MAINTENANCE RESOURCE MANAGEMENT (MRM) IN COMMERCIAL AVIATION: REDUCING ERRORS IN AIRCRAFT MAINTENANCE DOCUMENTATION

TECHNICAL REPORT
10/31/94

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SUMMARY

One airline's efforts to audit and reduce paperwork errors through improved error measurement, feedback and training have resulted in lowered rates of total errors. Within those general efforts, a specific program called "MRM," or Maintenance Resource Management, has produced further specific reductions in paperwork errors. MRM is a unique program of joint cooperation among trade union, management, and government regulators to reduce maintenance errors through improving communication and increasing trust. Initial MRM experimental findings suggest that improved quality of paperwork and documentation results from increased paperwork training, from opening communication between mechanics and foremen (and between those two groups and higher management), and direct involvement of mechanics in improving forms design.

Overall, however, these “experimental” results reflect the patchwork nature of the solutions implemented during the initial MRM interventions. The data obtained during the MRM project are clear in their message that poor management communication practices were central to reduced quality of work and to quality of working life. Technical training was seen to overcome technical deficiencies, but only temporarily. The results reported here are promising, but they also indicate much room for improvement: Communication between and within maintenance operations departments needs to be improved before substantial and sustained reduction in the number of record keeping errors can be expected.

INTRODUCTION

Origins of MRM.

In 1991, representatives of three institutions recognized that they shared a problem. Maintenance trade union officials, an airline's maintenance managers, and managers from the local FAA office joined together and created MRM to better understand the problem they shared and to seek ways to cure it at its source. The problem was a high incidence of maintenance-related discrepancies in completing aircraft maintenance and repair documentation. A series of mergers with other airlines had increased the size and complexity of the company. Among other things, this led to confusion in sign-off procedures and compliance with regulations. During the early 1990's the number of paperwork discrepancies rose dramatically.

The company's independent efforts to improve aircraft documentation quality.

The company's ongoing efforts to change and improve its record of paperwork errors predate MRM. As early as 1989, managers in the company were concerned about the high incidence of paperwork errors following the mergers. Three subsequent changes resulted. First, the Aircraft Records department improved its audit productivity. In 1989 and 90, audit productivity rose by increasing the number of records clerks, following the company's last and largest merger. During 1991 and early 1992 (preceding MRM) these new records clerks increased their audit skills and their productivity in finding errors and reporting them to maintenance foremen and mechanics. The Aircraft Records department continued to evolve, with a change in management, a reduction in force, and tightening of its audit and quality standards. Second, the company changed its signatory requirements to include employee number as well as more legible signatures. This change in procedure opened new avenues for errors to occur (e.g., the employee I.D. number not previously being required), plus the opportunity to more easily identify those charged with errors of unclear signature. In early 1994, the company made a third change to improve paperwork quality, which was to require use of stamps, instead of mechanics' signatures, on all forms except the aircraft logbook.

The Broader Implications of MRM.

The problem of paperwork errors, although important in its own right, has broader implications, which were recognized by the three parties to MRM. They felt that errors or discrepancies in maintenance paperwork were a sign of lowered motivation, and low trust within the maintenance system, which could lead to lowered quality of the maintenance itself. The objectives of MRM, as it began in mid-1992, were therefore defined 1) to reduce maintenance-related errors and improve maintenance quality, and 2) to build trust among members of the maintenance system and with the Federal Regulatory Authority. The MRM planners chose to begin with those ultimately producing the errors, to help discover the causes and intervening circumstances -- they involved mechanics, inspectors, their leads and foremen in a search for causes and paths for improvement.

The three institutional parties were represented by three individuals (and alternates) who formed a "steering committee" to create and manage the process. Among the first acts of the steering committee was to enlist the help of a human factors expert with a specialty in organizational psychology and a background of research in aviation maintenance. The addition of this “fourth party” (who also prepared this report) was the result of a search for an independent investigator to undertake data gathering and analysis of MRM.

The paucity of incentives available to the steering committee to obtain the participation and support of foremen and mechanics posed an obstacle. The original problem of paperwork discrepancies was revealed through the high number of FAA Letters of Investigation, and Enforcement Actions. Internal company audits confirmed that other discrepancies in maintenance documentation (not noted by FAA or otherwise not FAR violations) were on the rise as well. It was assumed that an individual mechanic or foreman committing an error would not be forthcoming to discuss its causes at the time because of possible ignorance of the discrepancy, or fear of personal retribution, or a skepticism that an “open communication” program, such as MRM, could succeed. The FAA did not offer immunity to individuals committing violations, so the MRM steering committee began the program based solely on support built from grass-roots communication by newsletters, by telephone and through personal introduction of the program by the steering committee members, at the stations involved.

Expectations about MRM.

In theory, MRM was intended to have both direct and indirect effects on reducing errors. Directly, MRM focus group interviews were intended to reveal the causes to be fixed. Focus group interviews were also designed as opportunities for foremen and mechanics to be involved -- in this case speaking confidentially, but knowing that their ideas would be summarized and made public to those who could make changes. The interest of the company, the union, and the FAA, would be demonstrated in their willingness to cooperate with one another and to endorse the recommendations of the focus groups. Those focus group sessions were expected to prove to mechanics and foremen that their cooperation, their openness and eventually their trust would lead to better quality of working life and greater quality of work performed. More specific management commitment to employee involvement, as MRM continued, was expected to further enhance the indirect effect of cooperation on quality.

THE STUDY

MRM focus group interviews were held with over 100 foremen, lead mechanics, mechanics, inspectors and support personnel, in mid to late 1992, and with an additional 60 people during 1993-94. These interviews revealed a number of common sources of errors and discrepancies in maintenance documentation, and solutions to correct them. Communication practices within the company are an underlying theme from the MRM focus groups for reducing the paperwork error mechanics and foremen experienced.

As a result of MRM, the company, initiated five changes during 1993-1994, which followed from the list of suggested solutions produced by the interviews. These changes included 1) The initiation of a telephone hotline for mechanics, and others, to report flight safety issues, 2) a paperwork procedures training program delivered to over 1,300 foremen and mechanics throughout the company; 3) the experimental use of foremen's pre-shift meetings with mechanics in one line maintenance station; 4) involving mechanics at that station in the redesign of the company's aircraft logbook; and 5) the participative revision of their General Maintenance Manual. Early results suggest that these changes were successful in contributing to the reduction of errors in maintenance paperwork.

What follows here is a report of the initial phases in a longitudinal research project to describe and assess the MRM program. The research reported here, spans a two year period, and has three parts: 1) developing a classification of error sources for aircraft maintenance and repair documentation, 2) determining potential solutions for lessening or eliminating those errors, and 3) beginning to evaluate the effect of planned improvement efforts (based on solutions proposed in part two) on documentation errors

METHODS

Gathering data from foremen and mechanics in the focus group interviews.

These interviews were conducted during two periods. Between May and September 1992, nearly 100 foremen, leads, and mechanics participated in 18 group interview sessions at four large line-maintenance stations. Between March 1993 and June 1994, an additional 60 foremen, leads, mechanics and inspectors participated in 10 more focus group interviews at three smaller line and maintenance stations. Engineers and Aircraft Records clerks at the company’s maintenance headquarters participated in separate focus groups. All focus group interviews were held at or near the work sites, with groups of five or six people; and at line stations, they were equally divided among the three shifts most stations worked. They were conducted by the independent investigator and lasted about two hours each. All sessions were personally introduced by three members of the MRM steering committee who answered questions and then left the group to work in private with the independent investigator. The sessions were conducted as brainstorming sessions to list paperwork errors and their causes, and to develop a set of possible solutions.

The analysis process.

The investigator summarized the raw data to ensure confidentiality and reduced redundancies among sessions and stations. The data were further organized by errors, causes, and solutions, and within each of those three, the priorities assigned by each focus group to items on their lists. The summarized data were then reviewed by the steering committee and decisions were made which classified data into categories. Initial lists of problems and solutions were developed and distributed to the company management, union officials, and the local FAA managers in early 1993. Over the total period, May 1992 to June 1994, the resulting common or core sets of paperwork problem causes, and solutions were tested and modified by the MRM steering committee as data continued to be collected.

RESULTS OF THE DATA GATHERING

I. Sources of documentation errors listed by MRM focus group participants.

In order to draw out the core set of items from the hundreds listed during the interviews, only those problems/issues which the focus group members determined were "most important" of those that they brain-stormed, were used in constructing the list that follows. These "most important" items represent less than 20% of their total problems/issues lists. Although there were natural variations in the phraseology used by the various groups interviewed, the intent contained in this core set was confirmed when possible and was established consistently across groups. The major issues identified by the 1992 focus groups were classified into ten categories. These are displayed in Table 1.

Table 1. Paperwork Error Sources Identified by MRM Focus Group Participants
1) Communication about technical information. The general feeling appears to be that upper management is not interested in communicating to lower management or hourly personnel. For instance, there are reports of few explanations or reasons for changes, discrepancies or inconsistencies in the General Maintenance Manual (GMM). Respondents believe problems in the GMM cause errors in paperwork.
2) Maintenance system practices regarding information. The comments include dissatisfaction with repair and signoff advice by Maintenance Control, and the Maintenance Planning department issuing incorrect phase check paperwork. Paperwork is reported to be often lost or misplaced in Maintenance Planning or Aircraft Records departments.
3) Merger-related information/communication issues. Respondents felt that management, by their actions, did not consider using documentation procedures (some of which were felt to be clearly superior) from other airlines it acquired.

4) Information about transit checks during the day. There is not enough time to accomplish transit checks and the associated paperwork during the operating day.
5) Logbook design and use. The logbook modification introduced in mid-1992 (and preceding editions) did not involve mechanics, and there was no subsequent training on its changes. Its design was reported to cause certain signoff and data errors.
6) Complex and/or redundant engineering information. Errors are reported to be caused by overly complex, unnecessary, and/or redundant engineering information, contained in Engineering Orders and Airworthiness Directives (AD notes). It is said that people in the Engineering, Programs, and Technical Publications Departments do not ask for input from mechanics before releasing documents.
7) General paperwork design and practice. There is not enough time for untrained people to complete the company's very complicated paperwork without making errors.
8) Clarity of manuals and their use. Policy manuals are not clearly written, hard to access, and very difficult to use paperwork errors are felt to result as a consequence.
9) Training in paperwork. Neither initial paperwork training, nor recurrent training is sufficient for mechanics to always complete paperwork in a timely or correct manner.
10) The type and condition of maintenance information technology. Microfilm machines are antiquated and information provided (especially about parts nomenclature and numbers) is distorted and/or unclear. The computer system is not user-friendly and not as integrated as it should be.

These ten categories represent the content of items in the total set of "most important" problems. They were identified by the groups interviewed in 1992. Of those ten, eight were also raised as important by the participants in the interviews conducted in 1993 and 1994. Only items #4 and #10 (time pressure for transit checks on thru-flights, and condition of microfilm hardware) did not emerge as important. In part this difference is because the company upgraded its microfilm readers in at least several stations during 1993, and the stations visited during 1993-94 had not been requested to work transit checks on thru-flights.

Data collected during the total period between May 1992 and June 1994 demonstrate limited maintenance system practices to encourage mutual trust and open communication. In short, these results reveal that paperwork errors are in large part the result of the company's management communication practices, with a contributing factor being the design of the forms themselves. Even the latter (confusing and unclear form design) is in part the effect of limited communication between those designing the forms and those using them, which also results from management practices. As stated in the conclusions of the report on the 1992 results, "Communication between and within maintenance operations departments needs to be improved before substantial and sustained reduction in the number of record keeping errors can be expected."

ADDITIONAL DATA ABOUT MAINTENANCE COMMUNICATION PRACTICES

During early 1994, it became possible to more closely examine the systemic context for the company's maintenance communication. An opportune case study of communication, within the maintenance department and between it and pilots, was approved as a part of the MRM research by the MRM steering committee. Although not directly involving paperwork discrepancies, the case promised to illustrate communication and compliance issues between management and mechanics, and communication by mechanics themselves. The case illustrates communication practices in newly implemented (1993-94) aircraft deicing operations. It was stimulated by an incident involving a lead mechanic who, while coordinating deicing operations one morning in January 1994, did not communicate what was expected (and required). Specifically, he omitted making four read-back statements, required by Federal Aviation Regulations when deicing, to several aircraft. Unfortunately for him, this occurred while being observed by an FAA inspector, a company quality assurance (QA) specialist and a company QA manager. He (the lead mechanic) was then informed of the violation and was disciplined with a furlough of five days. Management argued that the training and follow-up support for the new deicing communication requirements was abundant, and this particular lead mechanic "...should have known how to communicate to the pilot." "If this lead was uncertain or ignorant of the correct procedure," management continued, "the checklist was in front of him on the table, yet he ignored it." The subsequent case study, completed under the MRM program, examined the system-wide implications of this failure to communicate, and suggested its possible causes.

In February 1994 the MRM steering committee was provided background information and documents for the newly implemented deicing operations and the MRM project's independent investigator observed deicing operations at two stations and interviewed 14 maintenance people (management, auditors, trainers, foremen, leads, and mechanics) about 1993-94 deicing operations. This sample included people who were observed in similar lapses (or who had observed omitting the read-back statements in others or themselves), as well as people who described the training (either as participants or as trainers).

In general, the report resulting from that MRM deicing case study inferred that the company succeeded in some ways (and failed in others) to communicate deicing communication procedures to mechanics. They failed because of competing forces, which intervened to block mechanic comprehension (and subsequent compliance). In this case, creating memory aids such as pocket checklists and dash board reminders of the read-back statements was a benefit, but not reinforcing and practicing their message in other aspects of training and follow-through was an oversight. More importantly, replacing the traditional maintenance norm of a hand salute, with a formal script, didn't make an adequate adjustment to familiar and trusted ways. Not helping mechanics make this adjustment toward new, effective communication with pilots contributed as well. Without proper explanation or discussion, this procedure inadvertently became one more small step in minimizing the status and stature of the airline mechanic. It also placed mechanics in the position of performing verbal behaviors at which they are less prepared to excel. A vicious cycle of lowered trust and openness by both management and mechanics was caused by a combination of limited information available and time pressure (which limited explanations), together with confusion, lack of preparation, and historical enmity.

The case report concluded that maintenance system culture, communication practices and norms contributed to perpetuating a punitive, suspicious climate, which continued the cycle of distrust. Management sincerely felt that their efforts to communicate the new deicing procedures were not merely adequate, but ample (in interviews, management described that communication as "all out"). But this unintentional failure to communicate is similar to others reported during MRM focus group sessions dealing with aircraft documents. A second and related cause for this failure to comply with deicing procedures is that all parties within the system were not prepared for the confusion of dealing with a great many new aspects at once. In the deicing case, both trainers and trainees (foremen, leads, and mechanics) were able to focus on the new technical aspects of deicing, but they were occupationally and emotionally unprepared to appreciate the myriad of new requirements of the sociotechnical (i.e., the human interface) portion of new deicing regulations. Mechanics are, by choice, "tool and thing" people; but they are increasingly being asked to perform conceptual, verbal, and interpersonal tasks. The case illustrated for the MRM steering committee, the importance of management direction and training mechanics within the total environment and not merely its technical aspects. More specifically, the case study validates the widespread effects of management communication practices on foremen and mechanics' work behaviors already illustrated in the MRM "issues list" already presented in Table 1.

II. Solutions Suggested By MRM Focus Group Participants.

Because the MRM focus groups' solutions lists were each developed following the prioritization of their problems lists, they necessarily represent solutions to the "most important" issues. Both foremen and mechanic groups generated lists of similar solutions. Some of these solutions dealt directly with management-mechanic communications (frequent and effective crew meetings) while others addressed training. Many foremen and mechanics said they want to meet more with one another and with their support staff, their managers and with company executives. Further they said that they need to receive training in how to communicate more effectively, as well as training in how to use appropriate information and communication systems. The solutions listed in Table 2, below, are divided into the categories from Table 1 (the "major issues"). Virtually all the "most important" solutions listed during 1992 were replicated with the groups interviewed during 1993-94.

Table 2. Solutions to Reduce Paperwork Errors Proposed by MRM Focus Groups
1) Communication about technical information. Develop and implement an effective two-way communication network that includes, but is not limited to, regularly scheduled crew meetings and a media vehicle that will get information to every maintenance employee.
2) Maintenance system practices regarding information. Increase competency in Maintenance Control, re-evaluate the overnight phase check and increase Maintenance Planning department awareness of maintenance station problems; i.e., workplace and environment. Develop ways for people from different maintenance departments and divisions to understand one another's work. Provide communication training for people in all maintenance departments, and where possible train them in mixed groups.
3) Merger-related information/communication issues. Set up a task group, which includes mechanics to review the records and paperwork procedures of other airlines (especially those merged into the present company) and implement if they will cause fewer errors than current procedures.
4) Documenting transit checks during thru-flights. Reduce the number of transit checks during the day, if possible. Review flight schedule for these aircraft to ensure sufficient time to accomplish check per company policy. Improve the design of the transit check form, involving mechanics wherever possible.
5) Logbook design and use. Future revisions of the logbook should include input from the mechanics.
6) Complex and/or redundant engineering information. Require prototyping of all engineering orders (EOs) and publications from Maintenance Programs and Technical Publications departments. Provide mechanics better access to engineers and encourage engineers and mechanics to work together in creating EOs.
7) General paperwork design and practice. Form a task group, including mechanics; to review and act on these solutions listed.

8) Clarity of manuals and their use. Policy manual has evolved over the last 30 years. Need to rewrite the GMM and other maintenance manuals.
9) Training in paperwork. More emphasis on Line Maintenance paperwork training, including formal initial training and recurrent training, as well as guided videos, on the job training (OJT) by informed coworkers, and crew meetings. Be sure that instructors have direct and recent maintenance experience. Emphasize a standard paperwork practice at all stations across the company.
10) Information technology. Update to "state of the art" information hardware. Implement the use of computers for entering logbook information in real time, for generating appropriate and current transit check and A-check forms. Use the computer to merge and print the relevant sections of GMM and repair manuals, with engineering orders, AD notes, etc.

Over several months following the February 1993 report, management responded by changing or improving all the major sources identified by the focus groups. It is important to note that these changes dealt with the information technology and procedures, with management-mechanic communications, and with training.

CHANGES IMPLEMENTED FOLLOWING THE FEBRUARY 1993 REPORT

1) Telephone hotline.

As a first effort to open communication, and to expand the use of phone and FAX technology, management and the union jointly announced the creation of a telephone hotline. This hotline was intended for all airworthiness flight safety issues of non-emergency and non-grievance nature. Mechanics were instructed that separate hotline numbers would be used for voice and FAX and, although both the union and the company recommended that callers identify themselves, calls could also be made anonymously and union shop stewards would be available to act as intermediaries for follow-up discussions. The form that was created to classify the hot line items was flight incident-based and had no category for specific paperwork problems or form design issues. The hotline went into operation on June 15, 1993.

2) Line maintenance paperwork training course.

In April 1993 (following the February 1993 report of 1992 MRM results) the Vice President of Line Maintenance directed the Maintenance Training Director to establish a paperwork course and present it to all stations. In May, the Maintenance Training Director convened a meeting, attended by managers of several maintenance departments affected, to review the MRM results and their own perspective of paperwork problems. A month later a second meeting was held which included the same managers, plus a foreman, a lead and a mechanic to describe their experiences from the field. The training program was started in late July and was completed by mid-September 1993. A total of 1,314 people at 37 stations attended the program.

3) Shift crew meetings.

Shortly after the paperwork training was approved, the Vice President for Line Maintenance agreed to support, in one station, the use of crew meetings led by foremen. This decision resulted in hiring a consultant to design and deliver training in conducting "frequent, brief team meetings" (the description used in the company's request for consultant assistance) for the nine line maintenance foremen at the station. The eight-hour training (titled "Conducting Crew Briefings" by the consultant) was delivered to six foremen in two sessions during August 1993. A month later the remaining three foremen received the training. The foremen began holding daily meetings with their shift crews immediately thereafter, and these meetings have continued more or less on a daily basis. A sample of the foremen and mechanics at the station was interviewed in November 1993 and February 1994, and crew meetings were observed during all shifts. In November, all nine foremen were reported to still be employed at the station, but the following February found at least one of them transferred to another station and an untrained replacement took his place. The meetings were reported not usually to relate to paperwork changes or errors, but they do provide the opportunity for foremen to discuss housekeeping and safety, and for mechanics to speak-up about other matters of concern to them.

4) Involving mechanics in logbook modifications.

During August 1993, the mechanics in the station, which was designated to implement the crew meetings, were also informally invited to suggest improvements to the logbook. A manager from the Quality Assurance (QA) department, who was also a member of the MRM steering committee, conducted voluntary and informal sessions with mechanics on all shifts to obtain their ideas to improve the logbook. Like several of the other changes introduced as a result of MRM, this intervention followed directly from the suggested solutions generated by the MRM focus group interviews. These sessions continued periodically from August 1993 through February 1994. The sessions were used to provide updates on the changes being made and to invite further comment by mechanics before the logbook was printed again. The resulting new logbook was introduced system-wide in early April 1994.

5) Rewriting and redesigning the General Maintenance and Administration Manuals.

In June 1994, announcements were made by the company and by the mechanics' union to restructure the GMM and Administration Manuals. The announcements referred to the MRM data collection as a stimulus for the change, and promised to directly involve representatives of the trade union, as well as the company's Technical Publications and Quality Assurance functions. The announcements invited all members of maintenance operations to provide input about problems with, or suggestions for the manuals. Several committees of mechanics were thus formed by the union and the company to review and rewrite the GMM and Administrative manuals, as required. These groups continue to meet at the time of this writing. Their output is expected early in 1995.

PERFORMANCE RESULTS

Collecting data on paperwork errors.

The company has recorded paperwork errors since at least 1991. At that time, the error data were totaled, by station, for all forms and documents taken together. In 1992, discrepancies were reported both as raw data and as scores "normalized" (to permit comparison among stations) for paperwork load, by dividing the raw station totals by the number of forms processed per station. Beginning in January 1992, raw logbook errors (as well as errors made in other specific forms) were reported separately from total errors, but only for all stations combined. Logbook errors were not reported separately, by station, until May 1993. In preparing results for this MRM study, flight departure data have been used to normalize the discrepancy data to compare stations with different line maintenance activity loads for both logbook and total paperwork discrepancies. Unfortunately, the company has not retained and reported discrepancy data for every month between August 1991 and the present. Paperwork discrepancy results (in some form) exist for the months August 1991 through April 1992; May, August, and November 1993; and February through August 1994.

An overview of time series performance data.

Figure 1 shows the ratio of total paperwork errors to total flight departures, for all line stations combined, for all months that such data are available.

Figure 1. All Line Stations, All Periods

These results provide an overall perspective for the three-year period (8/91-8/94) which brackets the initiation of MRM (5/92) as well as other significant interventions to reduce paperwork errors. Figure 1, includes markers for the timing of several of the other significant interventions. These overall results show an decrease in errors prior to January 1992. The subsequent increase in errors coincides with the company's last and largest merger. By March 1992, increased audit productivity is associated with a further increase in reported errors. Although MRM begins with interviews in four stations during mid to late 1992, and another one in early 1993, not much overall subsequent effect on reducing errors is expected -- nor is it evident. By mid 1993, new GMM signatory requirements correspond to the highest reported paperwork error totals. The initial MRM recommendation for a paperwork-training program for all foremen and mechanics, however, was implemented in August and September 1993, and the subsequent period, to May 1994, is associated with an ever-decreasing error rate.[1] In early February 1994, mechanics were issued personal stamps to use in "signing off" for work accomplished on all maintenance forms except aircraft logbooks. The following three months show a further reduction in total paperwork errors.

EVALUATION OF MRM ACTIVITIES

In evaluating MRM, it is important to understand what improvements were intended, and how that was to be accomplished. MRM was designed for several purposes. First, MRM was intended to reveal sources and solutions of paperwork errors in the airline's line maintenance organization. Second, MRM was intended to begin a process of "open communication" among foremen, leads and mechanics, and between them and support staff, management and FAA inspectors, about the specific paperwork errors committed and to help in the solution to those problems. It was hoped that in the process of reducing paperwork errors, improved communication among the parties would also act to improve maintenance morale and quality in general.

The first objective has been addressed for line maintenance stations and the maintenance support units. The lists of paperwork issues and of solutions to improve error rates have been presented in Tables 1 and 2 above. The second MRM objective has begun to be realized as well. The data below will show that training and other planned changes intended to improve the record keeping process and/or improve communication coincide with improved error rates. Although coincidental data are the primary proof in this study, the types and numbers of associations between events and results are persuasive.

EVALUATION OF CHANGES

Methodology.

Having the MRM study divided into two periods (May to December 1992, and March 1993 to June 1994), with a report of interim findings and recommendations between them permits us to examine two sources of data for evaluating changes made. The first source of data, already introduced in Figure 1, is paperwork error data collected and reported by the company. The second source of data is the description and evaluation of the MRM interventions obtained in interviews conducted during the second period of study. As already described above, the continued MRM focus group interviews in 1993 and 1994 included some 50 additional foremen, leads, mechanics, and support personnel. Those respondents were asked to comment on their experiences with the August-September 1993 paperwork training as well as their knowledge about MRM. The one line station chosen to make use of the crew meetings and the informal logbook improvement sessions was visited twice following the onset of that experiment, and interviews were conducted. Both the error performance data and the results from these 1993-94 interviews will be used to evaluate the several changes implemented to date as a result of MRM.

Intervention 1: Initiation of a Quality Assurance "Hotline."

As a first effort to open communication, following the MRM report of February 1993, the telephone hotline was announced in June 1993. It went into operation on June 15, 1993. This hotline was intended for all airworthiness flight safety issues of non-emergency and non-grievance nature, and anyone in the company could use it. Mechanics were informed of the voice and FAX phone numbers and instructed in the hotline's purpose and its use. The form that QA created to classify the hot line items was flight incident-based and had no dedicated category for specific paperwork problems or form design issues.

The hotline resulted in 13 calls in the first 45 days, followed by a steady rate of about 10 per month for the remainder of 1993. 1994 hotline results, to date, show a lower rate of about 4 per month. Most calls came in on the voice line. The people calling have been primarily line mechanics. Overall paperwork errors portrayed in Figure 1 do not reveal a decline in the months following the in hotline's introduction, but the mere fact of mechanics and foremen being able to speak-out via an added communications medium was not expected to result in lower paperwork error rates.

Intervention 2: Aug-Sept 1993 Paperwork Training For All Foremen And Mechanics.

One thousand three hundred-fourteen people in 37 stations attended the custom-designed training program in paperwork procedures. That number represents two-thirds of all foremen and mechanics in the company at that time, in all of the current line stations. Twelve professional trainers were deployed throughout the maintenance system in order to complete this massive task in so short a time. Performance results subsequent to the paperwork training program are shown in Figure 2, which contains the same total error data as Figure 1, but which also includes Least-Squares Regression trends for the pre and post-training periods.

Figure 2. Training Effects on Total Paperwork Errors/flt. -- All Line Stations

Figure 2, provides evidence that the company-designed and implemented training program to improve paperwork is associated with subsequent reduction in paperwork errors. For the period before the implementation of training the total errors trend upward. In contrast, the post-training scores show a trend which is consistently downward; and the error rates for three of the four last months available (May-July, 1994) virtually equal the best pre-merger, pre-training score (November, 1991). The available data suggest that the results achieved by the training may not sustain low error rates beyond 12 months.

Interviews conducted in one line station during November 1993 (one to two months following the training) revealed that the training had been useful for newer mechanics, but was reported to have "covered old ground" for the more experienced line mechanics and foremen. Interviews in two other line stations during June 1994, revealed that no one among the 35 interviewed could even recall the paperwork training conducted in their stations nine or ten months earlier. It is likely that that the 1993 paperwork training did improve performance of new employees at that time, but some method of continuing the training (and perhaps making it more memorable) is required.

Intervention 3: Focus Group Interviews And Follow-Up Actions.

MRM was intended to begin a process of "open communication." The use of an independent person for data gathering was designed to provide confidentiality initially. It was reasoned that if the problems and solutions initially gathered in MRM focus groups were seen to lead to changes, then trust and open communication would increase and quality would improve. Since the MRM focus is on a particular quality (i.e., improving paperwork errors), then improved performance in that quality could be expected. However, the mere process of conducting "data-gathering focus group sessions," as a part of MRM, could not reasonably be expected to have much direct impact or paperwork errors. In fact there is no measurable coincident association between conducting MRM focus group interviews in five stations and their subsequent error scores. Figure 3 compares the total error rates, averaged over stations, for the five original MRM stations and the remaining 35 of the company's comparable maintenance stations.

Figure 3. MRM Focus Group Effects (original 5 stations) Compared to All Other Stations

Figure 3 shows the error rates for the five stations subsequently selected for the MRM project rose to high levels during the last three months before the program began (Feb.-April 1992). Following the onset of the MRM activities those five MRM stations achieved rates which more closely match the profile for the remainder of the company's maintenance stations. Anecdotal data suggest that the MRM focus group interviews, themselves, had some effect on awareness of errors. For instance, several focus group participants are reported (both by the company and by the union) to have subsequently volunteered information about recent instances of paperwork errors that they had been involved in. In addition, a number of mechanics and foremen have eagerly offered to help improve problems with maintenance paperwork, as the MRM project became more visible throughout the company.

The keys to making valid connections between MRM and favorable results include time lag of the effects, and their visibility. That means that any changes resulting from information gathered from focus group interviews should take place within a reasonable period and should be clearly identified as influenced by MRM.

The four stations interviewed during Summer and Fall of 1992, did not receive further information about MRM until one year later, when they (among 33 other stations) received the paperwork training -- and it is highly unlikely that the trainers consistently stressed the MRM origins of that program.

One line station as a natural experiment. One line station, participating in MRM focus group sessions during March 1993, did experience rapid and visible changes attributed to MRM. In August 1993, four months after their initial MRM focus group sessions, the mechanics and foremen in that station were the subjects of two visible, active, interventions, in addition to the paperwork training implemented at all stations. First, that station's foremen received training in communication and leading meetings and began holding daily crew briefings. Second, the mechanics had the opportunity to attend occasional, informal sessions to discuss improving the logbook. These sessions were led by a manager from the QA department. Mechanics and foremen at this line station, thus became an "experimental" group to test out some of the recommendations they themselves had provided four months earlier. The error rates for this "experimental station" were matched with another line station of similar size and location, which did not participate in the MRM interviews or in the "crew meetings" or "logbook improvement" programs. That matched station provides a comparison to the "experimental" station in order to examine the effect of the active MRM interventions. This comparison does not constitute a controlled laboratory experiment, but, instead, represents a "natural" or uncontrolled experiment. The main difference between the "experimental" and "comparison" stations was their reported morale and their relations with flight crews. During 1992-93, the morale and service reputation of the "experimental" station was considered poor, while the comparison station enjoyed a better image. This kind of variation among comparisons is not unusual in "real world" or natural experiments, but it should be considered when reviewing the resulting data.

Intervention 4: Conducting Crew Meetings

Comparing the performance results for the "experimental" station. Figure 4, compares the total paperwork errors (corrected for the total number of departures) for the "experimental" station, for the "comparison" station, and for the total average of all 45 line stations in the company.

Figure 4. MRM Line Station Crew Meeting Experiment: Total Errors/flt.

In May 1993, two months after the MRM focus group interviews in the “experimental” station (but before any feedback to that station), Figure 4 shows that station’s total errors are higher than either the comparison station or all stations combined. In August 1993, after the crew briefings and logbook discussions began there, the “experimental” station had lowered its total error rate and is lower than the other two. By November 1993, the error rate for the “experimental” station has dropped even lower, and that rate remains low for February 1994. For March through August 1994 the “experimental” station continues to show a lower error rate than either the comparison station or all stations combined. Thus, after the MRM interventions began there, the “experimental” station displays a lower total error rate than its two comparisons for every subsequent month reported[2].

Interview and observation assessment of the “experimental” station.

Following the visit for focus group interviews in March 1993, the independent investigator visited the “experimental” station twice more, together with the MRM steering committee members, in November 1993 and February 1994.

During the first follow-up visit, four foremen were observed conducting their shift meetings. These really were one-way “briefings” because the foremen did not encourage or solicit questions or comments from the mechanics. Review of the training aids, which the training consultant left with the company, confirmed foremen’s reports that they had been instructed to transmit information during meetings, but not to conduct discussions or encourage dialogue. Attendance at two briefings was about 50% and this was reported as typical on day and afternoon shifts. Attendance roll was called in the largest briefing observed, and mechanics later voiced considerable dissatisfaction with that aspect. In general, the foremen reported enthusiasm for the meetings, even if their performance was somewhat wooden. In talking with them later, it was clear they needed help creating agendas, managing questions in a group setting, and finding a source for company information during afternoon and night shifts. Three of the four foremen said they had received the "Crew Briefing Training" and found it useful, especially in team leadership skills, but they all reported still having some discomfort in responding to mechanics’ questions and obtaining information for deferred answers. They suggested that recurrent and frequent coach-counseling (some said by internal training specialists) would help them perform crew briefings better and feel more confident of their abilities. They said that the program of crew briefings needs to have more clear signs of upper management support, initially from the station maintenance manager, as well as from others up the line. All four foremen said briefings are a good idea, and many mechanics did too. Two of the four foremen actually conducted meetings on a daily basis. Several justifications for not leading daily meetings were given. Three of the four foremen reported that their station manager didn’t mandate daily meetings, and that it was a difficult task to stand up and face the mechanics in formal meetings every day. One foreman shared the same shift with another and left the briefing to the other fellow. Another foreman reported that his work schedule often had him following, through rotation, the shift of a foremen who covered the briefings “so well” that he “didn't need to.”

The visit in February 1994 confirmed the earlier visit. Both mechanics and foremen still complained that upper management doesn't encourage upward communication. The crew sessions observed were still one-way briefings and one was observed which was conducted by a foremen, new to the station, who hadn't received the "crew briefing" training. During interviews, mechanics reported several ideas for meetings, such as technical topics and more safety-related discussions. They also said that more crew discussions about improving the logbook would interest them. Both mechanics and foremen complained that certain issues are raised continually in the briefings and are not addressed. Mechanics said they get tired of posing problems if nothing gets done. Foremen said they couldn't get any information from upper management about many issues, so they couldn't answer the mechanics when they brought up their gripes during the meetings. Despite the reported room for improvement in open communication in the station, the interest shown in MRM by top management, the union and the FAA was noted and appreciated by the mechanics and foremen. Maintenance management reported that pilots' complaints about this maintenance station dropped by February 1994 and remained low through the summer of 1994. Both Flight Department Senior Management and FAA personnel performing enroute flight evaluations reported significant improvement at that station, e.g., "Whatever you're doing there, keep it up!"

Intervention 5: The Effects of Mechanic Participation in Modifying the Logbook

Between August 1993 and January 1994 the mechanics in the experimental station voluntarily attended informal meetings at the station to discuss improving the logbook. These sessions, initiated and led by a manager from the QA department, were held on average of once per month and met on all shifts. In interviews conducted during February 1994, these mechanics reported satisfaction with the logbook changes resulting from their input during the preceding months and they looked forward to seeing them soon in print.

Comparison in logbook errors between the "experimental" and comparison stations.

From May 1993, the first period the company reported logbook errors by station, the "experimental" station showed a high error rate. Figure 5, displays the monthly results and time series trends for the period of May 1993 to August 1994 for the "experimental" and "comparison" stations and all other line stations combined.

Figure 5. MRM Line Station Crew Meeting Experiment: Logbook Errors/flt.

Figure 5 shows a clear difference in trends over the one-year period (August 1993-August 1994) in which the "experimental" station began active involvement in the MRM program. The "experimental" station shows a trend toward lower logbook error rate, while the comparison station shows no such trend. The sharply increased error rate for the "experimental" station in April and May 1994, is not explained by information from informal reports by MRM steering committee members, QA hotline data, or formal company documents. Despite these two aberrant data points, the overall trends in Figure 5 support the expectations for the MRM program.

Figure 5 also compares the logbook error performance of the "experimental" and comparison stations with the average of all stations combined. This graph not only confirms that the "experimental" station rates trend downward, its actual rates of logbook errors compares the same or better than the rate for total stations for all months following the MRM intervention, except for May 1994. The station's direct involvement with improving the logbook corresponded with the its error rates during the time of its involvement (August 1993 to February 1994).

Longitudinal performance data comparisons for the "new logbook."

Apart from the motivational effects of participating in improving the logbook for the "experimental" station, is there an effect of the content of those changes suggested by line mechanics? The logbook, newly designed from recommendations from the "experimental" station, was placed in service throughout the company in early April 1994. If these changes make a difference, the data for April 1994 and later should reveal it. Figure 6, shows logbook error rates, corrected for monthly departures, for all stations (including the "experimental" and "comparison" stations), for all months for which logbook error data are available.

Figure 6. Logbook Errors for all Line Stations

The marked increase, in Figure 6, during the four months of pre MRM logbook error rates (January-April 1992) are largely artifactual. According to company documents, after February 1992, logbook pages that were not Faxed to the Aircraft Records department (despite being sent by company mail) were counted as "missing" when they "should" have been received -- thus counting as an error. Using the newly constructed March-April 1992 data as a baseline, Figure 6 shows logbook error rates steadily dropping thereafter. . We may infer from Figure 6, that all efforts to reduce errors in logbooks since mid 1992 have contributed to success in this endeavor. That conclusion can be extended to the participatory effort at the "experimental" station during the fall and winter of 1993-94. In evidence of this, May-July 1994, the first months following the introduction of the "new" logbook, show the lowest reported rate for all line stations combined since the present method of logbook error calculation was established. Given the inevitable "shake-down" period of accommodating to a change, such a low total rate is remarkable. The ratio increase in the logbook error rate for August 1994 over July is roughly 1.6:1. That rate of increase is not substantially greater than the increase of all errors except logbook for the same two months, which was about 1.5:1. Whatever caused the increases, the logbook errors do not behave differently from all errors combined. A longer time series of logbook error data should substantiate the improvement of the "new" form over its predecessor.

Interview data confirm the success of the "new" logbook.

All seven of the maintenance groups at two stations interviewed during June 1994 said they liked the new logbook better than old one. Several groups paid the new logbook their highest compliment that it was a "maintenance-oriented log, at last." The new form excited such interest in its first ten weeks that these interviewees had a list of suggestions to make the logbook even better.

CONCLUSIONS

The various comparisons of the time-series paperwork discrepancy data before, during, and after several MRM interventions demonstrate that those interventions can be separated from the effects of a number of independent company-initiated changes in documentation procedures during the same three year time period (1992-1994). The MRM results show that observations and suggestions made by line maintenance foremen and mechanics were appropriate subjects for improvement efforts, because responding to those suggestions led to the intended reduction in errors. Those maintenance personnel suggested additional training in paperwork procedures, increased involvement in forms design, and the introduction of crew meetings as three avenues for improvement. The company introduced these three changes during 1993 and the subsequent improvement in paperwork error support a cause-and-effect relationship. Despite the small number of individuals and stations directly involved in the form design (logbook) and crew meetings experiments, and the relatively short period available for assessing error rates, these results are consistent with those expected.

The experiment in helping foremen conduct crew meetings has met with partial success. Although a uniquely improved error rate, for both logbook and total errors in the experimental station, coincides with the onset of crew briefings, mechanics complained that two-way communication is still not encouraged. Possible solutions to be tested in subsequent use of crew meetings include focusing the purpose of the program and its training as two-way (rather than one-way) communication; obtaining consistent and active support from the station manager; and designing and implementing appropriate continuation training in the leadership of meetings; in addition to providing timely feedback about the actions taken as a result of the meetings.

The 8/93 system-wide training in paperwork procedures was followed by a fairly consistent reduction in error rate throughout maintenance operations. This improvement continued for almost a year, until 8/94 the last month measured, when the trend was reversed. Interviews conducted after the training with foremen and mechanics revealed moderate enthusiasm two months afterward, but literally no memory of the training six to nine months later. In comparison to the two more participative MRM-initiated “experimental” interventions, the costs and benefits of system-wide training interventions such as this one appear to result in possibly shorter-term returns.

Ways to Improve Paperwork Accuracy
• **Foremen and mechanic participation in changing work processes (i.e., forms design)**

- **Regular and frequent crew meetings for mechanics conducted by foremen**

- **Formal skills training**

Together, these findings suggest that three specific solutions (see box) will improve paperwork accuracy. This study documents the advantages of encouraging open communication and a more participative management style in the airline industry.

Diffusion of results.

During the MRM data collection phases (May-September 1992, March 1993, and June 1994) many mechanics and their foremen independently appealed for greater involvement and participation in modifying and improving their forms and documents. Since that time, the notion of foremen and mechanics throughout the company getting involved in improving the forms they use has quickly spread and is becoming an idea "in good currency." By July 1994, three of the company's 40 line maintenance stations (that were not a part of the MRM data collection or experimental phases) have variously acted to demonstrate their willingness to participate. In April, 1994, foremen from one station contacted the company's QA department with their voluntarily offer to help redesign their "A" Check forms. They still await direction and encouragement to begin the effort. Mechanics and Leads at another station took matters into their own hands and independently developed a new "A" Check form for the Boeing 757 fleet of aircraft they service. They submitted their new form to the trade union member of the MRM steering committee for assessment by QA

There is a growing interest in employee involvement in this company's maintenance system -- especially in its line stations. Although it is difficult to prove that this change has resulted directly from the MRM program, it seems likely, given the visibility achieved by both the management and the union MRM steering committee members and the ground swell of interest that the MRM Steering Committee members have received from maintenance workers in the year since the MRM interventions took place. Paperwork errors may seem less important when compared with other airline maintenance activities, but as this study shows, the improvement in this one area due to worker participation can be applied to other, more critical areas, such as safety of flight.