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MOCA—A Knowledge-Based System for Airline Maintenance Scheduling

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American Airlines currently operates in excess of 550 aircraft and flies over 2200 scheduled flights a day to over 160 destinations worldwide. Maintenance planning in a route network of American's magnitude is a complex, decision-intensive task that is managed at the Maintenance Operations Center (MOC) in Tulsa, Oklahoma.

The employees in this center are responsible for planning all maintenance on aircraft owned or leased by American Airlines. This planning problem grows in complexity with the dynamic nature of American's fleet: On average, an aircraft remains on its current routing for only one to three days before a change in the routing occurs. The aircraft routing might change as a direct result of weather, crew constraints, unanticipated maintenance, air traffic control restrictions, or other events. Making certain that all aircraft receive their maintenance on time in such a dynamic environment is a difficult and time-consuming task.

American's fleet is heterogeneous by nature, with aircraft of multiple types from multiple vendors. These aircraft are split into two body types (wide and narrow) and are organized into four distinct groupings (or subfleets) for the purpose of maintenance scheduling. These subfleets are managed at “desks” within the operations center and are organized as follows:

MD-80 Desk:	All McDonnell Douglas Super-80 aircraft
727 Desk:	All Boeing 727-100 or 200 model aircraft
Wide-Body Desk 1:	All McDonnell Douglas DC-10 models
Wide-Body Desk 2:	All Boeing 767, 757, and AirBus models

The process of routing aircraft for maintenance has evolved over the years but until recently was still a manual process, involving many large paper documents, that was the responsibility of the Maintenance Operations Center controllers. Historically, as a desk grew, the operation center had to add controllers to route the aircraft. The MD-80 fleet, which was American’s first pure fleet and was planned to be over 200 aircraft, was projected to grow too large for the controllers to manually route the aircraft. It would have been difficult to further divide the fleet without adding personnel, possibly lowering productivity in the area, and increasing the exposure of unskilled controllers.

The automation approach chosen was to build an expert system application called the maintenance operations controller adviser (MOCA). MOCA is a knowledge-based system that automates the previously manual planning and document maintenance (paperwork) tasks. MOCA was implemented as an operational system in April 1990 for the MD-80 desk. A 727 implementation is targeted for mid-1991, with wide-body implementations planned by the end of 1991.

Operational Environment

The Maintenance Operations Center comprises several different organizations, numerous telephones, speakers, paper documents, and people, all performing their part of a global task to safely route aircraft for maintenance requirements. Figure 1 presents a high-level overview of the center’s current environment.

The grey shaded area in the figure represents the span of control of the controller and the decisions and data elements contained within this span. This environment is described in the following sections. Each section refers to pre- and post-MOCA implementations.

The FOS System

The flight operations system (FOS) is a near real-time transaction-processing system that contains all information pertinent to the daily airline operation. FOS is used to control, communicate, and track the execution of the daily plan. This system maintains information such as flight schedules, maintenance information, and aircraft assignments.

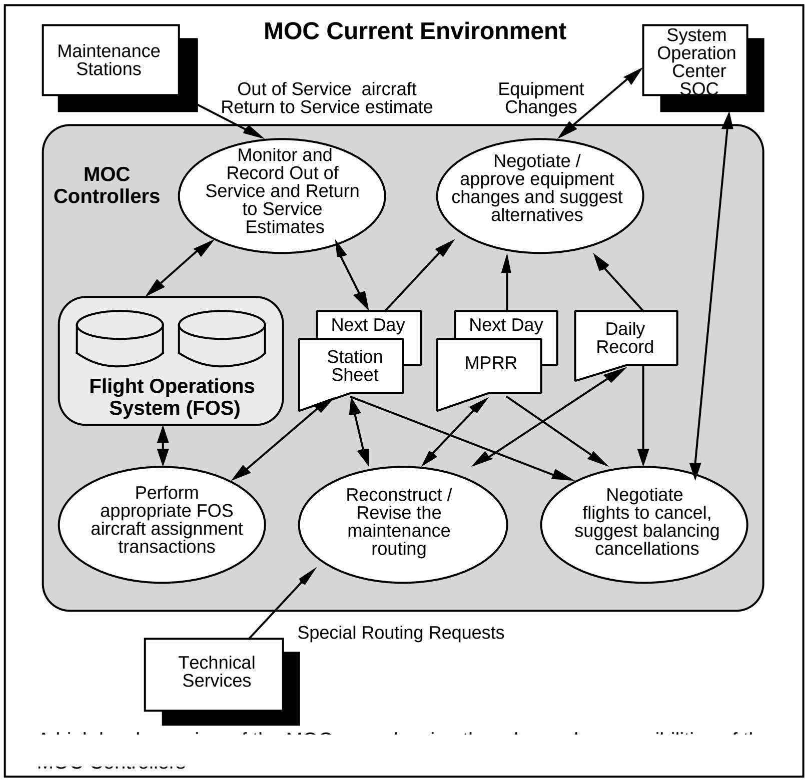

Figure 1. Overview of Current Maintenance Operations Center Environment.

MOCA connects to, receives data from, and sends data to FOS. The method in which this communications link is established is detailed in System Architecture.

Paper Documents

Hard-copy documents were heavily relied on to perform the tracking and planning functions performed by the maintenance operation controllers. The paper documents are replicas of the information that could be retrieved through transactions from the FOS system. The paper documents are described in the following subsections.

Station Sheets. The *station sheets* are large double-sided documents that represent the current aircraft routings by fleet type for all flights flown in a single day. The MD-80 desk maintains two sets of sheets, one for the current day and one for the next day. The station sheets are organized by stations-cities, showing inbound flight number, date and time, aircraft assigned, a maintenance indicator if the aircraft is on a routing, next sequence of flights to fly, outbound flight number, date, and departure time.

The controllers use these sheets to monitor the status of all aircraft and flights flown throughout the day. Special indicators show which aircraft are currently on maintenance-planned routings. All changes or events that occur during the day must manually be updated on the station sheets. It is common to change over 30 percent of the information on these sheets each day.

MOCA electronically automates the station sheets in the form of periodic updates from FOS and controllers' acceptance of routing alternatives that were created by MOCA. This task alone can save the controllers one to three hours of work during an eight-hour shift, depending on the work load. The automation of this task is achieved through an interactive user-friendly interface.

MPRR. The *maintenance planned routing record* is used to indicate the planned routing for all the aircraft that are currently planned for maintenance within the next seven days.

Prior to MOCA, the controllers would manually find valid routings when planning an aircraft for maintenance. Once a valid route was found, it would be written on this routing record. Changes affecting the routing would necessitate manually rerouting the aircraft for maintenance as well as manually erasing the old routings and writing the new routing on the sheets of the maintenance planned routing record.

MOCA automates the task of maintaining the routing record by automatically generating it as maintenance routings created by MOCA are accepted by the controllers. Planned routings that are dynamically affected are automatically deleted from the record by MOCA. The automation of this task allows the controllers to maintain routings for as many as seven days instead of the previous three to four days with the manual method.

Daily Record. The *daily record* is used by the controllers as a snapshot of the current planned maintenance events. This sheet shows the terminating station-city for this night by aircraft and whether the aircraft is currently on a planned maintenance routing. Changes to an aircraft routing were also manually maintained by the controllers prior to MOCA. MOCA automates this task by dynamically updating the daily record as changes are made in the system.

Higher Ops. A fourth document, not shown in figure 1, is a weekly computer printout referred to as the *higher ops*, which lists all maintenance requirements for aircraft and the type of maintenance to be performed. Maintenance routings are generated based on the requirements listed in the higher ops document. Requirements includes both routine and nonroutine maintenance. MOCA currently automates the higher ops sheets for the most important routine maintenance associated with the aircraft type.

Note: All paper documents previously used in the Maintenance Operations Center were replaced by the MOCA system with the exception of the higher ops.

Controller Tasks

The ovals shown in figure 1 represent some of the daily tasks handled by the controllers. The arrows in the figure represent analysis of information on the paper documents or in FOS to make the appropriate decisions.

Each day, the controllers must plan new routings for aircraft; replan maintenance routings that were affected; and react to dynamic events such as weather, delayed flights, cancellations, out-of-service aircraft, or other scheduling-related problems. Any or all of these dynamic events can cause problems to the current planned routings of the aircraft. As much as 75 percent of the fleet can be on some type of maintenance routing. On an average day, a controller needs to route approximately 60 to 100 aircraft on the MD-80 desk. When routings are modified from the aircraft's current route, changes must be made in FOS; prior to MOCA, these changes were made on the paper documents.

For example, if a severe weather problem was affecting one of the major airports, the controller might not be able to manually maintain all the routing changes for the next seven days. Many of the paper documents become unusable, and the controller is forced to use the first route found that satisfies the maintenance requirement rather than continue to look for a near-optimal solution. If the routing is not needed in the next one or two days, it can be deferred until there is enough time to perform all the routing changes. MOCA allows the controllers to maintain their routings for as many as seven days and create new routings much faster than previously possible during irregular operations.

External Influences

The boxes outside the grey shaded area in figure 1 represent other operating entities of the airline that affect the maintenance routings created by the Maintenance Operations Center.

The Systems Operation Center is responsible for the daily operation of the airline. The dispatchers working in this environment have the final word on events that affect the daily operation of the airline. For example, if weather problems at the Dallas–Fort Worth (DFW) Airport affect the number of takeoffs and landings that can occur, the dispatchers in this center are responsible for determining which flights to divert to other airports or cancel.

Operational problems accumulate and cause problems for the maintenance operation controllers because the aircraft that are affected in the more global running of the airline might be on maintenance routings. These aircraft would have to be replanned by the controllers to ensure maintenance is received. The system and maintenance operation centers communicate constantly in trying to minimize disturbances and maintain the most effective combinations of routings. MOCA has been a tremendous benefit to both centers for irregular operations, assisting in determining which would be the best aircraft to use for a particular flight and which aircraft are not currently assigned to a flight in an airport.

Project Justification

Several attempts had been made to automate this process of planning aircraft for maintenance using traditional operation research and conventional programming techniques. All these attempts were unsuccessful because of the complexity of the problem. A prototype system built over a three-month period from December 1987 to February 1988 successfully validated that a knowledge-based system approach could be used to solve the planning problem. The functions demonstrated accounted for about 10 percent of the total solution.

The prototype was followed by an additional feasibility study beginning in late February 1988 and continuing through April. The feasibility study determined the time frame, personnel, and best approach required to build the MOCA system. It was decided that because of the growth plan of the airline and, specifically, the MD-80 fleet, that the knowledge systems group at American Airlines should first address building a solution for the MD-80 desk followed by phased-in approaches for the other fleets.

The project was fully funded as an operational necessity required to successfully maintain the current growth plan of the airline. A cost-benefit analysis showed that not having to hire additional personnel could, alone, over a five-year period pay for the system. In addition, the manual process was clearly becoming overwhelming, even for the most qualified maintenance operation controllers.

The feasibility study also defined two potential improvements that the system could provide for the current operation: (1) a reduction in the number of *flight breaks* (switching two aircraft assigned to direct flights at an intermediate station) that were scheduled by the controllers and (2) an increase in the *yield* (a comparison of the time remaining to perform a maintenance check with the time allowed to perform this check) for maintenance checks.

The feasibility study clearly indicated a knowledge-based system was a good approach to solving the controllers' planning problem. Three other factors were involved in the decision:

First, a knowledge-based system solution would add consistency to the controllers' decision-making process. Knowledge acquisition allowed us to capture the heuristics of the best controllers in regard to routing aircraft for maintenance. A better standard could be maintained and implemented by the knowledge-based system.

Second, a knowledge-based system could broaden the decision-making parameters. A computer can more easily generate thousands of potential routes for planning aircraft for maintenance routings. Even the best controllers often stopped once a valid solution was found.

A knowledge-based system approach with a user-friendly, reliable, and interactive interface automates the routine aspects of the controllers' jobs. Automating the manual paperwork process allowed the controllers to save many hours of propagation work: copying, erasing, and modifying information on the paper documents when changes were necessary.

System Description

The MOCA project was divided into a set of modules, each responsible for its own unique function. Figure 2 shows a functional diagram of the MOCA system. The MOCA solution was provided by tightly integrating the modules, providing the following functions:

First is FOS communications and database access, including provisions for terminal emulation, system initialization, and recovery.

Second is daily plan generation and maintenance. This module controls the startup and initialization of the knowledge base, the parsing of the data into structures, the update mechanism, and the initial generation of the aircraft normal routings.

Third is the *planning module*, which is responsible for the resolution of all planning goals presented to it.

Fourth is the *dynamic changes module*, which is responsible for resolving problems with the aircraft routings caused by System Operations Center requests, canceled flights, *out-of-type events* (using aircraft from a different fleet type), or special maintenance requests.

Fifth is the *impact analysis module*, which suggests a list of possible solutions and an explanation of the differences between solutions when routing aircraft for maintenance.

Sixth is the user interface, which presents the information to the user and allows the user to input and request information from the knowledge base, including hard-copy capabilities.

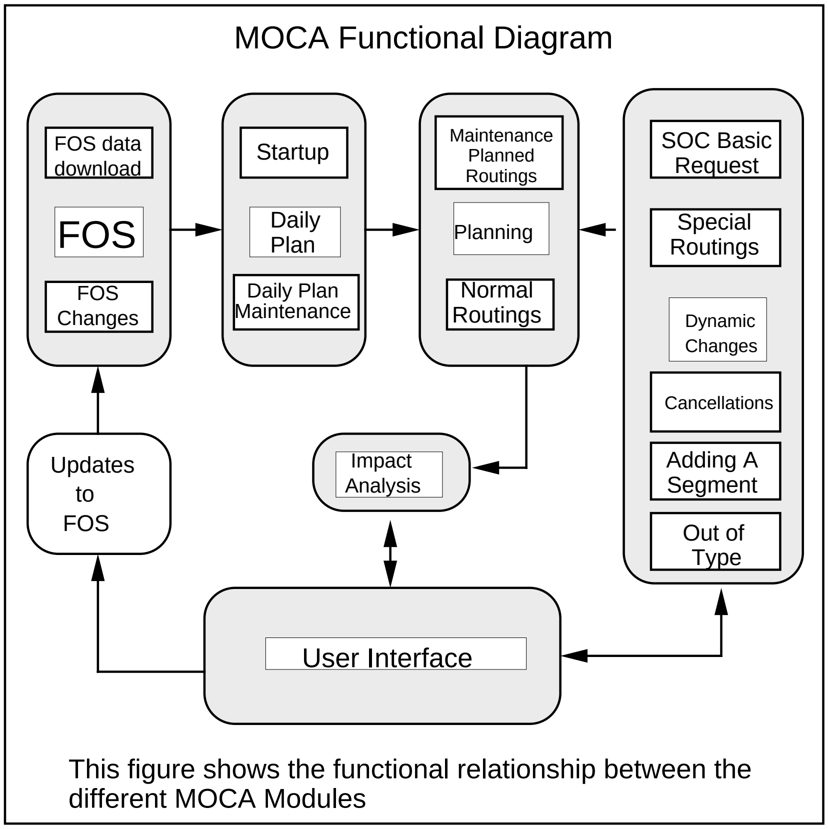

Figure 2. The MOCA System.

System Architecture

This section describes the MOCA system architecture. We discuss the hardware and software environment, the FOS connectivity and data access, the local database, the user interface, and planning.

Hardware and Software Environment

MOCA was developed on the Texas Instruments MicroExplorer workstation, using ART from Inference Corporation. The MicroExplorer is built on a Macintosh II, using an additional Lisp coprocessor board. The Macintosh was connected to FOS through a specialized communications board developed for American Airlines.

FOS Connectivity

Perhaps the most challenging function provided on the system integration side was physically connecting a Macintosh with a Lisp coprocessor board to the transaction-processing facility host-based environment. The following tasks were completed for the MOCA project:

We used an AirLine Control (ALC) connectivity board to connect the Macintosh II to the host transaction-processing facility. The ALC board was supplied by Innosys and was in its beta form at the start of the project. The board would reside on a gateway machine, allowing 16 other devices to connect to the host through the gateway machine. This same board would also provide SABRE terminal emulation on the Macintosh II platform. The ALC board provided a hardware and software solution, allowing the 6-bit ALC protocol on the host transaction-processing facility to be converted to an 8-bit protocol on the Macintosh side, with additional low-level error checking being performed.

An application was written allowing the Macintosh to communicate, send, and retrieve information through the buffer on the gateway machine. This application was written in C and ran on the Macintosh processor as opposed to the Lisp coprocessor. Finally, remote procedure calls from the MicroExplorer Lisp side and the communications application allowed the data to be parsed and asserted into the MOCA knowledge base.

Access to FOS Data

A mechanism was built that allowed a large data source to be retrieved from the host system and maintained on the local Macintosh machine. A time-stamping mechanism was also required, only allowing updates of changes to the requested data from FOS to be sent since the last time stamp.

Two special transactions were written in the transaction-processing facility that allowed a calling application to request flight-specific or aircraft-specific data from the host transaction-processing system.

MOCA sends a request to receive the initial flight- and aircraft-specific data downloaded during system initialization. It then periodically sends a request with a time stamp to receive all data that have changed since the last update.

The download and update mechanism greatly reduces the number of transactions that would typically have been sent to the transaction-processing host because the same data are on the local machine and can be accessed through the user interface. Prior to MOCA, hundreds of transaction-processing facility transactions were requested each day by each controller.

Local Database

MOCA maintains a local in-core data store that is both a subset of the

FOS database and an extension, providing additional data required for the user interface and planning capabilities. This local data store contains the information MOCA uses to present the current state of the MD-80 fleet to the user as well as all information needed to route aircraft. At program initiation, MOCA downloads seven days of flight data from FOS as well as data on all aircraft within the fleet. During operation, MOCA receives updates from FOS every five minutes that consist of all modifications made to the FOS database that affect any record previously downloaded, for example, updated flight status, departure times, or aircraft flying hours.

User Interface

The man-machine interface automated a complex task by using a highly interactive, yet easy-to-use mouse-driven interface. The user interface consists of over 20 tables of information, allowing the user to browse through different views of the information contained in the local database.

The user interface was designed and built to be reliable, interactive, and user friendly. The data displayed on the screen are automatically changed as an update from FOS makes modifications. The users are presented with the information on overlaying tables that were specifically designed to optimize the amount of data shown but maintain the related tables that are required for simultaneous display. The users can modify several of the tables to obtain information about the fleet in multiple ways, allowing the user maximum utility from the displays.

Flexibility became more evident as the system was initially rolled out. The users gave feedback to the knowledge engineers on ways to improve the type of information they wanted to see displayed on the screen (sorting data, viewing information through multiple approaches, and so on, became important to the users). Because the data are available through the knowledge base, the knowledge engineers were able to build accessor functions that display different views of the data to the users.

Planning

Each aircraft within the fleet has requirements for scheduled and unscheduled (routine and nonroutine) maintenance and is assigned to fly a particular set of routes. It is the responsibility of the Maintenance Operations Center controller to make certain that all maintenance requirements for each aircraft are met, making changes to the routing of the aircraft if necessary.

This task requires the ability to generate aircraft routings in a rapidly changing, dynamic environment. MOCA uses a modified A* search algorithm to search the state space of all possible routing combinations looking for a minimal cost solution. This technique was chosen because it can find solutions quickly and efficiently, even when the search space is large, as is the case with the set of all routes that a fleet of aircraft might fly.

The planning module seeks to model the objects and relationships that are necessary for the controller's task of routing aircraft. The objects modeled include aircraft, flight leg segments, maintenance capabilities, requirements and assignments. Each database object is implemented as a Lisp structure. Garbage-free data structures were created for all objects to reduce the need for MOCA to interrupt processing to reclaim garbage memory.

MOCA maintains a list of aircraft that need planning for maintenance, which is displayed to the controllers through the user interface. From this list, the controller selects an aircraft to plan. MOCA then sets up an internal list of tasks it must perform called *planning goals*. These goals correspond to the maintenance requirements of the basic data model. An example goal might be to find a route that will get an aircraft to the Chicago O'Hare (ORD) airport for a B-check within three days.

The A* search utilizes a best-first methodology to apply the most promising routing modification operators to the current state of the database to arrive at a solution based on the current set of goals. An example state-space search operator would be to swap two aircraft (placing one on the other aircraft's outbound flight) when their routings meet each other at approximately the same time in the same station. The application of this operator might allow the aircraft to satisfy its maintenance requirement goal, or additional or alternative operators can be applied. A cost-estimating function is applied against each of the operations available to determine the lowest-cost operator to apply. Examples of costing parameters used in the search include overnight ground time, early or late termination in a station, early or late origin, delay, overbooking of maintenance capabilities, or use of spare aircraft to satisfy a routing. All these costs can affect the routing solution.

Each modification to the database through the use of these operators creates a new child state within MOCA. The new state is identical to the parent state in every way except for the modifications made by applying the operator. Each new state is evaluated, and the lowest-cost operators are applied to the current state until all the planning goals are satisfied. If an operator can be applied to a previously generated state that results in a lower cost, MOCA redirects its search to the other state.

A simple example of the use of the planning algorithm is shown in figure 3. The initial state contains the routings for aircraft 400 and 401. A goal was generated to find a route to get aircraft 400 to Chicago O'Hare (ORD) for maintenance. The child state, or swap state,

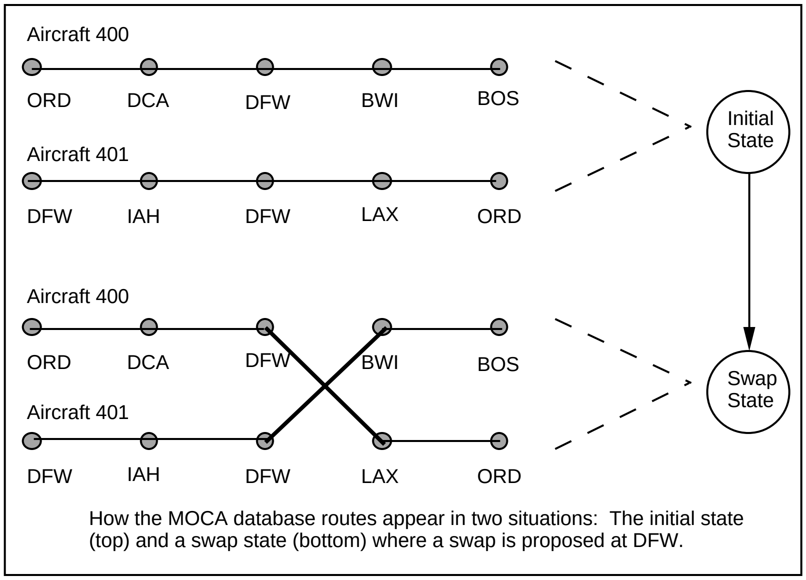

Figure 3. The Use of the Planning System: An Example.

demonstrates a swap operator being applied to the two aircraft at the Dallas-Ft.Worth (DFW) airport. The goal is now satisfied because aircraft 400 will be at ORD.

When MOCA determines a suitable solution to the current planning goal, the proposed routing is presented, along with the current routing, for the user's approval. The user can elect to have MOCA continue to search for additional routings that satisfy the planning goals or can select any of the generated solutions for acceptance.

The basic routing heuristics used in the planning algorithm are not likely to change significantly. However, the cost associated with the operators used in the search could change, and these changes were anticipated by making the object representation for the costing functions modifiable. An extension of the user interface could be added to allow the users to modify the cost associated with key operators, such as flight breaks and delays.

Deployment

Several factors directed the approach for deploying the MOCA system for use by the maintenance operation controllers. First, the users were not computer literate. Over 80 percent of the controllers were unfamiliar with a mouse or a window-oriented interface. Second, the system was going to automate the manual process currently in place. Third, it was difficult to get dedicated training time with the controllers outside normal working hours because of shift rotation and overtime allotment. Fourth, inadequate test systems in place at American Airlines did not allow sufficient testing of each incremental release of the system. The combination of these four items required a phased-in approach, with a lot of cooperation from the controllers. Complete deployment of the system took several months, in the phases described in the following paragraphs:

Phase 1: The first phase of training replaced the current ICOT, or dumb, terminal with a Macintosh II with a 19-inch monitor running an ICOT terminal emulation program. This step allowed the controllers to become familiar with the look and feel of the screen, keyboard, and, most importantly, the mouse without greatly affecting their daily job functions. Each controller was given a two-hour overview of the terminal emulation software, including the execution of the program, windowing features, use of the mouse, and function-key definition. The controllers used the terminal emulation software for several months before MOCA went into operation.

Phase 2: The second phase involved placing a functional version of the MOCA software on the Macintosh II, allowing the controllers to browse through the functions provided by the MOCA system. The controllers went through 3 two-hour sessions with knowledge engineers to become familiar with the different browsing capabilities. This process involved coverage 24 hours a day for 1 week by the knowledge engineers in the Maintenance Operations Center to answer questions.

Phase 3: During the third phase, the controllers made aircraft assignments through MOCA. This step allowed them to link 1 or 2 aircraft to different outbound or originating flights. This step also required 24-hour coverage for a 1-week period.

Phase 4: The final phase of training involved a 1-day class on the planning functions of the MOCA system, including distribution of user manuals to all the controllers. This training was followed by 6 weeks, 24 hours a day, of on-the-job training for the controllers. The knowledge engineers worked directly with the controllers to convert the process from manual to automated.

This phased-in approach allowed the knowledge engineers to modify or extend the features of the system as requirements changed or as extensions were needed for successful operation and deployment. During each of these phases, occasional bug fixes to the operational system were made when errors occurred.

The controllers now use the system 24 hours a day, 7 days a week, to perform the entire planning process. On an average day, the controllers can plan or replan more than 60 aircraft.

User Acceptance

It was important to the success of the project that the controllers felt they had a tool that was both easy to use and solved their problem. The amount of experience of the controllers in routing aircraft varied from several months to many years. Not many of the controllers trained for the MD-80 desk were familiar with a window-oriented, mouse-driven interface.

The MOCA system was required to provide the following capabilities:

First, it must be as easy to use MOCA as it is to manually perform the task. This capability could only be proven over time as the controllers began to realize the true impact and benefits of the system. The system was designed and built around the idea that the manual propagation with the paper documents would be avoided with the MOCA system.

Second, the system must be reliable. The FOS system operates with greater than 99 percent reliability and was almost always available to the controllers. MOCA provides a similar reliability and is available to the controllers when FOS is not operational.

Third, maintenance-planning solutions must be provided in a timely manner. Much of the acceptance of the MOCA system depended on the amount of time MOCA took to find a valid route. The controllers required that MOCA be able to route aircraft fast enough to maintain the fleet in the worst periods of operations (for example, severe weather operations). Response time has been adequate and continues to improve. By automating many of their manual operations, MOCA has provided the controllers with more time to handle irregular operations.

Fourth, the solutions provided must be equal in quality to the routings provided by the controllers. About 95 percent of the first routes found while routing A-checks (the most common routine maintenance check) in MOCA are accepted by the controllers today. Additionally, the MOCA system has not missed any routine maintenance since it was implemented.

Fifth, the system must be able to handle data-consistency problems. The FOS database contained inconsistencies such as flights without aircraft assigned, two aircraft assigned to the same flight, and disjointed flight segment connections. MOCA has been able to maintain a consistent and complete local database despite these problems. MOCA is able to react to external events such as cancellations, diversions, and so on, sometimes even before the Maintenance Operations Center is contacted by the System Operations Center or the maintenance bases.

To summarize, MOCA allows the controllers to view their world in a much more consistent manner. They have access to many different views of the current operating environment with a single keystroke or click of the mouse. The controllers feel they have a system that does indeed solve and, in some instances, go beyond the initial business requirements. Most importantly, the controllers are using the system.

Innovations

The MOCA project was innovative in its approach, and its success is significant to both the AI industry and American Airlines Sabre Computer Systems. The following paragraphs summarize the significant innovations.

Other techniques in both operations research and conventional programming approaches had failed. MOCA was American Airlines' first use of AI techniques to route aircraft within the company.

The Maintenance Operations Center is considered a mission-critical, mainstream business function within the airline. Using AI technologies such as a data-directed, best-first search and a tightly integrated graphic interface, MOCA has allowed American to enhance its efforts by automating its maintenance operations.

By using an efficient search algorithm, MOCA is able to evaluate more potential solutions than the controllers in a shorter amount of time. MOCA provides a higher level of consistency for the planning problem. The system is also able to provide multiple exchanges of aircraft routings (multiple swaps), which is difficult for a human to do because of the increased information that must be evaluated and maintained.

The system would not have been able to successfully perform without a highly interactive, user-friendly means to determine the current status of all aircraft and flights within the fleet. This interface had to be integrated into the planning capabilities to allow the controllers to browse through the current status of the fleet while MOCA provided modifications to the current routings.

MOCA was also innovative within the Sabre Computer Systems organization in that it solved some difficult system integration problems, including connecting a Lisp-based machine to a transaction-processing facility and maintaining a large data source of information on the local machine.

Benefits

First and foremost, MOCA's successful implementation allowed the American Airlines fleet to grow and the Maintenance Operations Center to better address its planning problem. The controllers themselves believe MOCA is capable of routing aircraft more consistently and efficiently than previously routed using the manual method, especially during adverse or irregular operations.

Besides the benefit of eliminating all paper documents, which has saved the controllers many hours of labor, MOCA has had an impact on the operation of the airline in three other distinct areas:

First, the system has resulted in a reduction in the number of flight breaks. Flight breaks occur when an aircraft has to deviate from its normal operating schedule to satisfy some other external constraint. Some of the reasons for a flight break include air traffic control delays, crew scheduling problems, cancellations or diversions because of weather, or maintenance-related problems with the equipment. The airline understands that flight breaks cause a significant delay in the normal operation of the airline. The airline must react to such problems as additional baggage and freight handling, passenger connections, and crew changes. All these factors increase the cost of providing the daily service.

In regard to MOCA, the controllers have expressed that when planning an aircraft for its maintenance routing, there is a significant reduction in the number of scheduled flight breaks. This reduction can primarily be attributed to the fact that MOCA can view many more possible swap alternatives than the human controller.

Second, the system has produced an increase in the *A-check yield* (the average number of hours the aircraft flies before receiving its next A-check). Since April 1990, the A-check yield for the MD-80 fleet has increased by about 10 percent. Increasing the yield should allow the Maintenance Operations Center to perform more maintenance checks without having to add additional personnel.

Third, the system has allowed the size of the fleets handled by the Maintenance Operations Center to grow without proportionately increasing the amount of personnel. Prior to MOCA, plans called for the implementation of seven controller desks by the end of 1992. Each desk would require a minimum of three full-time people and one vacation relief person to be trained in the area. With MOCA, it is realistic to keep the Maintenance Operation Center at its current staffing of four desks.

Summary

Using AI technologies, MOCA has allowed American Airlines to expand its operations by automating a critical business operation that had become increasingly complex and people intensive. Operating a well-maintained fleet of aircraft while providing outstanding service to its customers is the highest priority for American. Without the assistance of an automated computer system, the controllers would have had a more difficult time in providing all the routings necessary for the expansion of the MD-80 fleet. MOCA is able to provide new routings and maintain consistency with the existing routings. In addition, MOCA uniquely combines this routing capability with an interactive, user-friendly means of determining the current status of all aircraft and flights within the fleet. This combination has provided a mission-critical system that operates in real time at the heart of American Airlines' business.

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