARMINGTON has approach control radar
FARMINGTON has approach control communications
FARMINGTON has tower control communications
FARMINGTON has no ground control communications
FARMINGTON special operating hours are within 10 min. of ETA
FARMINGTON has parking space readily available
FARMINGTON meets approach minimum standards
FARMINGTON safety crew duty time can be met
FARMINGTON enroute traffic has no conflicts
FARMINGTON approach traffic has some conflicts
FARMINGTON runway traffic has no conflicts
FARMINGTON within airspeed safety limits
FARMINGTON no severe turbulence
FARMINGTON is within structural limits
FARMINGTON route would not cause any icing
FARMINGTON allows the airplane to be above minimum enroute altit
ude
FARMINGTON has all aircraft required landing equipment

AIRFIELD STATUS ATTRIBUTES FOR FARMINGTON

FARMINGTON has a runway of 8,000 feet or greater
FARMINGTON airport is open
FARMINGTON has a slush on the runway

FARMINGTON

ATTRIBUTES FOR FARMINGTON

FACILITIES ATTRIBUTES FOR FARMINGTON

FARMINGTON has non-company parts and maintenance available
FARMINGTON has fire and emergency equipment available
FARMINGTON has suitable stairs readily available
FARMINGTON has power cart readily available
FARMINGTON does not have relief crew available
FARMINGTON has no air or surface transportation to passenger dest.
FARMINGTON has poor hotel accomodations if greater than a 6 hour l
ayover

PASSENGER COMFORT ATTRIBUTES FOR FARMINGTON

FARMINGTON cabin altitude descent rate less than 500 ft/min
FARMINGTON has no turbulence
FARMINGTON route would not require any maneuver above 1 G
FARMINGTON route would require less than a 30 degree bank angle
FARMINGTON route would not require any large power changes

SCHEDULE ATTRIBUTES FOR FARMINGTON

FARMINGTON requires holding pattern of 0 - 10 minutes
FARMINGTON has terminal delay of between 0 and 10 minutes
FARMINGTON has no gate taxi delay
FARMINGTON has turn around time of between 30 and 60 minutes
FARMINGTON has no departure delays
MORE

DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: KCOS

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AIRFIELDS

1. DENVER 318
2. ALAMOSA 296
3. FARMINGTON 288
4. PUEBLO 0
5. SANTA-FE 0

Exit

DENVER

ALAMOSA has turn around time of greater than 60 minutes
DENVER has company facilities for unscheduled maintenance
ALAMOSA has no provisions for unscheduled maintenance

DENVER has approach control radar
ALAMOSA has no approach control radar
DENVER has approach control communications
ALAMOSA has no approach control communications
DENVER has company parts and maintenance available
ALAMOSA has no parts and maintenance available
DENVER has suitable stairs readily available
ALAMOSA does not have suitable stairs readily available
DENVER has relief crew available if required
ALAMOSA does not have relief crew available
DENVER has company air transportation to passenger destination
ALAMOSA has surface transportation to passenger destination
DENVER has good hotel accomodations if greater than a 6 hour layove
r
ALAMOSA has poor hotel accomodations if greater than a 6 hour la
yover
DENVER cabin altitude descent rate less than 500 ft/min
ALAMOSA cabin altitude descent rate greater than 2000 ft/min
DENVER route would not require any maneuver above 1 G
ALAMOSA route would require 1 G +- .7G
DENVER route would require less than a 30 degree bank angle
ALAMOSA route would require bank angle between 30 and 60 degre
es
DENVER route would not require any large power changes
ALAMOSA route would require large power changes
DENVER has no turn around delay

ALAMOSA

Comparison of DENVER vs. ALAMOSA

Advantages of ALAMOSA

ALAMOSA exceeds approach minimum standards
DENVER meets approach minimum standards
ALAMOSA enroute traffic has no conflicts
DENVER enroute traffic has some conflicts
ALAMOSA approach traffic has no conflicts
DENVER approach traffic has some conflicts
ALAMOSA route would not cause any icing
DENVER route would cause light icing
ALAMOSA has all aircraft required landing equipment
DENVER has some aircraft approach landing equipment inoperative
ALAMOSA has no turbulence
DENVER has light turbulence
ALAMOSA requires holding pattern of 0 - 10 minutes
DENVER requires holding pattern of 10 - 20 minutes
ALAMOSA has no departure delays
DENVER has departure delays between 0 and 10 minutes
ALAMOSA landing fees are between $100 and $500
DENVER landing fees are greater than $500
ALAMOSA crew duty time is between 10 & 30 mins. less than origina
l dest.
DENVER crew duty time is equal to original destination

DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: KCOS

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NASA - LaRC

AIRFIELDS

1. DENVER 318
2. ALAMOSA 296
3. FARMINGTON 288
4. PUEBLO 0
5. SANTA-FE 0

Exit

DENVER

FARMINGTON scheduled maintenance would cost $1,000 - $5,000
DENVER has company facilities for unscheduled maintenance
FARMINGTON has no provisions for unscheduled maintenance

DENVER has a dry runway
FARMINGTON has a slush on the runway
DENVER taxiways open
FARMINGTON taxiway to gate closed
DENVER all instrument approach aids operational
FARMINGTON ILS, DME, & marker beacon out
DENVER has ground control communications
FARMINGTON has no ground control communications
DENVER has no special operating hours
FARMINGTON special operating hours are within 10 min. of ETA
DENVER has company parts and maintenance available
FARMINGTON has non-company parts and maintenance available
DENVER has relief crew available if required
FARMINGTON does not have relief crew available
DENVER has company air transportation to passenger destination
FARMINGTON has no air or surface transportation to passenger des
t.
DENVER has good hotel accomodations if greater than a 6 hour layove
r
FARMINGTON has poor hotel accomodations if greater than a 6 hou
r layover
DENVER has no turn around delay
FARMINGTON has turn around time of between 30 and 60 minutes
DENVER would require fuel use of less than 1,000 pounds
FARMINGTON would require fuel use of 1,000 - 2,000 pounds
DENVER scheduled maintenance would cost less than $1,000

FARMINGTON

Comparison of DENVER vs. FARMINGTON

Advantages of FARMINGTON

FARMINGTON enroute traffic has no conflicts
DENVER enroute traffic has some conflicts
FARMINGTON route would not cause any icing
DENVER route would cause light icing
FARMINGTON has all aircraft required landing equipment
DENVER has some aircraft approach landing equipment inoperative
FARMINGTON has no turbulence
DENVER has light turbulence
FARMINGTON requires holding pattern of 0 - 10 minutes
DENVER requires holding pattern of 10 - 20 minutes
FARMINGTON has no departure delays
DENVER has departure delays between 0 and 10 minutes
FARMINGTON landing fees are less than $100
DENVER landing fees are greater than $500

ORIGINAL PAGE IS
OF POOR QUALITY

DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: KCOS

LOCKHEED
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WEIGHTS

Safety Attributes
Airfield Status Attributes
Facilities Attributes
Economy Attributes
Schedule Attributes
Passenger Comfort Attributes
Exit

AIRFIELD STATUS WEIGHTS

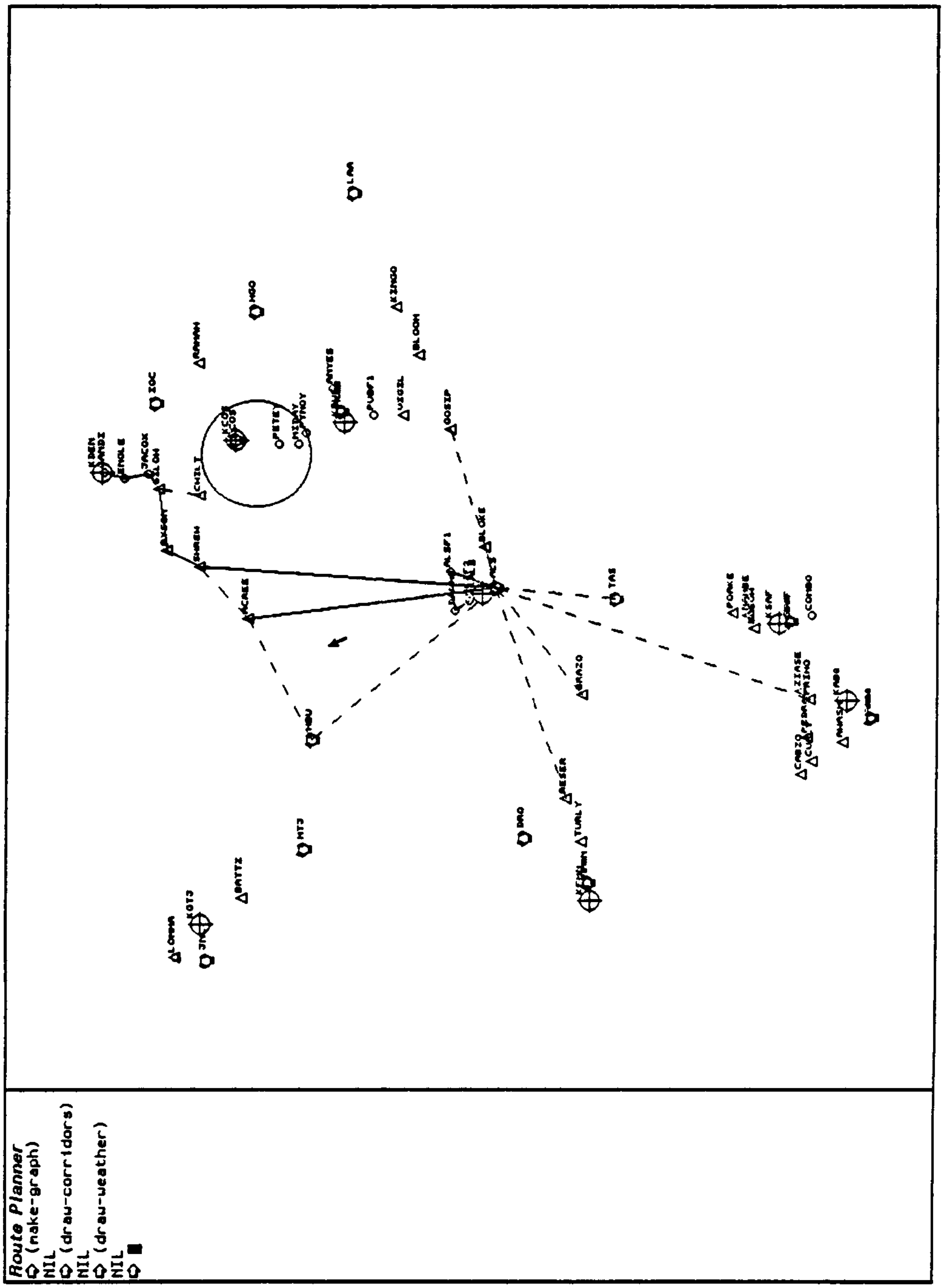
AIRFIELD STATUS CONDITIONS

CONDITIONS	ALS	PUB	SAF	FMN	ABQ	DEN	GJT
Runway Length (ft) < 5000 ft. = 1, 5000 = 5, 6000 = 6, 7000 = 8 , > 8000 ft. = 10	10	10	8	10	10	10	10
Runway Open/Closed Open = 10, Closed = 1	10	10	10	10	10	10	1
Runway Conditions Ice = 1, Slush = 5, Wet or Snow = 7, Dry = 10	10	10	7	5	10	10	10
Taxiway Open to Gate Open = 10, Closed = 2	10	10	10	2	10	10	10
Lighting (dayweather) Yes = 10, No = 2	10	10	10	10	10	10	2
Lighting (night) Yes = 10, No = 2	10	10	10	10	10	10	2

AIRFIELD STATUS WEIGHTS

AIRFIELD STATUS CONDITIONS

CONDITIONS	ALS	PUB	SAF	FMN	ABQ	DEN	GJT
Instrument Approach Aids (weather) ILS & VOR out = 1, ILS, DME, & marker beacon out = 5, ILS & marker beacon out = 6, DME out = 7, Marker beascon out = 8, All operational = 10	10	7	1	5	8	10	6
Approach Control Radar Working No = 5, Yes = 10	5	10	5	10	10	10	10
Approach Control Communications OK No = 5, Yes = 10	5	10	10	10	10	10	10
Tower Communications No = 5, Yes = 10	10	10	10	10	10	10	10
Ground Control Communications OK No = 5, Yes = 10	10	10	10	5	10	10	10
Special Operating Hours Closed win 60 min. of ETA = 1, Closed win 30 min. of ETA = 4, Closed win 10 min. of ETA = 6, Closed win 10 min. of ETA = 9, No Special operating hours = 10	10	10	10	6	10	10	1
Parking Space Available No = 4, Yes = 8	8	8	8	8	8	8	8


Route Planner
(nake-graph)
NIL
(drau-corridors)
NIL
(drau-weather)
NIL

DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: DENVER	RANKED ROUTES DIST-TO-DEST(nm)
Diverterting because of Severe Weather..... Suggests new route to DENVER is ALS-SHREW-BYSON-JACOX-GANDI-KDEN	1.ALS-SHREW-BYSON-JACOX-GANDI-KDEN 164 2.ALS-ACREE-SHREW-BYSON-JACOX-GANDI-KDEN 180 3.ALS-HBU-ACREE-SHREW-BYSON-JACOX-GANDI-KDEN 229 4.ALS-LAA-HGO-RAMAH-IOC-JACOX-GANDI-KDEN 320 5.ALS-LAA-HGO-RAMAH-IOC-GANDI-KDEN 308
DENVER	*DENVER*
THE BEST ROUTES DUE TO WEIGHTING FACTORS ARE: the weight of ALS-SHREW-BYSON-JACOX-GANDI-KDEN = 119 the weight of ALS-ACREE-SHREW-BYSON-JACOX-GANDI-KDEN = 117 the weight of ALS-HBU-ACREE-SHREW-BYSON-JACOX-GANDI-KDEN = 107 the weight of ALS-LAA-HGO-RAMAH-IOC-JACOX-GANDI-KDEN = 113 the weight of ALS-LAA-HGO-RAMAH-IOC-GANDI-KDEN = 111 I just sent waypoints = (ALS SHREW BYSON JACOX GANDI KDEN)	DENVER has been chosen as the destination DIVERTER recommends the route to DENVER to be ALS-SHREW-BYSON-JACOX-GANDI-KDEN

DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: DENVER	RANKED ROUTES / DIST-TO-DEST(nm)
Diverterting because of Severe Weather..... Suggests new route to DENVER is ALS-SHREW-BYSON-JACOX-GANDI-KDEN	1.ALS-SHREW-BYSON-JACOX-GANDI-KDEN 164 2.ALS-ACREE-SHREW-BYSON-JACOX-GANDI-KDEN 180 3.ALS-HBU-ACREE-SHREW-BYSON-JACOX-GANDI-KDEN 229 4.ALS-LAA-HGO-RAMAH-IOC-JACOX-GANDI-KDEN 320 5.ALS-LAA-HGO-RAMAH-IOC-GANDI-KDEN 308
ALS-SHREW-BYSON-JACOX-GANDI-KDEN	ALS-SHREW-BYSON-JACOX-GANDI-KDEN
ATTRIBUTES FOR ALS-SHREW-BYSON-JACOX-GANDI-KDEN SAFETY ATTRIBUTES light enroute weather no enroute traffic no approach traffic conflicts runway traffic conflicts within A/S limits within A/C icing parameters above MEA AC maintenance no factor PASSENGER COMFORT ATTRIBUTES cabin descent rate less than 500 ft/min virtually no turbulence no maneuver above 1 G less than 30 degree bank I just sent original alternate message	ATTRIBUTES FOR ALS-SHREW-BYSON-JACOX-GANDI-KDEN SCHEDULE AND ECONOMY ATTRIBUTES holding < 20 mins. wind effects < orig. dest. costs meets time slot +- 5 seconds shortest approach descent distance ROUTING ATTRIBUTES enroute descent to straight in restricted area < 5 min. add. time military ops areas no extra time no climb required no climb required for emergency no descent until 2-5 mins. out due to terminal area restrictions

DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: DENVER

List and Compare Airfields
Select In-flight Problem
Show Attribute Weights

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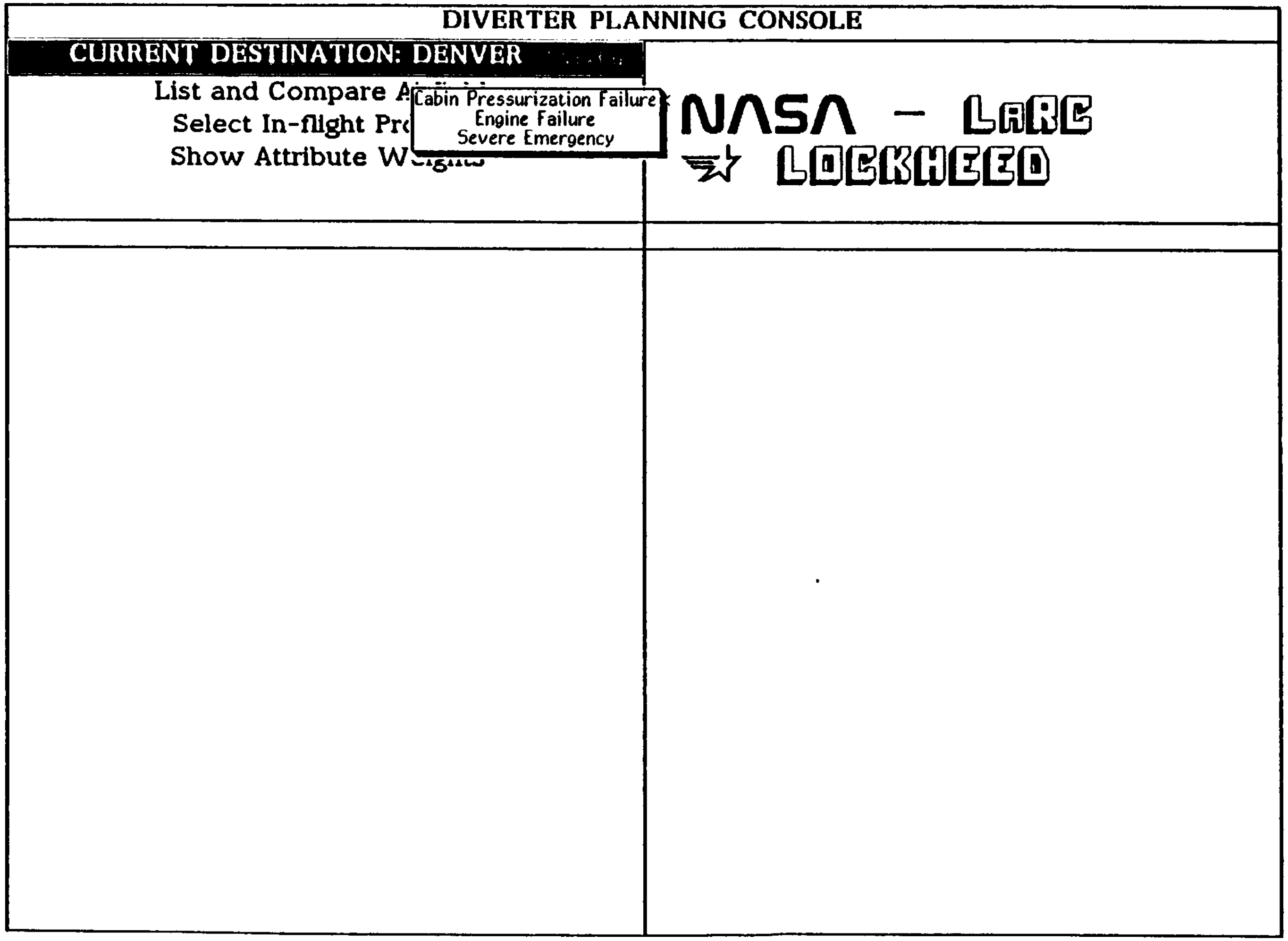
The new waypoint info is ((ALS 105 49 37 21 72 48 35000) (SHREW 105 40 39 10 4 109 35000) (BYSON 105 32 39 22 27 14 29000) (JACOX 104 5 4 39 29 76 30 10000) (GANDI 104 53 39 45 3 16 7500) (KDEN 104 53 39 46 0 1 5333))

PILOT ROUTE CHOICE:
ALS-SHREW-BYSON-JACOX-GANDI-KDEN


DIVERTER PLANNING CONSOLE
CURRENT DESTINATION: DENVER
List and Compare A
Select In-flight Pr
Show Attribute W
Cabin Pressurization Failure
Engine Failure
Severe Emergency
NASA - LaRC
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DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: DENVER	RANKED ROUTES DIST-TO-DEST(nm)
Diverterting because of Cabin Pressurization Failure..... Suggests new route to DENVER is ALS-BLOKE-GOSIP-BLOOM-KINGO-HGO-RAMA H-IOC-GANDI-KDEN	1.ALS-BLOKE-GOSIP-BLOOM-KINGO-HGO-RAMAH-IOC-GANDI-KD 2.ALS-GOSIP-PUB-COS-IOC-ENGLE-GANDI-KDEN 212 3.ALS-GOSIP-PUB-IOC-ENGLE-GANDI-KDEN 208 4.ALS-HBU-CHILT-SILOW-JACOX-KDEN 239
the weight of ALS-HBU-CHILT-SILOW-JACOX-KDEN = 0 the weight of ALS-GOSIP-PUB-IOC-ENGLE-GANDI-KDEN = 0 the weight of ALS-GOSIP-PUB-COS-IOC-ENGLE-GANDI-KDEN = 0 the weight of ALS-GOSIP-KINGO-HGO-IOC-ENGLE-GANDI-KDEN = 107 The new plan has been calculated I just sent waypoints = (ALS BLOKE GOSIP BLOOM KINGO HGO RAM AH IOC GANDI KDEN)	Re-calculating current route due to failure of PRESSURIZATION SYSTEM DIVERTER recommends the route to DENVER to be ALS-GOSIP-KINGO-HGO-IOC-ENGLE-GANDI-KDEN Route planning optimized, DIVERTER recommended route to DENVER now is ALS-BLOKE-GOSIP-BLOOM-KINGO-HGO-RAMAH-IOC-GANDI-KDEN This route has a total distance of 295 nautical miles This route was calculated based on : MAX ALTITUDE allowed AIRCRAFT STATUS ENVIRONMENT status DISTANCE

DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: DENVER

List and Compare Airfields
Select In-flight Problem
Show Attribute Weights

NASA - LaRC
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The new waypoint info is ((ALS 105 49 37 21 72 48 35000) (GOSIP 104 34 37 38 74 62 35000) (PUB 104 25 38 18 10 41 35000) (IOC 104 20 39 26 3 68 29000) (ENGLE 104 56 39 38 294 30 9000) (GANDI 104 53 39 45 18 7 7500) (KDEN 104 53 39 46 0 1 5333))

PILOT ROUTE CHOICE:
ALS-GOSIP-PUB-IOC-ENGLE-GANDI-KDEN

DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: ALAMOSA	RANKED ROUTES DIST-TO-DEST(nm)
Diverterting because of Severe Emergency..... Suggests new route to KALS is ALS-ALSF1-DANNE-ALSF2-KALS	1. ALS-ALSF1-DANNE-ALSF2-KALS 92
The new plan has been calculated I just sent waypoints = (ALS ALSF1 DANNE ALSF2 KALS)	Re-calculating current route due to a SEVERE emergency Route planning optimized, DIVERTER recommended route to KALS now is ALS-ALSF1-DANNE-ALSF2-KALS This route has a total distance of 92 nautical miles This route was calculated based on : AIRCRAFT STATUS ENVIRONMENT status DISTANCE MAX ALTITUDE

DIVERTER PLANNING CONSOLE

CURRENT DESTINATION: ALAMOSA

List and Compare Airfields
Select In-flight Problem
Show Attribute Weights

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The new waypoint info is ((ALS 105 49 37 21 72 48 29000) (ALSF1 105 42 37 38 18 18 16400) (DANNE 106 0 37 36 262 14 10000) (ALSF2 105 55 37 31 142 6 10000) (KALS 105 52 37 26 155 6 7535))

PILOT ROUTE CHOICE:
ALS-ALSF1-DANNE-ALSF2-KALS

NASA National Aeronautics and Space Administration

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15. Supplementary Notes

Langley Technical Monitor: George G. Steinmetz
Technical Representative of the Contracting Officer: Cary R. Spitzer
Final Report - Task 4

16. Abstract

It was determined that a system to incorporate artificial intelligence into airborne flight management computers is feasible. The AI functions that would be most useful to the pilot are to perform situational assessment, evaluate outside influences on the contemplated rerouting, perform flight planning/replanning, and perform maneuver planning.

A study of the software architecture and software tools capable of demonstrating Diverter was also made. A skeletal planner known as the Knowledge Acquisition Development Tool (KADET), which is a combination script-based and rule-based system, was chosen and used to implement the system. A prototype system was developed which demonstrates advanced in-flight planning/replanning capability.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
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