Phase VIII Progress Report

CHAPTER 1
PHASE REPORT SUMMARY AND PROGRAM REVIEW

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1.1PROGRAM PERSPECTIVE

Nineteen ninety-eight marks the completion of ten years of the formal existence of the Federal Aviation Administration (**FAA**) Office of Aviation Medicine research program on human factors in aviation maintenance. Since the inception of the program, in the Fall of 1988, the program has generated 10 phase reports, some in multiple volumes, over 400 technical reports (see bibliography at www//http://hfskyway.com), hundreds of conference presentations, three editions of the *Human Factors Guide for Aviation Maintenance*, and 12 Symposium that have attracted nearly 3000 participants. The annual FAA Human Factors in Aviation Maintenance CD-ROM, produced since 1993, has become the primary source of human factors information for the aviation maintenance community worldwide. Distribution of the 1998 CD-ROM shall exceed 4000. Finally, the website for the FAA Human Factors in Aviation Maintenance (hfskyway.com) has been accessed over 1.5 million times since 1996; and, the site had been accessed an average of 100,000 times per month since the beginning of 1998.

The success of the research program is attributed to numerous factors. **Table 1.1** lists the factors that contribute to the success. First, and foremost, the program's research and development tasks are customer driven. The customers include a wide variety of entities including, but not limited to, the following: the FAA Flight Standards Service, the Office of Aviation Medicine, the National Transportation Safety Board, the airline industry, the Air Transport Association, the repair stations, the maintenance supplier industry, aircraft and component manufacturers, aviation maintenance technician schools, universities, and the general aviation maintenance community. The research is driven by requirements and ideas specified by these customers.

Table 1.1. Contributing Causes for Success of FAA Maintenance Human Factors Research Program
Customer Driven
Adaptive to Dynamic Safety Issues
Active Industry Participation
Multi-Disciplinary Research Team
Pragmatic Approach
Wide-scale Information Dissemination

A second factor contributing to the success of the research program is the manner in which research tasks are adapted to immediately meet the ever-changing safety requirements of the industry. As an example, recent accidents have placed focus on FAA and airline oversight of repair stations. Therefore, in 1998, the research program conducted an in-depth review of training and qualifications of repair station personnel (Goldsby, 1998). Additional repair stations studies are currently in progress. Another example of responsiveness to changing safety needs and customer requirements is the Performance Enhancement Systems (PENS), now called the On-Line Aviation Safety Inspection System (OASIS). Back in 1993, the research program developed PENS in response to the FAA requirement and strategic plan to empower inspection personnel with improved technology for airline oversight. OASIS has evolved to an FAA-wide system for all Aviation Safety Inspectors.

The industry has taken a very active role in the research activities, which is a third factor contributing to the success of the program. Most of the research activities have an active industry partner. The industry has provided not only guidance but also full-scale participation and numerous services in-kind, including but not limited to, air travel.

The research team, for the past ten years, has included a multi-disciplinary group of researchers with an ideal mix of industry experience and academic credentials. University researcher participants have combined sound scientific principals applied to pragmatic aviation maintenance topics. The team includes experienced psychologists, engineers, educators, lawyers, Airframe and Powerplant Technicians, and pilots. This diverse mix ensures that all aspects of aviation maintenance human factors is considered.

A fifth, and very important ingredient for success, is the extremely pragmatic focus of the program. The research team has endeavored successfully to cooperate with **FAA** and industry to identify real-world opportunities to improve human performance in maintenance. The legacy of results, over the past decade, demonstrates the pragmatic approach.

Finally, the research program publishes and disseminates results to the industry. The list of technical publications, CD-ROMS, and website information, described above, clearly demonstrates the commitment to getting the research results to the users. This phase report, distributed on the annual CD-ROM and the Websites, is yet another example of such information dissemination.

1.2PHASE REPORT SUMMARY

This year's Phase report runs the gamut, from human factors training projects to the design of maintenance documentation to a study of norms in the aircraft maintenance workplace. This year the team concentrated on the evaluation of selected human factors interventions. The evaluations look at training for situation awareness, assessment of ground damage interventions, and evaluation of formats for maintenance documentation. As usual, the CD-ROM and full-text website are also deliverables.

1.2.1 Evaluation of Team Situation Awareness

Chapter 2 describes the evaluation of classroom training for situation awareness. This topic was once reserved to such operational environments as the fighter jet or airliner cockpit to the air traffic control room. Now it has been revamped and applied to the aviation maintenance workplace. A training course was developed and evaluated with a partner airline. The course focused on five topics including the following: shared mental models, verbalization of decisions, shift meetings and teamwork, feedback, and general situation awareness. The training evaluation was based on delivery of approximately 12 hours of Situation Awareness Training presented to 72 participants from nine different locations of a major airline. All participants also received a basic Maintenance Resource Management class as a prerequisite to the Situation Awareness class. A course outline and post training questionnaire are included in **Chapter 2**.

Chapter 2 shows the results of measures related to value and usefulness of the training, pre and post training attitudes, and changes in behavior in job performance. Results showed that the students rated most aspects of the training to be valuable, identifying class discussions and case studies as the most desirable instructional method. The pre and post training attitudinal measures suggested that the course would have a positive affect on each individuals situation awareness. The questionnaires, administered one month after training, suggested that course material did transfer to job performance.

1.2.2 Develop Line-Oriented Human Factors Training for Maintenance

Chapter 3, entitled "Line-oriented Human Factors Training: MRMIII," looks at Maintenance Resource Management (MRM) training compared to Crew Resource Management (CRM) training. The purpose of the comparison is to speculate how MRM is likely to evolve. The authors emphasize the importance of training for communication and for teamwork. Using a map for the "categories of learning," the authors show how the instructional delivery methods vary from lecture, for conveyance of basic information, to the use of discussing simulation and gaming to ensure "higher order learning." Evolving MRM training, therefore, must become simulation-oriented not unlike the line-oriented flight training (LOFT) that is a final stage of CRM training for pilots. The chapter offers a variety of alternative considerations for advanced MRM training.

1.2.3 Distance Education for Maintenance Resource Management

Chapter 4 also addresses training; however, the focus is on applying web-based technology for distance education. The Gore Commission (Final Report to President Clinton by the White House Commission on Aviation Safety and Security, http://www.aviationcommission.dot.gov) encouraged the **FAA** to capitalize on advanced technology to improve aviation safety. The chapter describes distance education as an "instructional approach where people engage in educational activities without having to be at the site where the instruction is occurring."

This chapter describes the system called Safe Maintenance in Aviation Resource Training Center (SMART). It is an exemplary infrastructure for on-line computer-base training that uses the World Wide Web. Located at http://www.hfskyway.com, the SMART prototype provides a virtual classroom, including such features as the following: on-line registration, a calendar, videos, chat groups, a Federal Aviation Regulations (FAR) glossary, an archive of documents, on-line testing, and a means for students to include material in the on-line archive. This chapter also describes the variety of instructional alternatives that shall soon emerge as web-based distance education.

1.2.4 Evaluation of Ground Damage Interventions

Chapter 5 describes aircraft ground damage, which costs the world's airlines as much as twenty billion US dollars a year. The Chapter begins by describing the impact, causes, and historical research associated with aircraft ground damage. The authors report their efforts to quantify the effectiveness of human factors interventions in ground reduction at one airline. Further, they present standardized means to establish a methodology for "analysis of incidents, deriving interventions and measuring the effectiveness of interventions that can be used by other airlines and for other human error outcomes."

Chapter 5 offers a classification system of active failures, or hazard patterns, that characterize most ground damage accidents. The chapter also offers a summary of interventions used at the participating airline and a safe practices checklist to minimize ground damage.

1.2.5 A Study of AMT Norms and Work Habits

Chapter 6 describes a study of the "Norms and Work Habits" of aviation maintenance technicians. The research looked at social factors affecting human error in maintenance. " Norms are socially accepted workplace procedures that do not necessarily conform to company written procedures. They are implicit work rates by definition. Norms are unwritten procedures. Thus a study of unwritten procedures was a particular challenge. The chapter describes how norms are reinforced by such factors as on-the-job training or time pressures to complete a given maintenance task.

The Chapter offers the results of a questionnaire-based study conducted in cooperation with Transport Canada. The questionnaire was designed to assess worker attitudes regarding workplace norms. The 138 questionnaire respondents in the study were involved in a human factors training course delivered in Canada. While the researchers did not claim that the report was a definitive study on norms there were some interesting results. First, respondents felt that norms had a positive, not negative, impact on safety. Respondents felt that many "standard operating procedures" do not reflect the reality of the maintenance workplace. Respondents also felt that they were not negatively pressured by existing norms. Managers were more likely to admit that they follow norms, mostly due to the pressure to "get the aircraft out." While such interesting data emerged, the chapter authors emphasized the mere questionnaire data is not sufficient to make significant conclusions and recommendations regarding norms. The authors recommend a more substantive study including extensive workplace observation and interviews.

1.2.6 Enhancing Safety with Advanced Training Models

Chapter 7 focuses on building a framework for understanding and improving inspection performance. Models are often used to ensure a complete understanding of a domain before computer-based training is developed. The researchers, therefore, first review the literature associated with training for inspection. Secondly, the researchers describe human inspection performance using an engineering model. Finally, the chapter describes an Automated System of Self Instruction for Specialized Training (ASSIST). The ASSIST system characteristics are described and prototype computer-based training screen displays are presented. A detailed development plan is included.

1.2.7 Evaluation of Documentation Formats

Chapter 8 reports on the evaluation of documentation formats at a participating airline partner. The chapter describes a documentation design job aid then includes evaluative information from airline users of the job aid. A formal experiment was conducted to measure the difference between the same document presented in two different formats. One format followed the airlines conventional layout, the second format used the Documentation Design Aid (DDA). The DDA was previously developed, by this research program, as a job aid highlighting application of simplified English. The study showed that there were fewer interpretation errors on the redesigned document. Further, the chapter reports that the revised document shows measurable improvement in comprehension and reduced reading time.

1.2.8 The NTSB Maintenance Accident Report Online Archive and CD

Chapter 9 describes the production process to convert 24 National Transportation Safety Board (NTSB) hard copy documents into a digital database for inclusion on the FAA's annual CD-ROM and on the hfskyway.com website. Of course the end product has greater value than the report on how the work was accomplished. The chapter is interesting because it shows that conversion of primary source hardcopy or microfiche documents to fully searchable electronic documentation presents numerous challenges. This project was undertaken at the request of the NTSB, as an attempt to provide a research database for maintenance-related accidents.

1.2.9 Wireless technology: Delivering Technical Information to Line Maintenance Mechanics

Chapter 10 describes a field study of the application of wireless technology for delivery of technical manuals for airline line maintenance. The study had two purposes: to evaluate human factors aspects of wireless equipment and to assess the feasibility of such devices in the flight line environment. The chapter describes the evaluation reporting that both radio frequency and portable data terminals are suited to flight line access of technical manuals.

1.3OTHER REPORTS

Four of the reports published by the research program for 1997-1998 were written to stand alone and are not included herein. These reports had an audience with an immediate need . Therefore, they were distributed in low volume hard copy. These reports shall be available on the 1999 CD-ROM. The reports shall also be available on the hfskyway.com website during 1998.

1.3.1 AMT/AMT-T Curriculum: An Alternative Method of Compliance with Federal Aviation Regulation Proposed Part 66

The first “stand-alone” report was written by Charles W. White of Aviation Technical Training and Consulting, and Michael J. Kroes of Purdue University. The report, used as a supplement to the **FAA** workshop on **FAR** 66, presents a proposed curriculum matched to expected regulatory changes. The report also contains presentation slides and handouts from the three workshops conducted by the researchers.

1.3.2 Learning from our Mistakes: A Review of Maintenance Error Investigation and Analysis Systems

The second report was written by David Marx. It is an excellent summary of the various aviation maintenance error reporting systems that have emerged and evolved since 1994. While not endorsing any of the reporting systems, the strengths and weaknesses of each system are detailed.

1.3.3 Comparative Study of Personnel Qualifications & Training at Aviation Maintenance Facilities

The third report was written by Raymond Goldsby and Galaxy Scientific Corporation. In this report the researcher does an insightful review of personnel training and qualifications comparing airlines to repair stations. He finds that manufacturers and large airlines offer the very best training. He also contends that the **FAA** and the entire industry should “take serious and rapid action toward raising the standards for maintenance training and qualifications, especially the minimum standards.”

The information for the report was gleaned through numerous site visits, telephone discussions, and questionnaires. The researcher, having over 30 years of airline maintenance experience, was able to collect an immense amount of data throughout all levels of the industry. The chapter, therefore, details the regulatory requirements, reports on the current status of training throughout the industry, and ends with a set of summary concerns and suggestions for action. Of particular interest are the many frank comments from managers, aviation maintenance technicians, and other personnel from manufacturers, airlines, and repair status.

1.3.4 Advisory Circular for MRM and Prototype MRM Training Program

The fourth stand-alone report is a draft Advisory Circular regarding training programs for Maintenance Resource Management. The author, Ben Sian, builds on various systems developed throughout the industry, especially those in which Dr. Michelle Robertson has worked. The report is clearly an excellent reference source for **MRM** training guidance.

1.4SUMMARY

This phase report and the associated three reports serve to document a large portion of the maintenance human factors research conducted in 1997 by **FAA** Office of Aviation Medicine. The research and development activities in progress for 1998 and planned for 1999 shall continue to seek pragmatic results working with industry and government partners.

CHAPTER 2
EVALUATION OF TEAM SITUATION AWARENESS CLASSROOM TRAINING

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2.1 OBJECTIVE

The objective of this effort was to provide an initial evaluation of the Team Situation Awareness (SA) Classroom Training Course[1,2] and to describe a methodology and instruments for conducting such evaluations in the future. The Team SA Training Course was developed based on an analysis of **SA** requirements and problems in aviation maintenance teams.[3,4] This analysis investigated situation awareness across multiple teams involved in aircraft maintenance. It identified several teams within the aviation maintenance setting, each of which involved leads and supervisors as well as line personnel: aviation maintenance technicians (AMT), stores, maintenance control, maintenance operations control, aircraft-on-ground, inspection, and planning. The analysis produced a delineation of situation awareness requirements for each of these groups and an understanding of the way in which each group interacts with the others to achieve SA pertinent to their specific goals. SA appears to be crucial to the ability of each group to perform tasks (as each task is interdependent on other tasks being performed by other team members), their ability to make correct assessments (e.g., whether a detected problem should be fixed now or later [placarded]), and their ability to correctly project into the future to make good decisions (e.g., time required to perform task, availability of parts, etc.) As a part of the analysis, certain shortcomings — both in the technologies employed and in the organizational/personnel system — were identified that may compromise team SA in this environment.

From the analysis, five major areas for improving **SA** in aviation maintenance were identified:

1. There were significant differences in the perceptions and understanding of situations between teams that were related to differences in the mental models held by these different teams. The same information would be interpreted quite differently by different teams leading to significant misunderstandings and system inefficiencies.

2. Not verbalizing the information that went into a given decision (the rationale and supporting situation information) was problematic. Only the decision would be communicated between teams. This contributed to sub-optimal decisions in many cases as good solutions often required the pooling of information across multiple teams.

3. A lack of feedback in the system also was present. The results of a given decision would not be shared back across teams to the team initiating an action. This contributed to the inability of people to develop robust mental models.

4. The importance of teamwork and the need to use shift meetings to establish both shared goals and a shared understanding of the situation was noted. The conduct of shift meetings for accomplishing these objectives was found to be highly variable in this environment.

5. Finally, several problems that can reduce situation awareness in individuals were noted in this domain, including task-related and other distractions, negative effects of noise and poor lighting, vigilance, and memory issues.

The Team **SA** Training Course[1,2] was developed to address the following five **SA** Training concepts:

1. Shared mental models
2. Verbalization of decisions
3. Better shift meetings and teamwork
4. Feedback
5. SA training

In addition, the course also provided a review of Maintenance Resource Management (MRM) principles which are considered to be prior knowledge requirements for the trainees. The Team **SA** Training Course was designed to be presented as an eight-hour classroom delivery course. The course was designed to be presented to personnel from across all maintenance operations departments (also called technical operations in some airlines). The course is best taught to a class composed of a mixed cross section from different maintenance operations organizations (e.g., stores, **AMT**s, inspectors, maintenance operations control, etc.) This is because the course focuses on helping to reduce the gaps and miscommunications that can occur between these different groups. It was anticipated that much of the course's benefit would come from the interaction that occurs when trainees share different viewpoints and information in going through the exercises.

An extensive set of Powerpoint® slides covering the Team SA Training principles, group exercises, maintenance examples, and case studies are included as part of the course to encourage active learning. The instructional strategy used for the course features adult inquiry and discovery learning. This allows a high level of interaction and participation amongst the trainees creating an experiential learning process. The Team SA Training Course strongly encourages participation in problem solving, discussion groups, and responding to open ended questions, thus promoting the acquisition and processing of information.

2.2 TRAINING EVALUATION METHOD

Two types of training evaluations were used in the Team **SA** training assessment: formative evaluation and summative evaluation. Formative evaluation occurs during the prototyping phase of the training implementation. Immediate feedback is gathered from the trainees about the effectiveness of the course. Specific questions were asked about the usefulness of the course and what could be done to improve the course. This information in turn will be used to modify and edit the existing course. Summative evaluation takes place after the prototyping of the course occurs and looks at overall effectiveness of the training course, changes in work performance attitudes, behaviors and knowledge, and the impact it has on organizational performance. Data collected from the Team SA Evaluation Assessment Instruments will be used to determine which areas of the training course will need to be revised or modified and to determine the effectiveness of the course.

2.2.1 Implementation of the Training

The Team **SA** Training Course was delivered by a major airline at four of its large maintenance bases. Most of the technical operations personnel in this airline had already received **MRM** training which is considered to be a precursor to the Team SA Training Course. The course was delivered over a two-day period by this airline. (It was expanded from the original eight-hour course design by this airline to allow for more group exercises, interaction and case studies.)

The Team **SA** Training Course was delivered in a classroom that was arranged to support group exercises and interactions, as well as multimedia presentations. Several tables were arranged in the room with four to five participants at each table forming a small group for the group exercises. A flip chart was provided to each group for the exercises. A break area was also provided, allowing for an atmosphere of teamwork and casual interaction. Participants used this area for informal discussions about the training material.

The course was delivered by one facilitator from the airline's Human Factors Group. The facilitator created and produced a participant handbook that included copies of the Powerpoint® slides, group exercises, and case studies. Informational and resource material regarding internal departments within the airline was provided. This material could be used to address issues regarding procedures, workcards, health and safety issues, and maintenance policies. Outside references related to human factors and risk management were also included in the handbook. This handbook was designed as a future reference and reinforcement tool for the newly acquired Team **SA** skills.

The instructional delivery methods were varied and multimedia oriented. There was an effective mix of the instructional technologies including slides, videos, and 35 mm slides. The pace of the course was kept at a reasonably high level. In group exercises, each small group of trainees met to analyze a case study or identify a particular set of problems and solutions. After each group exercise their results were scripted on a flip chart and one representative from the group presented their findings to the main group. All of these flip charts were then posted around the room for future reference. At the end of the day the facilitator used them to reinforce the key learning accomplishments of the day and how the Team **SA** skills applied in the training activities.

2.2.2 Course Participants

Seventy-two people from nine different maintenance locations attended the training sessions at which the present evaluation took place. Participation in the course was voluntary and participation in the course evaluation was also voluntary and confidential. Participants were present from a full cross-section of shifts, as shown in **Figure 2.1**. The majority of the participants were male (86%), however, 14% of the participants were female. The participants came from a wide range of technical operations departments and job titles, as shown in **Figure 2.2**. The most frequent job title was that of line mechanic (**AMT**), followed by leads and supervisors. A good cross section of other organizations within the Technical

Operations Group were also represented, including inspection, planning, and documentation support personnel. Attendees were very experienced at their jobs and within the organization and had a fair amount of education as shown in **Table 2.1**.

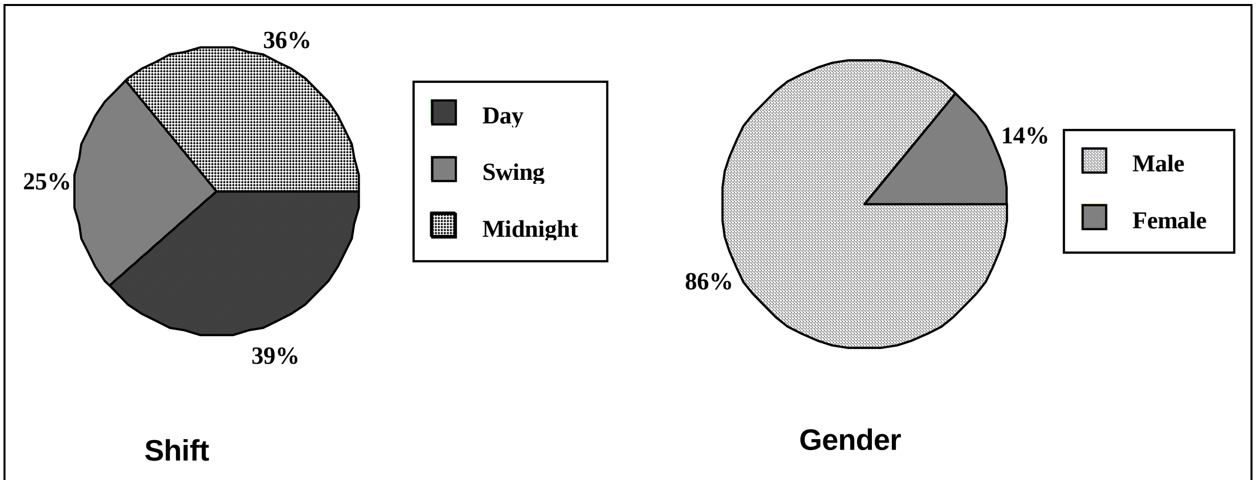


Figure 2.1. Participants' Work Shift and Gender

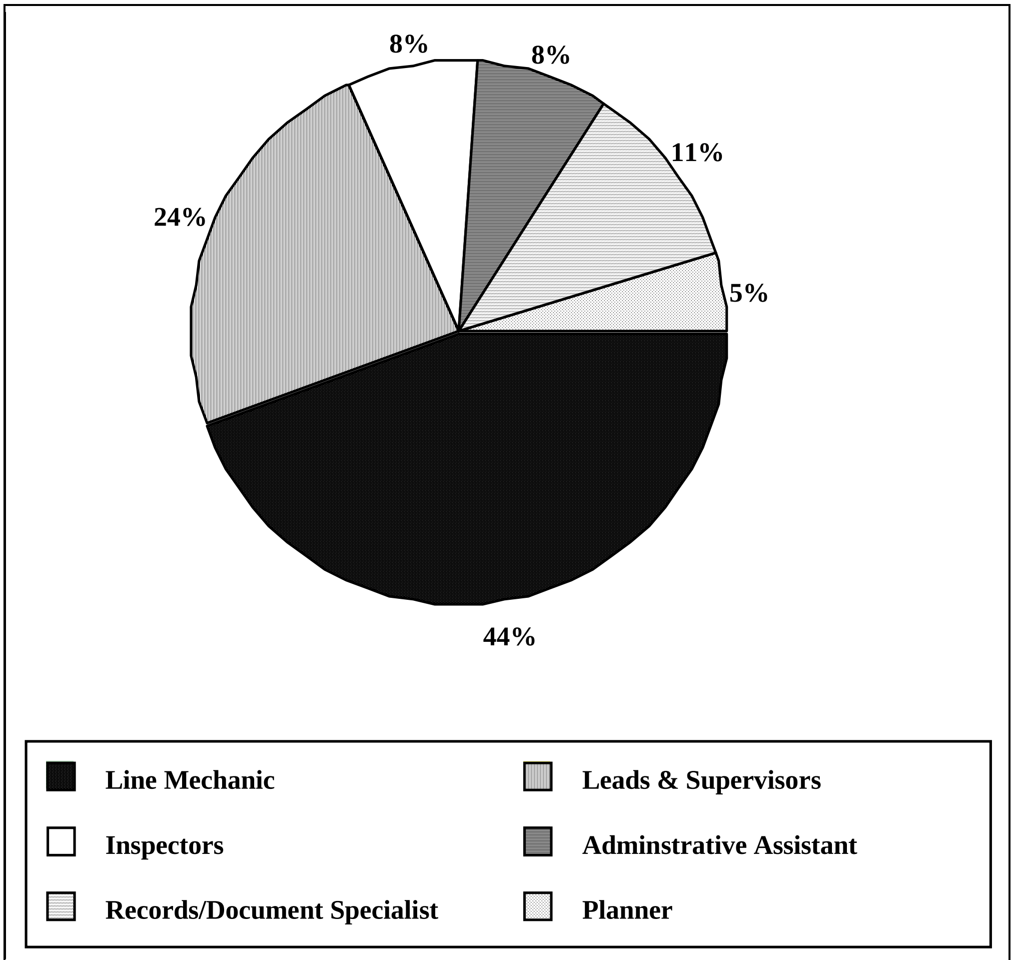


Figure 2.2. Participants' Job Titles

Table 2.1. ParticipantsÆ Age, Education and Experience		
Demographic	Mean Years	Standard Deviation
Years in Position	10.14	14.04
Years at Airline	12.16	5.37
Military Experience	4.71	2.66
Trade School	2.28	0.87
College	2.33	0.76
Age	40.11	7.5

2.2.3 Course Evaluation Measures

The Team **SA** training evaluation process consisted of three levels:

1. value and usefulness of the training
2. pre/post training measures
3. changes in behavior on the job.

2.2.3.1 Value and Usefulness of the Training

There were a number of questions that were asked of the participants to gage their reactions to the training: how they liked it and how useful they felt that it was for their jobs. Shown in **Appendix 2-A**, this Training Evaluation addressed the following questions:

- Did the trainees find the training concepts important to their jobs?
- Will they be able to use the training concepts and skills in their jobs?
- What were the particularly good aspects of the training?
- Does this training have the potential to increase aviation safety and Team SA effectiveness?
- What improvements can be made to the training?

2.2.3.2 Pre/Post Training Measures

The amount of learning in attitudes and behaviors related to **SA** was also measured. Shown in **Appendix 2-B**, this evaluation was provided immediately prior to the training to assess knowledge and behaviors of the trainees related to SA. It was administered again immediately following the course to measure changes in attitudes and self-reported intentions to change behavior as a result of the training. It addressed the following aspects of the training:

- The trainees' current knowledge of factors related to Team SA.
- Self-reported behaviors related to Team SA.
- The current level of the trainees' perceived importance regarding the training concepts.
- The intended behaviors of the trainees--How will they use the training on their jobs?

2.2.3.3 Changes in Behavior on the Job

Shown in **Appendix 2-C**, the same pre/post training evaluation measure was administered again one month later to determine actual changes in **SA** related performance behaviors on the job as a result of the training course. In addition, open-ended questions were provided as a follow-up. It addressed the following issues:

- How have the trainees used the Team SA concepts in their jobs?
- What self-reported behavior changes have occurred?
- What were useful aspects of the training?
- What improvements could be made to the training?

2.3 ANALYSIS METHOD

The feedback from the course was tabulated and analyzed to determine the trainees' perceptions towards the Team SA Training Course. The course evaluation form was analyzed to determine descriptive statistics regarding the participants' opinions regarding the course material and content. These evaluations were compared to participant demographics using analysis of variance to ascertain any meaningful differences between the participants. A .05 level of significance was used for all statistical analyses.

The **SA** behavior evaluation forms were analyzed to determine changes in **SA** behaviors and knowledge for each participant based on the three administrations of the form (pre-training, post-training, and one month after training). A factor analysis was applied to the questionnaire to determine whether subsets of the form were appropriate. A Wilcoxon non-parametric analysis was then applied to determine which factors on the questionnaire were affected by the Team SA Training Course, comparing each item on the pre-test to the same item on the post-test. The same statistical analysis was conducted to determine whether these measures changed after one month on the job following training or remained stable by comparing each item on the post-test to the corresponding item on the one-month questionnaire. A .05 level of significance was used for all statistical analyses.

2.4 RESULTS OF TRAINING EVALUATION

2.4.1 Value and Usefulness of the Training

The post-training course evaluation was used to measure the level of usefulness and perceived value of the course. Course participants scored each subsection of the course on a five-point scale which ranged from 1 (waste of time) to 5 (extremely useful). As shown in **Figure 2.3**, they rated the **MRM** review topics very highly. On average, they rated these topics as very useful (mean scores between 3.5 to 4.4). The discussion of chains of events leading to accidents and "link-busters," techniques for breaking the chain of events, were rated among the highest in the MRM section. There were very few ratings in the low end of the scale on any of the MRM training content topics.

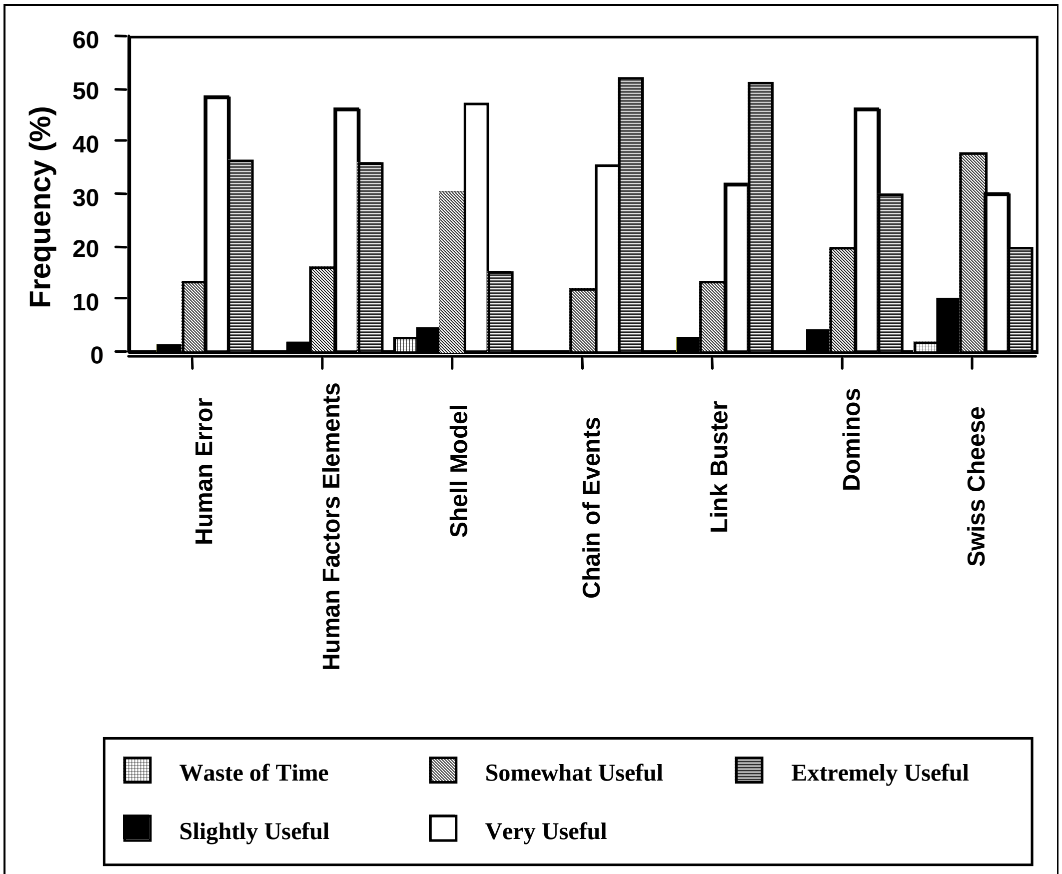


Figure 2.3. Evaluation of Course Module: MRM Review

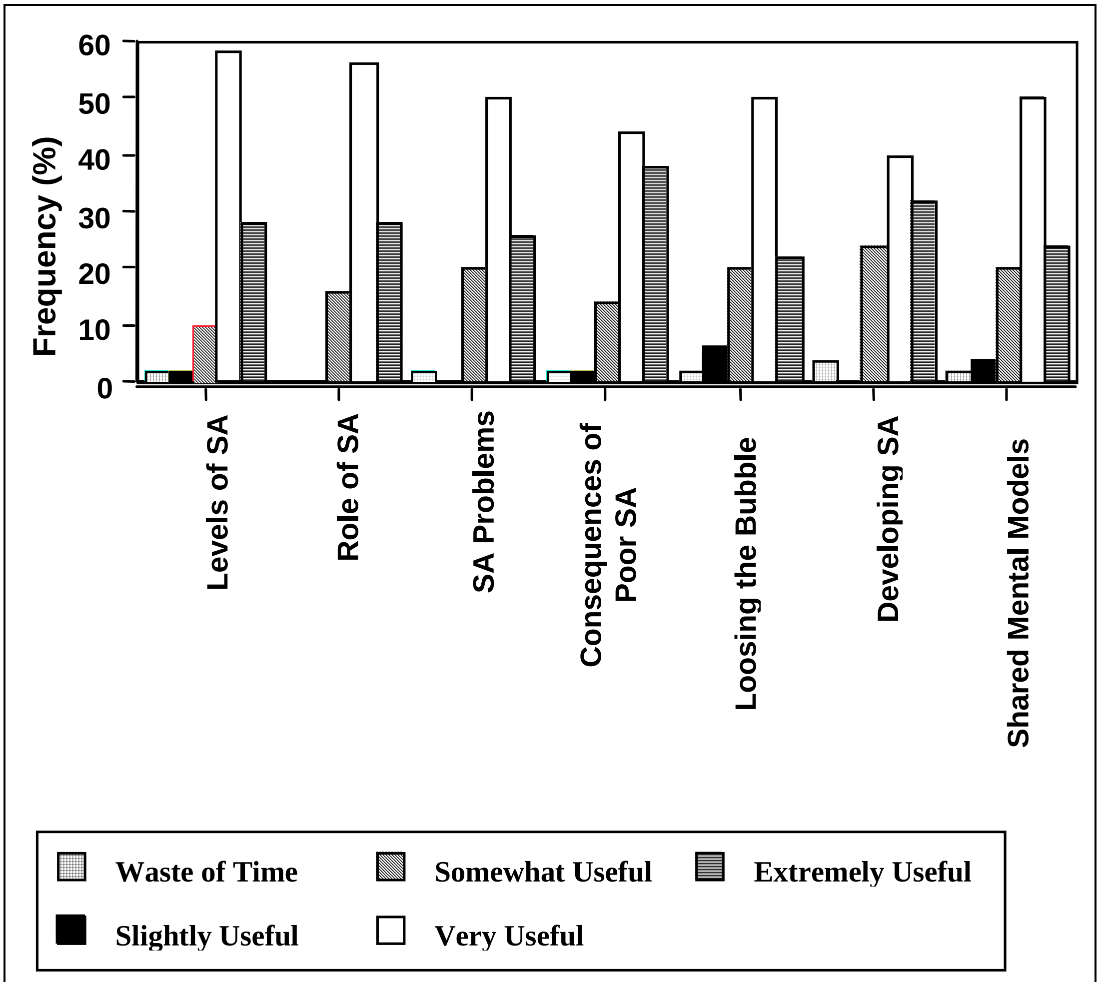


Figure 2.4. Evaluation of Course Module: SA Topics

Figure 2.4 shows the ratings for the components of the course that presented and discussed situation awareness principles directly. Again, these topics were rated very highly with most participants (72% to 86%) evaluating the training material as very useful or highly useful. Mean scores on these **SA** topics ranged between 3.8 and 4.1.

Training evaluation ratings related to the three final training objectives--communicating decisions, teamwork and shift turnovers, and feedback--are shown in **Figure 2.5**. Ratings on these training objectives were very good as well. Mean ratings varied between 4.3 and 4.7. Between 88% and 96% of the participants rated this information as very useful or highly useful.

As the course was designed to encourage a great deal of participation and interaction on the part of the trainees, it utilized appropriate instructional techniques, including aviation maintenance videos, case studies, and group exercises to reinforce the concepts taught in the course. Twelve different maintenance case studies were included in the course. The mean rating for these case studies was 4.2, as shown in **Figure 2.6**, corresponding to a rating slightly over very useful. Mean ratings for each individual case study varied from 4.0 to 4.4. All of the case studies were viewed very positively by the participants. Similarly, the maintenance video used in the course received a mean rating of 4.2, indicating it was also viewed as very useful. The six group exercises included in the course each received a mean rating of between 4.0 and 4.3, averaging to a mean rating of 4.2. Again this material was viewed very positively by the course participants.

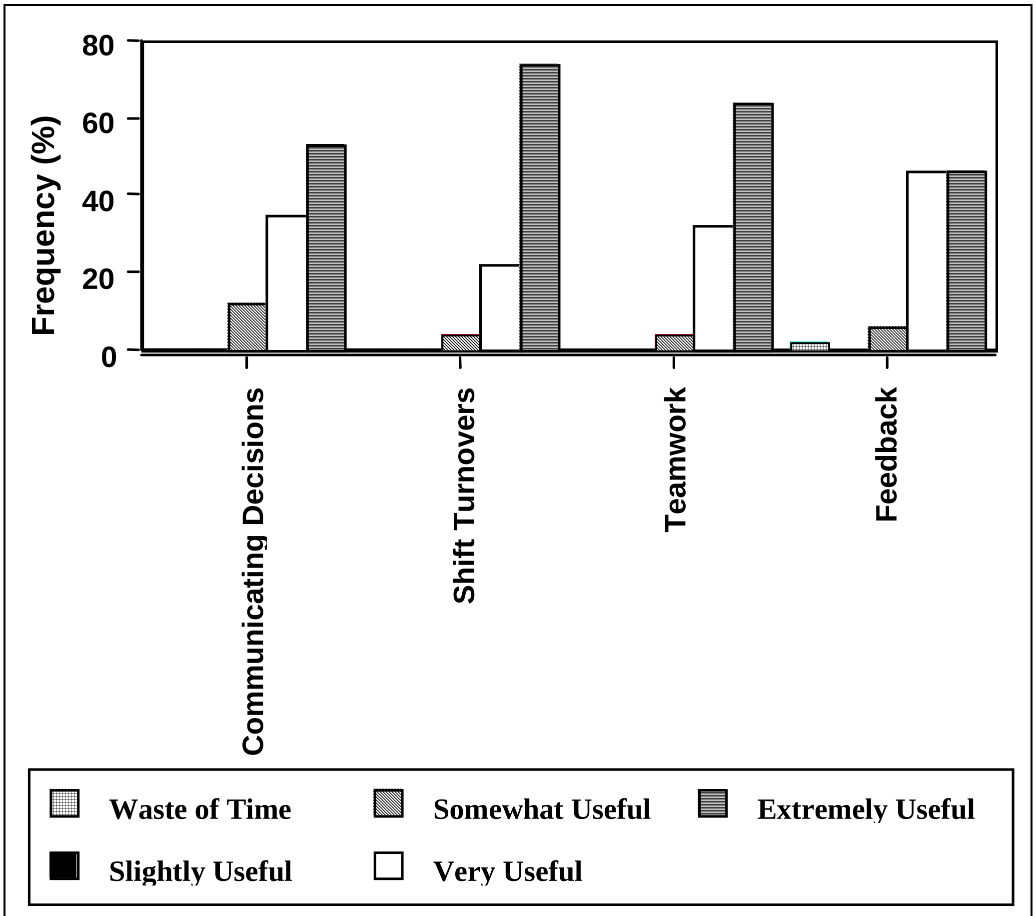


Figure 2.5. Evaluation of Course Module: Communications Topics

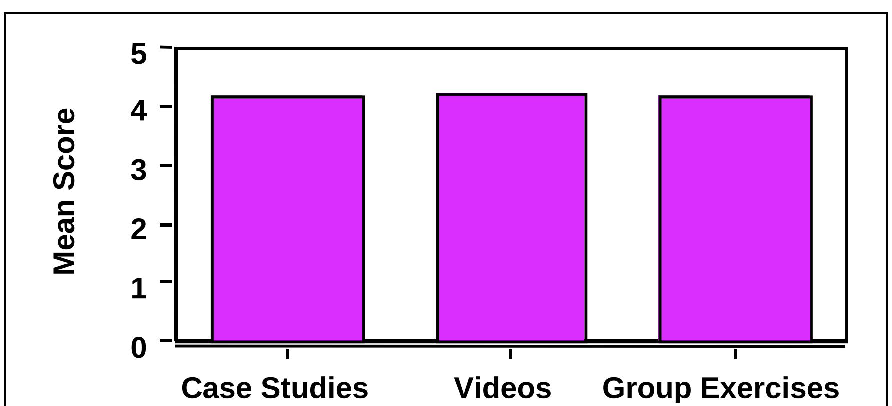


Figure 2.6. Evaluation of Course Training Methods & Media

In addition to rating topics in the course, participants also answered several questions related to the course as a whole, shown in **Figure 2.7**. The mean rating for the course overall was 4.3, corresponding to better than very useful. A whopping 89% of the participants viewed the course as either very useful or extremely useful, representing a high level of enthusiasm for the course. There were no low ratings of the course as a whole. Over 94% of the participants felt the course was either very useful or extremely useful for increasing aviation safety and teamwork effectiveness (mean rating of 4.4). Over 89% felt the course would be either very or extremely useful to others (mean rating of 4.3). When asked to what degree the course would affect their behavior on the job, 83% felt they would make a moderate change or a large change, as shown in **Figure 2.8**.

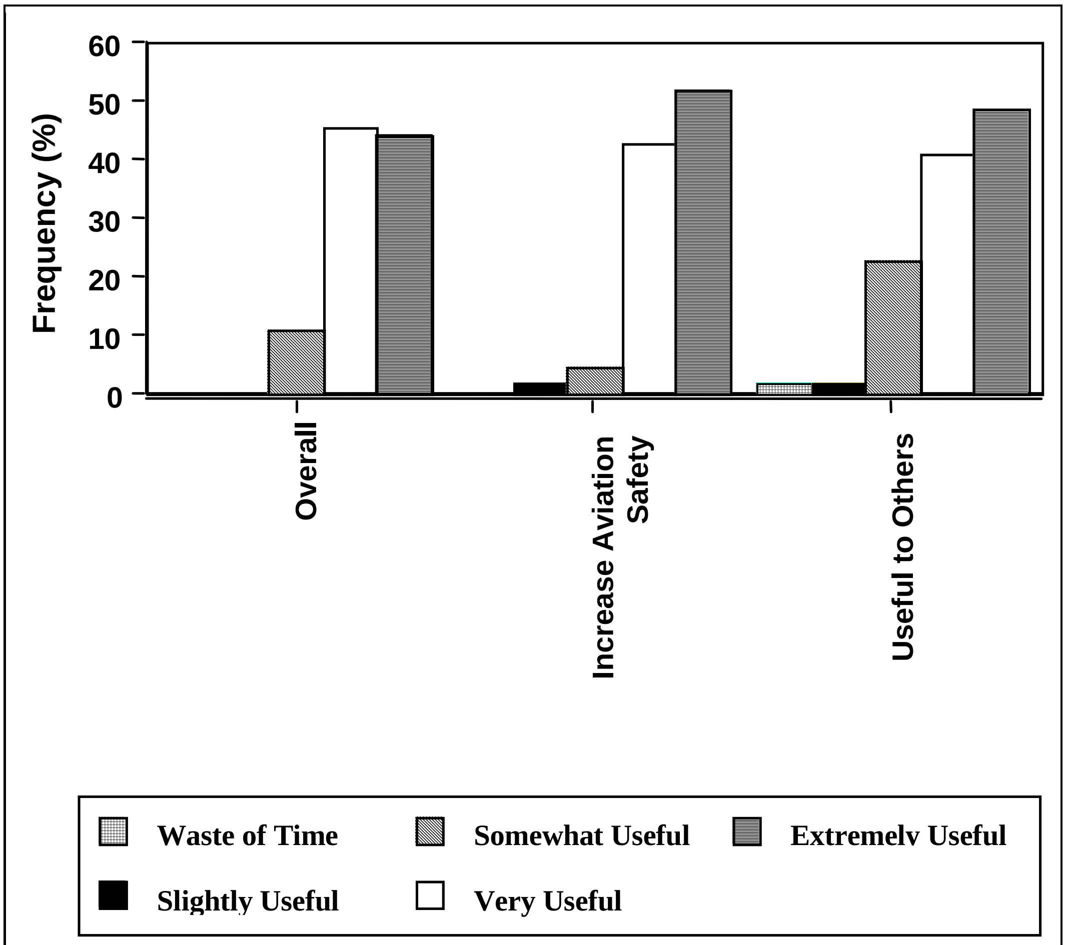


Figure 2.7. Overall Course Evaluation

Trainees also provided written comments on the course regarding how they would use the material. Over 95% of the course participants provided written comments. These comments were content coded and categorized into groups. As shown in **Figure 2.9**, participants stated they would use the training on the job to: become more aware and improve **SA** on the job (39%); increase open, positive communication including written communications (26%); and to try to learn more about other departments and improve SA between departments (21%). They also mentioned having better shift turnovers (14%), improving job flow and following procedures (11%), and breaking the chain of events to improve safety (12%).

Aspects of the course which participants particularly liked are shown in **Figure 2.10**. These comprised group involvement and discussion including interaction between different departments (55%), understanding how to communicate better (28%), and the case studies (22%). Also listed were **SA** as a whole (12%), chain of events and link busters (10%), videos (10%), and all of it (12%). Ten percent stated that they felt all **AMT**s needed this training.

Recommended improvements to the course are shown in **Figure 2.11**. Participants suggested providing even more examples, case studies, exercises, and discussion (26%), keeping a mix of trainees from different departments in the course (13%), and providing follow-up training (13%). Approximately 17% of the participants said no improvements were needed.

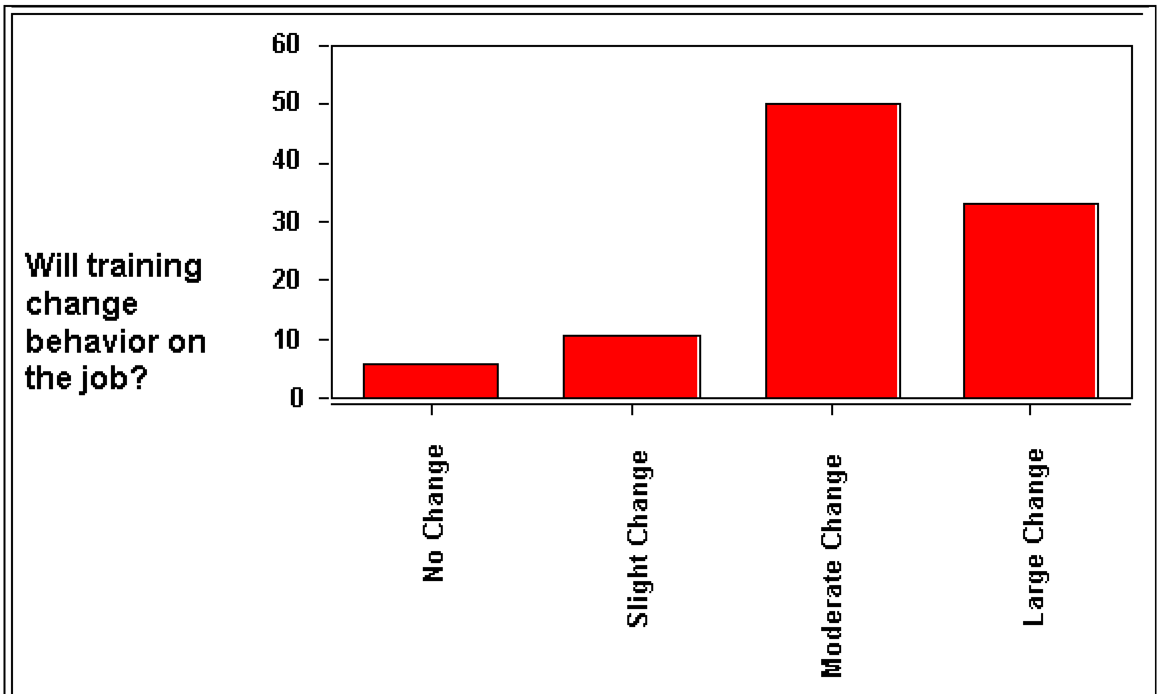


Figure 2.8. Perceived Affect of Course on Behavior

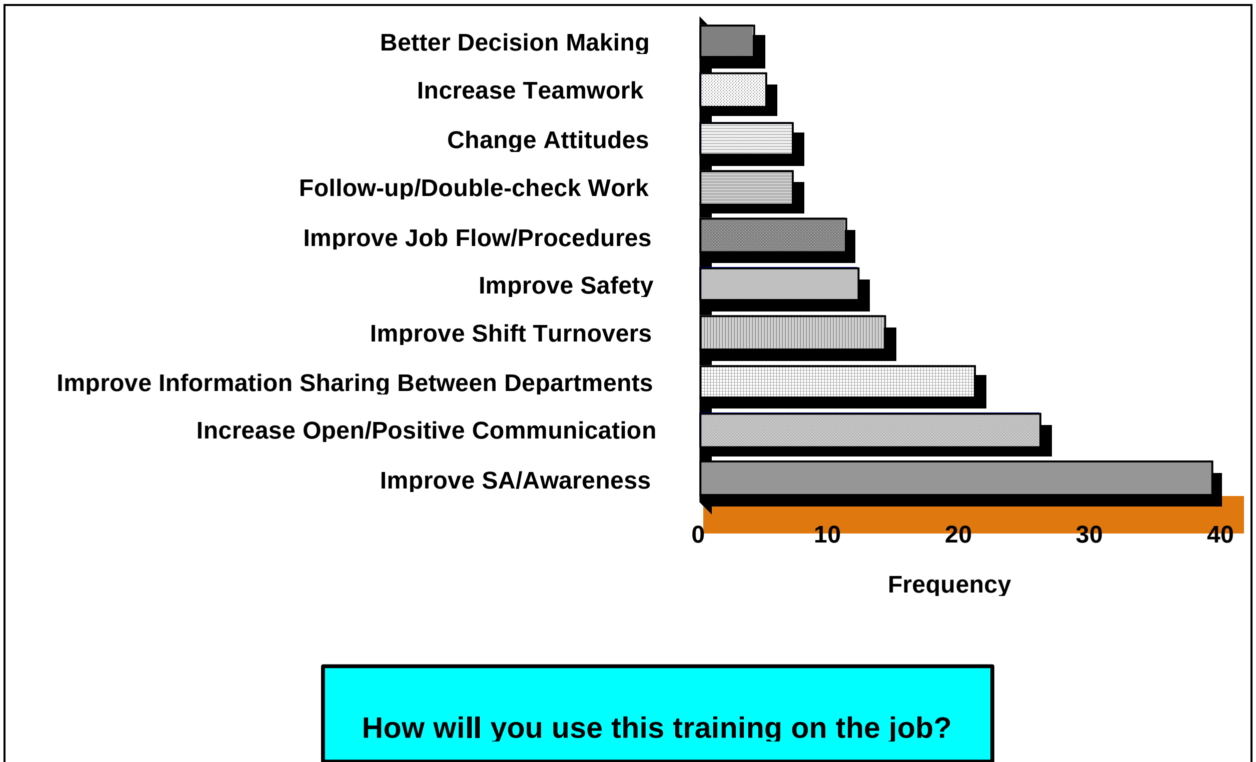


Figure 2.9. Participant's Use of Training on the Job

Overall, the evaluation that participants provided after taking the **SA** Team Training Course was overwhelmingly positive. Trainees felt the course was very useful and were complimentary about almost all aspects of the course. In particular they felt the amount of participation and job relevance provided by the examples, case studies and exercises were particularly important and wanted even more.

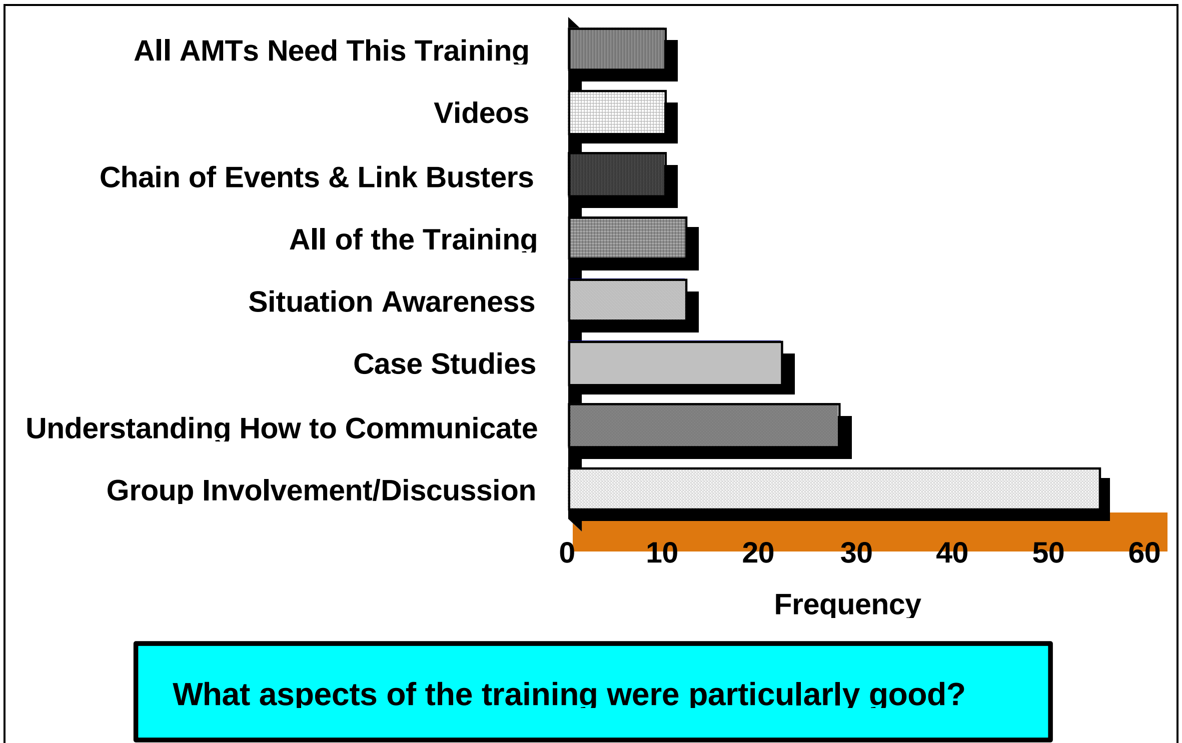


Figure 2.10. Preferred Aspects of the Training

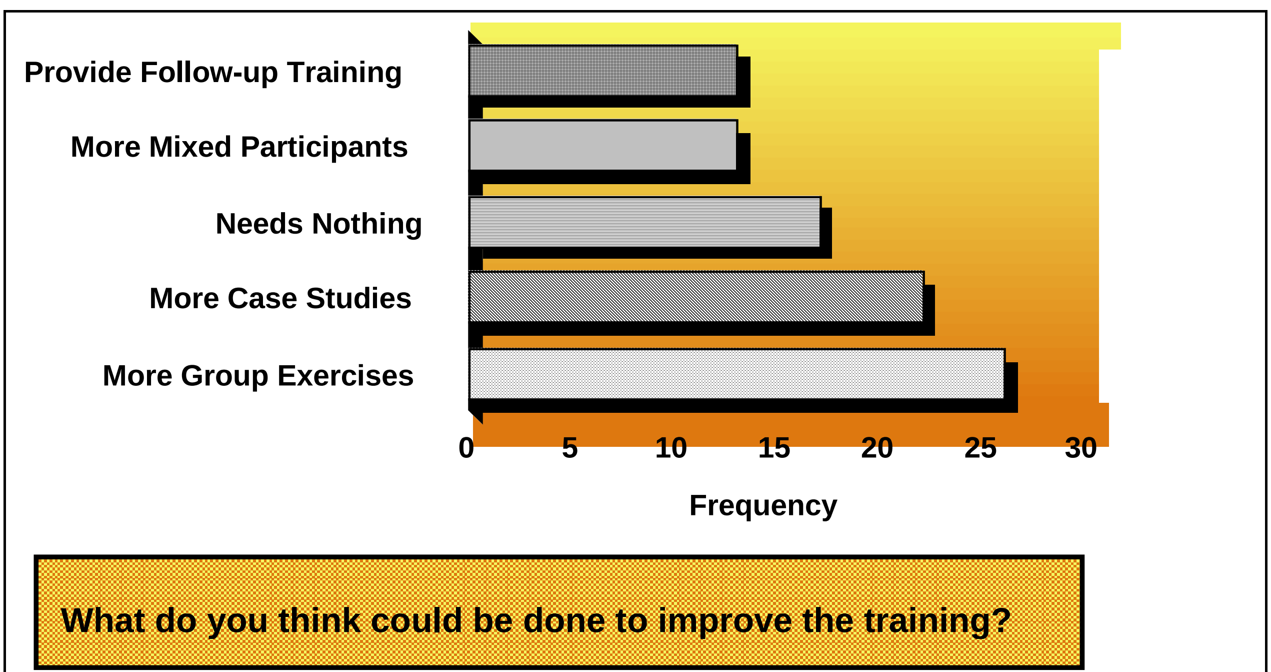


Figure 2.11. Recommended Course Modifications

2.4.2 Pre/Post Training Measures

The mean change in the post-test compared to the pre-test on each behavior (described in the pre/post self-reported **SA** behavioral measure form **Appendix 2-B**) was also assessed. A factor analysis on the questionnaire revealed a moderate degree of homogeneity. That is, responses on the items were somewhat interrelated; however, no large groupings of related factors were revealed to explain a large portion of the variance. Only one factor accounted for more than 10% of the variance, with most accounting for less than 5%. The questionnaire was, therefore, treated as a set of independent items. Changes on each item were compared for each subject using a paired comparison analysis (pre-test to post-test).

The Wilcoxon non-parametric statistical analysis revealed that attitudes and self-reported behaviors changed significantly on seven of the 33 items. These are shown in **Figures 2.12** and **2.13**. Participants reported after the training they would be more likely to keep others up-to-date with their status as they perform their jobs (an increase of 15%). They also were slightly more likely to report that they would try to keep up with what activities others were working on over the course of the shift (an increase of 10%). Both of these items relate to improved situation awareness across the team.

Participants reported they would be more likely to try to understand others' viewpoints when engaged in a disagreement with other departments (an increase of 15%). This relates to an effort to develop better shared mental models regarding other departments. In addition, participants reported changes in several behaviors related to improved communications and teamwork. They were more likely to report improved written communication when sending an aircraft with a minimum equipment list (MEL) to another station (an increase of 21%). Participants were more likely to report that they would make sure to pass on information about an aircraft and work status to the next station (an increase of 13%).

They were also more likely to report making sure all problems and activities are discussed during shift meetings (an increase of 11%), and encouraging others to speak up during shift meetings to voice concerns or problems (an increase of 12%).

These differences between the pre-test and post-test measures on **SA** related behaviors and attitudes indicates that in addition to participants responding positively to the course, they reported actual changes in behaviors they would make on the job as a result of the course, thus improving SA on the job both between and within maintenance teams.

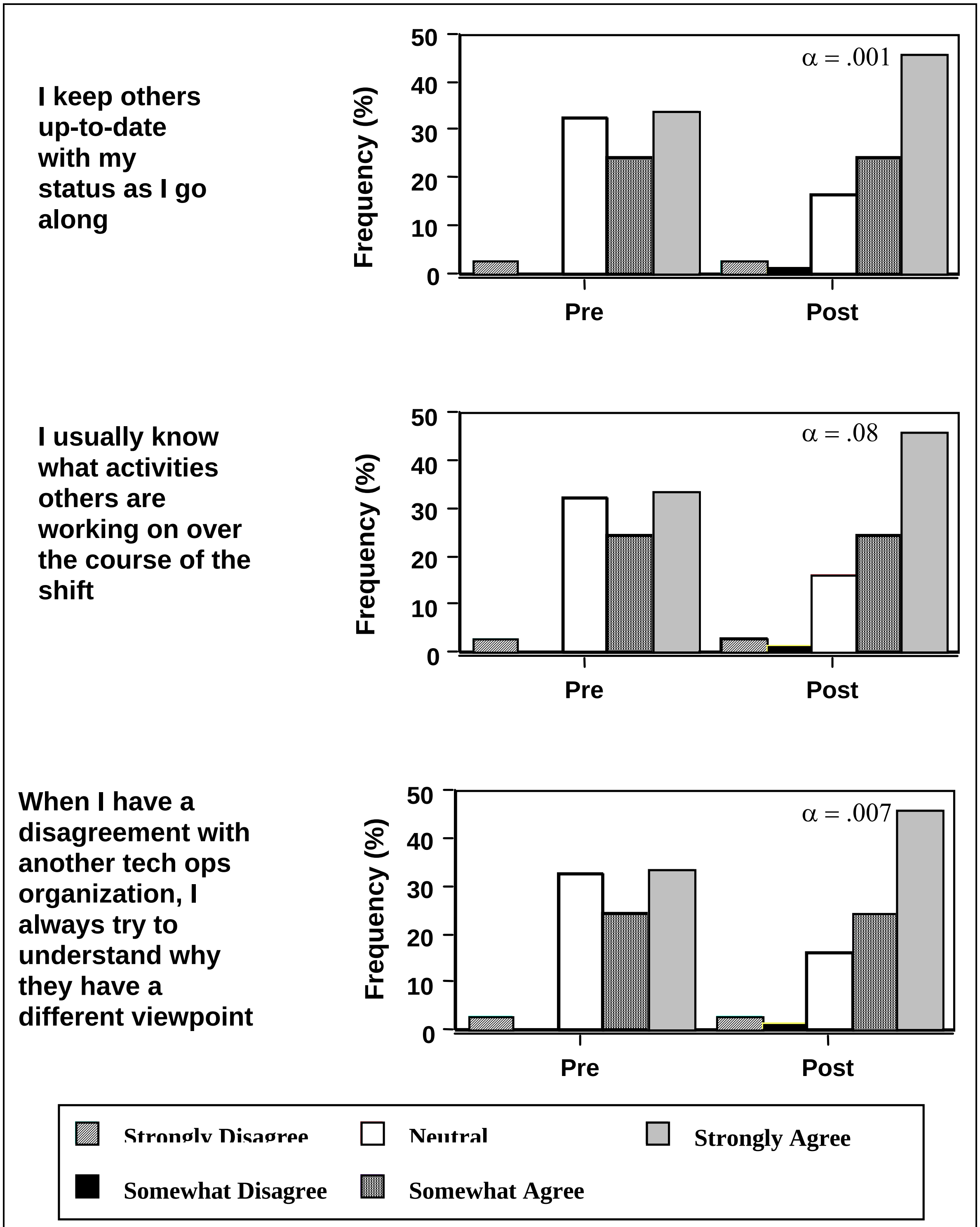
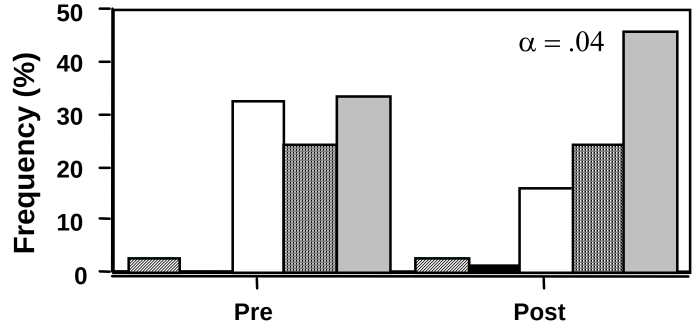
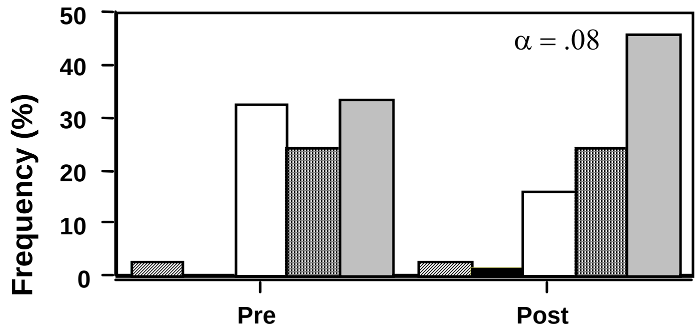


Figure 2.12. Reported Behavior Changes Resulting From Training

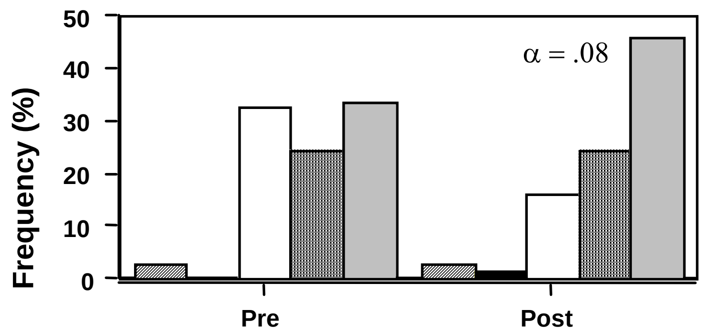
When I must MEL a problem for another shift or station, I always write down all the trouble shooting steps I have taken as well as what I think needs to be done



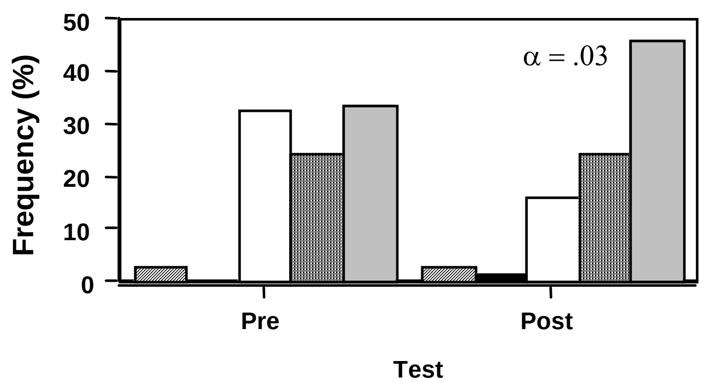
I always make sure all problems and ongoing activities are discussed during shift meetings



I always make sure to pass on information about each aircraft and work status when it goes to the next station



I work to encourage everyone to speak up during shift meetings to voice their concerns, problems and suggestions



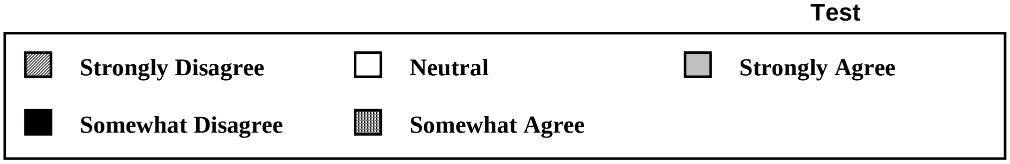


Figure 2.13. Reported Behavior Changes Resulting From Training

2.4.3 Changes in Behavior on the Job

In order to assess whether participants actually made the intended changes in their job behaviors following the course, the same form was again administered one month following the course. At the time of this analysis, the participants of only one course had been on the job for a full month

after the training session. Of these participants (17), six responses were available for this analysis (representing a return rate of 35% which is typical of mail-in questionnaires). A paired comparison of responses on each item between the post-test questionnaire and the one-month questionnaire was made using the Wilcoxon test. This analysis revealed no changes on any of the test items at a .05 level of significance. Therefore, it would appear that the behaviors participants reported they would engage in following the training were carried out in practice, at least for this small sample.

In addition, participants provided written comments to four questions. All returned forms included responses to these questions. These comments are summarized in **Tables 2.2** and **2.3**. As shown, these comments mirror the written comments provided immediately following the training.

Table 2.2. Comments on Training After 1 Month: Changes on Job
What changes have you made as a result of the Human Factors/MRM training?
Stop and think before charging through
Be more attentive to how Human Factors elements impact my work
Follow-up and double check all work
Provide better information for others
Spend more time learning other departments functions and point of view
More assertive, verbal and express concerns
How will you further use Human Factors/MRM training in the coming months?
Be a better team player
Teach others by example
Continue to be attentive and safety minded
Continue to pass on information to others
Be aware how my decisions affect others
Continue to spend time learning other departments function and viewpoints
Continue to work better with others

Table 2.3. Comments on Training After 1 Month: Evaluation
Looking back on it now, what aspects of the training were particularly good?
Group exercises
Being aware of when the slightest piece of the puzzle is missing can lead to severe consequences
Interaction in small groups with people from other departments (4)
What do you think could be done to improve Human Factors/MRM training?
Have management reinforce this training more actively
More case studies
More group exercises & interaction (2)
Discuss & practice more teamwork skills
More training

2.5 DISCUSSION OF FINDINGS

Overall, the **SA** Team Training Course was highly successful. The course content associated with all of the major training objectives was rated very highly with the vast majority of participants rating each area as very useful or extremely useful. The course was viewed overall as being between very useful and extremely useful for increasing aviation safety and in terms of usefulness to others. The course training methods and media (including the case studies, videos, and group exercises) were viewed as particularly successful and supportive in acquiring the learning objectives. In fact, the only suggestion many participants had for improvement was to use even more of these materials. Clearly an instructional strategy that emphasized experiential learning and participation was effective for achieving the training objectives and facilitating the learning process.

The course was administered to a fairly experienced aviation maintenance group who represented a wide range of departments and skill areas within the Technical Operations Department of the airline. The fact that the course included such a mix of participants also was viewed as a key ingredient in its success. The mixed group allowed people from different areas to better understand each other's viewpoints, contributing to the development of shared mental models and open communications for future decision making.

The majority of participants felt that the course would result in making changes in their behaviors on the job. The results of the follow-up questionnaire, administered one month after the training course, supported these intentions. The self-reported behavior follow-up questionnaire showed that participants were making the changes they had intended to make following the training.

These results are very similar to those achieved in previous evaluations of **MRM** training programs which have been shown to be highly successful in improving safety and performance in aviation maintenance. **Figure 2.14** illustrates the enthusiastic support for Crew Resource Management (CRM) and MRM courses by flight operations and maintenance participants respectively as measured immediately following training.[5] This is compared to the response measured in this study to the Team **SA** Training Course. Nearly two-thirds of the flight operations groups reported that the CRM training was very useful or extremely useful.[6] Even though this response is very strong, the response of maintenance personnel to the MRM training was even stronger. Ninety percent of the maintenance personnel sampled at two different airlines felt the course was very useful or extremely useful.[7,8] The Team SA Training Course, evaluated in this study, drew a response that was comparable to that found for the highly successful MRM Training program that was conducted at the same airline.5 Based on this result, it can be concluded that the Team SA Training Course is viewed as highly useful at a rate that is favorably compared to previous courses in the MRM/CRM area.

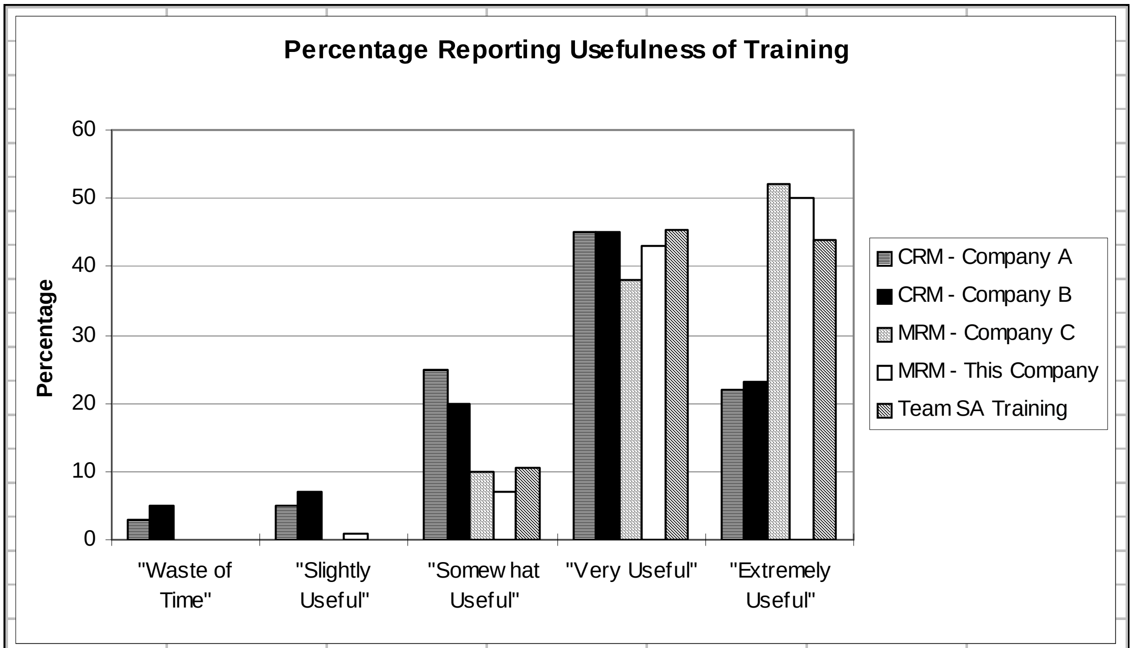


Figure 2.14. Comparison of Team SA Training Course Usefulness to CRM/MRM Courses

Figure 2.15 compares the post-training assessment of the degree to which trainees felt they would change their behavior as a result of the course to similar assessments from **CRM** and **MRM** programs.[5] The comparison samples are from flight operations CRM courses[9] and a maintenance operations MRM course conducted at the same airlines as the present study.[5] Nearly 90% of the trainees in the MRM course felt they would make a moderate or large change as a result of the course, as compared to approximately 30% in the flight operations sample. In comparison, 86% of the trainees in the Team **SA** Training Course gave a similar response, again comparing favorably with previous MRM evaluations. The maintenance groups regard MRM and Team SA Training as having a strongly positive potential for impacting both job performance and safety.

2.6 RECOMMENDATIONS

As a result of this analysis, very few modifications to the course appear to be needed. Participants mainly wanted more of everything: more interaction, more case studies, more group exercises and more discussion. They particularly felt management support of the concepts (both in training and in practice) and the mixing of the departments was important. As the course already features a high level of all these elements, these findings can be taken to mean that the course is designed and developed effectively, supporting the achievement of the training objectives. These findings can serve to reinforce the value of the instructional design and the delivery of the course by the airline facilitator who provided many case studies and exercises in addition to those initially provided.

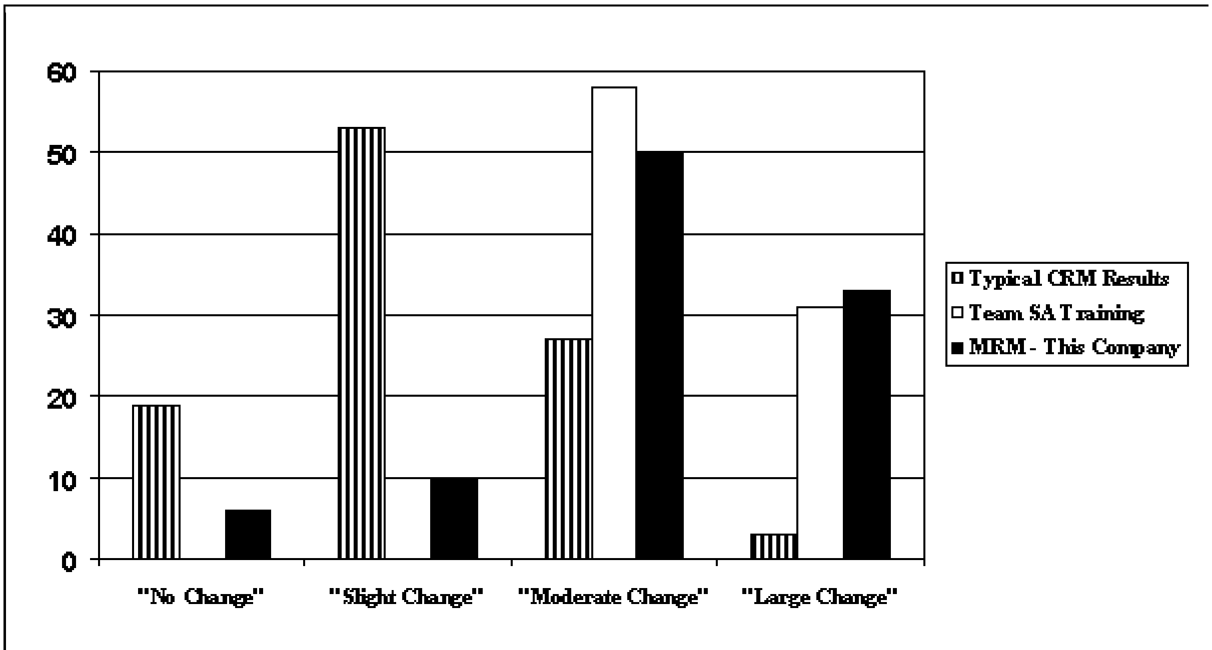


Figure 2.15.   Comparison of Self-Reported Behavior Change with Team

This evaluation represents an initial evaluation of the Team **SA** Training Course in its prototype implementation phase. It was the first time the course had been offered to a group of technical operations personnel. The fact that it was viewed so positively as useful to maintenance operations is highly indicative of its success. It is strongly recommended that the airline continue to implement the course and that additional airlines consider adopting the course.

These findings are based on the responses of an initial group of course participants. To further validate these findings, this evaluation should be continued with succeeding groups of trainees in the course. In addition, more follow-up research is needed to validate the results of the on-the-job behavior changes. At the time of this analysis, very few course participants had been back on the job for one full month. Therefore, the sample size for this analysis was very small, probably too small for much confidence in the results. By following up with the remaining participants at the one month point (and again at longer durations), more reliable results can be obtained regarding the degree to which the training effected job behaviors related to **SA**.

Finally, it would be highly desirable to ascertain the degree to which the training impacts critical maintenance performance measures at the airline. The bottom-line objective is to reduce maintenance errors, improve aviation safety and improve performance. Since the course had been administered to so few participants (scattered over 9 cities), making any meaningful assessment of the effect of the training on performance outcomes was not feasible in this study. In the future, however, the effect of the training implementation on several key safety and performance measures should be assessed. These include:

- Safety performance measures: ground damage, occupational injury rates, loss days
- Dependability performance measures: departures times, head starts
- Efficiency performance measures: **MEL**s, rotable and expendable parts, overtime.

A longitudinal trend analysis of these measures across departments and locations with personnel participating in the training would be highly beneficial. This must be done over a period of time in which large portions of the airline receive the Team **SA** Training program.

Overall, the value of the Team **SA** Training Program has been supported by this analysis and its future implementation within this airline and others is strongly encouraged.

2.7 REFERENCES

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International Journal of Aviation Psychology, *1*(4), 287-300.

2.8 APPENDICES

2.8.1 APPENDIX 2-A: TRAINING ASSESSMENT FORM

MRM--II Team **SA** Training Experience and Evaluation

For each of the topic areas of training techniques listed below, please rate the value of this aspect of the training to you. Rate each item by choosing the number on the scale below which best describes your personal opinion and then write the number beside the item.

1	2	3	4	5
Waste of Time	Slightly Useful	Somewhat Useful	Very Useful	Extremely Useful

MRM Review and Background

____ Human Error

_____ Human Factors Elements

_____ SHELL

_____ Chain of events

_____ “Link Busters”

_____ Dominos

_____ Swiss Cheese

Situation Awareness (SA)

____ Levels of **SA**

____ Role of **SA**

____ **SA** Problems

____ Consequences of Poor **SA**

____ "Loosing the Bubble"

____ Developing **SA**

____ Shared mental models

1	2	3	4	5
Waste of Time	Slightly Useful	Somewhat Useful	Very Useful	Extremely Useful

Communication

_____ Communicating Decisions

_____ Shift Turnovers

_____ Teamwork

_____ Feedback

CASE STUDIES

____ American Airlines Flight #191

____ Aloha Airlines, Flight #243

____ Nationair, Flight #2120

____ British Airways, flight #5390

____ **AMT** trapped in MLG Doors

____ Eastern Airlines, Flight #855

____ Loss of Thrust Reverser on Landing

____ Inflight Separation of the Horizontal Leading Edge

____ Inadvertent Engine Start in Hangar

____ Maintenance Taxi- Collision with another Aircraft

____ Maintenance Taxi into Terminal #1

____ Maintenance Taxi into Terminal #2

1	2	3	4	5
Waste of Time	Slightly Useful	Somewhat Useful	Very Useful	Extremely Useful

VIDEOS:

_____ Maintenance Video

GROUP EXERCISES:

____ **SA** problems and solutions within Tech Ops

____ Gaps between Maintenance Operations groups

____ Written communication

____ Information "gaps" between maintenance operations groups

____ Teamwork Exercises

____ Feedback Exercise

____ **OVERALL,** how useful did you find the training

HUMAN FACTORS AND MRM **TRAINING**:

1. Human Factors/**MRM** training has the potential to increase aviation safety and teamwork effectiveness.

1	2	3	4	5
Waste of Time	Slightly Useful	Somewhat Useful	Very Useful	Extremely Useful

2. This Human Factors/**MRM** seminar will be useful to others.

1	2	3	4	5
Waste of Time	Slightly Useful	Somewhat Useful	Very Useful	Extremely Useful

3. Is the training going to change your behavior on the job? (circle one from list below)

No Change **A Slight Change** **A Moderate Change** **A Large Change**

4. How will you use this training on your job?

____

____

____

5. What aspects of the training were particularly good?

____

____

____

6. What do you think could be done to improve the training?

____

____

____

PLEASE GO ON TO THE NEXT PAGE

BACKGROUND INFORMATION

JOB TITLE: ____

YEARS IN PRESENT POSITION with CAL: ___________

TOTAL YEARS with CAL: ______________

DEPARTMENT YOU WORK IN: ___________________________

YOUR CITY NAME OR CODE: _______________________

SHIFT: _______________________

PAST EXPERIENCE or TRAINING (# OF YEARS: fill in below)

__________ MILITARY

__________ TRADE SCHOOL

__________ COLLEGE

__________ OTHER AIRLINE

(Specify ____________________________)

YEAR of BIRTH: 19______

MALE (**M**) or FEMALE (**F**): __________

2.8.2 APPENDIX 2-B: PRE/POST EVALUATION FORM

Pre-Training Last 4 digits of SS#_________

Session_____

MRM II: Situation Awareness

Rate the degree to which the following statements describe your **<u>current</u>** behavior in the workplace:

1	2	3	4	5
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

_____ (1) It takes unneeded effort to find the information I need on workcards, logs and the computer.

_____ (2) When performing my tasks, I am often distracted by other tasks that need my attention.

_____ (3) I often already know what is wrong with a system, even before I take it apart because I have worked on aircraft for so long.

_____ (4) When performing my tasks, I am often distracted by the conversations and activities of others around me.

_____ (5) I try to develop a better understanding of how systems work by learning from each job.

_____ (6) I keep others up-to-date with the status of my tasks as I go along.

_____ (7) I usually know what activities others are working on over the course of the shift.

_____ (8) I make sure to pass on to the next shift the status of all ongoing activities and tasks.

_____ (9) I actively work with people from the prior shift to find out what tasks have been done and what tasks still need to be done.

_____ (10) I am extra vigilant in making sure that I read information correctly when working in poorly lit environments.

_____ (11) At the end of the shift I always make sure to double check for loose parts and tools.

_____ (12) During walk arounds, I am extra careful to check for loose parts and tools.

_____ (13) I am always careful to follow the workcards exactly on every step.

_____ (14) When I have made a difficult repair, I follow up down the line to make sure the repair worked to solve the problem.

_____ (15) I never assume that someone else has performed a task or step; I always check to insure that it has been done.

_____ (16) I fully understand the tasks and goals of other tech ops organizations.

_____ (17) When I have a disagreement with another tech ops organization, I always try to understand why they have a different viewpoint.

_____ (18) When working with others, I always tell them what I think needs to be done.

_____ (19) I always explain the reasons for my decisions when I am telling others what needs to be done.

_____ (20) When I must **MEL** a problem for another shift or station, I always write down all the trouble shooting steps I have taken as well as what I think needs to be fixed.

_____ (21) When I am having a disagreement with someone, I always try to understand why they are making a different recommendation or decision.

_____ (22) I always make sure all problems and ongoing activities are discussed during shift meetings.

_____ (23) I always make sure to pass on information about each aircraft and work status when it goes to the next station.

_____ (24) When I am involved in a difficult joint trouble shooting problem, try to be very explicit with others about what has been done and what I think needs to be done.

_____ (25) I always document everything I do very carefully and fully in the log.

_____ (26) During a shift meeting I make sure that I pass on known information on aircraft status and special problems.

_____ (27) During a shift meeting I work to create a shared understanding of what is going on across the whole team.

_____ (28) I make the goals of the maintenance team as a whole explicit during the shift meeting.

_____ (29) During a shift meeting I work to insure that each person understands their individual tasks and how their tasks may have an impact on or by impacted by the tasks of others.

_____ (30) People on my team work to help each other with their tasks.

_____ (31) People on my team usually understand what tasks others on the team are doing.

_____ (32) People on my team work to keep each other up-to-date on the status of their activities over the course of the shift.

_____ (33) I work to encourage everyone to speak up during shift meetings to voice their concerns, problems and suggestions.

Post-Training Last 4 digits of SS#_________

Session_____

MRM II: Situation Awareness

Rate the degree to which the following statements describe your **intended** behavior in the workplace:

1	2	3	4	5
strongly disagree	disagree	somewhat	neutral	somewhat
			agree	strongly agree

_____ (1) It takes unneeded effort to find the information I need on workcards, logs and the computer.

_____ (2) When performing my tasks, I am often distracted by other tasks that need my attention.

_____ (3) I often already know what is wrong with a system, even before I take it apart because I have worked on aircraft for so long.

_____ (4) When performing my tasks, I am often distracted by the conversations and activities of others around me.

_____ (5) I try to develop a better understanding of how systems work by learning from each job.

_____ (6) I keep others up-to-date with the status of my tasks as I go along.

_____ (7) I usually know what activities others are working on over the course of the shift.

_____ (8) I make sure to pass on to the next shift the status of all ongoing activities and tasks.

_____ (9) I actively work with people from the prior shift to find out what tasks have been done and what tasks still need to be done.

_____ (10) I am extra vigilant in making sure that I read information correctly when working in poorly lit environments.

_____ (11) At the end of the shift I always make sure to double check for loose parts and tools.

_____ (12) During walk arounds, I am extra careful to check for loose parts and tools.

_____ (13) I am always careful to follow the workcards exactly on every step.

_____ (14) When I have made a difficult repair, I follow up down the line to make sure the repair worked to solve the problem.

_____ (15) I never assume that someone else has performed a task or step; I always check to insure that it has been done.

_____ (16) I fully understand the tasks and goals of other tech ops organizations.

_____ (17) When I have a disagreement with another tech ops organization, I always try to understand why they have a different viewpoint.

_____ (18) When working with others, I always tell them what I think needs to be done.

_____ (19) I always explain the reasons for my decisions when I am telling others what needs to be done.

_____ (20) When I must **MEL** a problem for another shift or station, I always write down all the trouble shooting steps I have taken as well as what I think needs to be fixed.

_____ (21) When I am having a disagreement with someone, I always try to understand why they are making a different recommendation or decision.

_____ (22) I always make sure all problems and ongoing activities are discussed during shift meetings.

_____ (23) I always make sure to pass on information about each aircraft and work status when it goes to the next station.

_____ (24) When I am involved in a difficult joint trouble shooting problem, try to be very explicit with others about what has been done and what I think needs to be done.

_____ (25) I always document everything I do very carefully and fully in the log.

_____ (26) During a shift meeting I make sure that I pass on known information on aircraft status and special problems.

_____ (27) During a shift meeting I work to create a shared understanding of what is going on across the whole team.

_____ (28) I make the goals of the maintenance team as a whole explicit during the shift meeting.

_____ (29) During a shift meeting I work to insure that each person understands their individual tasks and how their tasks may have an impact on or by impacted by the tasks of others.

_____ (30) People on my team work to help each other with their tasks.

_____ (31) People on my team usually understand what tasks others on the team are doing.

_____ (32) People on my team work to keep each other up-to-date on the status of their activities over the course of the shift.

_____ (33) I work to encourage everyone to speak up during shift meetings to voice their concerns, problems and suggestions.

2.8.3 APPENDIX 2-C: EVALUATION OF CHANGES ON JOB

Post-Training: 1 month followup Last 4 digits of SS#_________

Session_____

MRM II: Situation Awareness

Rate the degree to which the following statements describe your **current** behavior in the workplace:

1	2	3	4	5
strongly disagree	disagree	somewhat	neutral agree	somewhat agree	strongly

_____ (1) It takes unneeded effort to find the information I need on workcards, logs and the computer.

_____ (2) When performing my tasks, I am often distracted by other tasks that need my attention.

_____ (3) I often already know what is wrong with a system, even before I take it apart because I have worked on aircraft for so long.

_____ (4) When performing my tasks, I am often distracted by the conversations and activities of others around me.

_____ (5) I try to develop a better understanding of how systems work by learning from each job.

_____ (6) I keep others up-to-date with the status of my tasks as I go along.

______ (7) I usually know what activities others are working on over the course of the shift.

______ (8) I make sure to pass on to the next shift the status of all ongoing activities and tasks.

______ (9) I actively work with people from the prior shift to find out what tasks have been done and what tasks still need to be done.

______ (10) I am extra vigilant in making sure that I read information correctly when working in poorly lit environments.

______ (11) At the end of the shift I always make sure to double check for loose parts and tools.

______ (12) During walk arounds, I am extra careful to check for loose parts and tools.

______ (13) I am always careful to follow the workcards exactly on every step.

______ (14) When I have made a difficult repair, I follow up down the line to make sure the repair worked to solve the problem.

______ (15) I never assume that someone else has performed a task or step; I always check to insure that it has been done.

______ (16) I fully understand the tasks and goals of other tech ops organizations.

______ (17) When I have a disagreement with another tech ops organization, I always try to understand why they have a different viewpoint.

______ (18) When working with others, I always tell them what I think needs to be done.

______ (19) I always explain the reasons for my decisions when I am telling others what needs to be done.

______ (20) When I must **MEL** a problem for another shift or station, I always write down all the trouble shooting steps I have taken as well as what I think needs to be fixed.

______ (21) When I am having a disagreement with someone, I always try to understand why they are making a different recommendation or decision.

______ (22) I always make sure all problems and ongoing activities are discussed during shift meetings.

______ (23) I always make sure to pass on information about each aircraft and work status when it goes to the next station.

______ (24) When I am involved in a difficult joint trouble shooting problem, try to be very explicit with others about what has been done and what I think needs to be done.

_____ (25) I always document everything I do very carefully and fully in the log.

_____ (26) During a shift meeting I make sure that I pass on known information on aircraft status and special problems.

_____ (27) During a shift meeting I work to create a shared understanding of what is going on across the whole team.

_____ (28) I make the goals of the maintenance team as a whole explicit during the shift meeting.

_____ (29) During a shift meeting I work to insure that each person understands their individual tasks and how their tasks may have an impact on or by impacted by the tasks of others.

_____ (30) People on my team work to help each other with their tasks.

_____ (31) People on my team usually understand what tasks others on the team are doing.

_____ (32) People on my team work to keep each other up-to-date on the status of their activities over the course of the shift.

_____ (33) I work to encourage everyone to speak up during shift meetings to voice their concerns, problems and suggestions.

1. What changes have you made as a result of the Human Factors/**MRM** training?

____

____

____

____

2. How will you further use the Human Factors/**MRM** training in the coming months?

____

____

____

____

3. Looking back on it now, what aspects of the training were particularly good?

____

____

____

____

4. What do you think could be done to improve Human Factors/**MRM** training?

____

____

____

____

BACKGROUND INFORMATION

JOB TITLE: ____

YEARS IN PRESENT POSITION with CAL: ____________

TOTAL YEARS with CAL: _______________

DEPARTMENT YOU WORK IN: ____________________________

YOUR CITY NAME OR CODE: _________________________

SHIFT: ________________________

PAST EXPERIENCE or TRAINING (# OF YEARS: fill in below)

___________ MILITARY

___________ TRADE SCHOOL

___________ COLLEGE

___________ OTHER AIRLINE
(Specify _____________________________)

YEAR of BIRTH: 19______
MALE (**M**) or FEMALE (**F**): ___________

CHAPTER 3
LINE-ORIENTED HUMAN FACTORS TRAINING:MRM III

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3.1 INTRODUCTION

This report was created to help plot future directions for Maintenance Resource Management. Maintenance Resource Management (MRM) is a "general process for improving communication, effectiveness and safety in airline maintenance operations."[1] Much as crew resource management (CRM) was created to address safety and teamwork issues in the cockpit, FAA researchers, in conjunction with industry partners, developed MRM to address teamwork deficiencies within the hanger. By doing so, it is hoped that MRM will foster a culture of safety in all maintenance operations.

Although **MRM** is an outgrowth of **CRM**, differences between the two exist. Other than the obvious (training population, training context), other, more subtle differences affect the transition from CRM to MRM.[2] The purpose of this report is three-fold. First, both MRM and CRM are reviewed within the context of safety and training. Second, the similarities and the differences between CRM and MRM are highlighted. Third, recommendations for developing the next stage in MRM training, MRM III, are presented.

3.2 ACCIDENT CAUSATION

An "accident" as defined by the Random House Dictionary of the English language (2nd ed.) is "any event that happens unexpectedly without a deliberate plan or causes; by chance, fortune, or luck." However, most accidents rarely occur by chance at all, and their causes can be tracked.[3] Accidents are usually the result of an accumulation of factors whose results are seen in their consequences. These factors are numerous and range from the measured reliability, both on an individual and organizational level, of completing a task successfully to reliability's converse, the incidence of error present during task completion.

A widely accepted model of human error is Reason's classification of unsafe acts.[3] The defining characteristic of Reason's taxonomy involves the intentionality of the act or behavior which led to the mishap. Reason asserts that unsafe acts can be categorized as either intentional or unintentional. Unintentional actions are due to either memory failures or failures of attention.

In addition to the intentionality of the error actions, error may have differential effects, especially in a systemic analysis of mishaps and disasters. Reason distinguishes between two types of errors: 1) active errors, whose effects are felt immediately in a system, and 2) latent errors, whose effects may lie dormant until triggered later, usually by other mitigating factors.[3] The presence of defenses or safeguards in a system can usually prevent the effects of latent errors from being felt by closing the "window of opportunity" during which an active failure may be committed.

Active errors are usually the result of "front-line" operators such as pilots, air traffic controllers, or anyone else with direct access to the dynamics of a system. Latent errors, on the other hand, are associated with those individuals separated by time and space from the consequences of the system. Examples include architects, hardware designers, and maintenance personnel. Differences between active and latent errors cannot be over emphasized; each type of error helps to shape the type of training required to correct them. Therefore, maintenance personnel may require more thorough human factors and operations training to account for their susceptibility to latent errors.

In an example specifically related to aircraft maintenance, Marx and Graeber categorized human error two ways.[4] The first refers to an error which results in a discrepancy that was not present prior to initiating the maintenance task. Such an error is comparable to an error of commission. Examples of these error types include the incorrect installation of a unit or damaging a piece of equipment in the maintenance process. The second error category includes those errors in which damage results from the failure to detect aircraft degradation in a maintenance task. This is akin to an error of omission. An example of such an error could include the failure to notice a structural fatigue crack in a visual inspection. Though **MRM** does not address these particular error categories short of training **AMT**s to be aware of them, it is important to note that many researchers have studied, and continue to study, the role of the AMT in accident causation.

3.3 INSTRUCTION SYSTEMS DESIGN

Training is defined by Goldstein as the "systematic acquisition of skills, rules, concepts, or attitudes that result in improved performance in another environment", and is divided into three phases.[5] The first is the *needs assessment phase*, a process of determining what "skills, rules, concepts, or attitudes" should be trained and whom should receive the training. The *training phase* which follows encompasses the selection and design of the actual training program and its implementation. Finally, the *evaluation phase* assesses a training program in order to judge its effectiveness or, in other words, test the notion that the training "resulted" in improved performance. Together, these phases embody the "systematic" process favored by most training theorists and practitioners. Though there are several models of training in the literature, **Table 3.1** lays out the basic instructional design as proposed by Goldstein.

Table 3.1. Generic Instructional Design Methodology

Phase I: **Needs Assessment**	1. Conduct needs assessment. a. organizational analysis b. task analysis c. person analysis 2. Create instructional objectives.	
Phase II: **Training and Development**	1. Select/Design instructional programs. a. select/develop media 2. Deliver training.	Develop evaluation criteria (occurs concurrently).
Phase III: **Evaluation**	1. Test training effectiveness. a. trainee reaction b. trainee learning c. trainee behavior d. organizational effectiveness 2. Revise training if necessary.	Match evaluation criteria to instructional objectives through experimental design (occurs concurrently).

3.3.1 Training Evaluation

The final step in a training development program is the training evaluation. Evaluation, as defined by Goldstein[5] is "the systematic collection of descriptive and judgmental information necessary to make effective training decisions related to the selection, adoption, value, and modification of various instructional activities." In short, the evaluation phase allows one to test if the training program is, first, beneficial and, second, has truly had the desired effect on trainees. This definition accounts for the dynamic nature of most training programs, allowing one to modify the evaluated course to achieve multiple instructional objectives. It is important to consider the evaluation stage of training *before* developing a final program. In most cases, the ability to evaluate properly a training program is driven by its initial structure. Therefore, a cursory discussion of training evaluation is presented.

Before choosing an evaluation technique, however, one must consider a variety of methodological and organizational constraints. From the methodological standpoint, just as criteria were developed for training to represent the desired job skills, criteria must also be developed to measure adequately a training program's success.[5] In order to achieve this, relevant criteria must be chosen that accurately reflect both the knowledge, skills and abilities (KSAs) developed during needs analysis *and* the objectives specified by the training program itself. For example, just because a trainee is able to demonstrate a new skill, such as the ability to use a new word processor, that does not ensure that the goal of the program, switching an entire office to a word processing standard, will be achieved. Thus, both goals are important for a full training evaluation.

Finally, four levels of evaluation criteria have been identified.[6] They are reaction, learning, behavior, and results. Reaction and learning refer to the extent that a trainee likes a program and learn relevant information from it, respectively. **MRM** III represents the final stage in the development of MRM training. Though reaction and learning-level criteria are important and can be measured, behavioral and performance-level criteria remain the primary focus of MRM III evaluation.

3.3.2 Safety Training

Training for enhancing safety has long been a practice in industry. Compliance with the Occupational Safety and Health Administration (OSHA) regulations has been the driving factor behind many of these safety training initiatives.[7] However, beyond this mere compliance, a safe workplace ensures uninterrupted and continuous operations, especially when reliability (e.g., smoothly running aircraft) is one of the workplace's main goals.[8] Therefore, safety training is well-known throughout industry.

One study that documents the impact of safety training on an organization was conducted by Komaki, Heinzmann, and Lawson.[9] The goal of this training program was to reduce the mishap rate in the vehicle maintenance division of a city's department of public works.

- Raters conducted a series of 165 observations, each lasting for a total of 60 minutes, over a 45-week period.
- "Safe" (e.g., wearing goggles) and "unsafe" (e.g., no goggles) behaviors were targeted.
- A multiple-baseline design was employed using five experimental conditions: baseline, training only, training with feedback 1, training only 2, and training with feedback 2.

The results indicate that training with feedback is the most effective at reducing accidents, though training by itself also helps to reduce unsafe behavior. The power of feedback is consistent with the definition of safety climate proposed by Zohar.[10] To review, safety climate relies on employee perceptions of how management prioritizes safety. Feedback from supervisors may provide salient examples to create a safety climate. Nevertheless, safety-related behaviors appear to be both trainable and beneficial to an organization.

Currently, a popular training method is on-the-job training (OJT), otherwise known as the "buddy" system.[8] However, anecdotal evidence indicates that the structure of such training in the hanger is mostly informal and depends heavily on the skills of the more experienced team member. In fact, most OJT programs in general are not planned and, as a result, do not work well.[5] In this sense, OJT has proven to be inadequate for teaching skills related to maintenance resource management.

3.3.3 Safety Training Evaluation

Because the focus of **MRM** training is on safety-related behavior, results-level measures can be difficult to obtain. Specifically, results-level measures of safety are best reflected by the number of mishaps occurring during maintenance activities. The success of MRM could then be measured in terms of the reduction of those mishaps. The general rarity of such phenomenon makes gathering enough data to perform significantly powerful statistical tests a lengthy process.[11] However, such data are typically collected in compliance with Occupational Safety and Health Administration (OSHA) regulations as well as for companies' own safety departments. Therefore, mishap data typically do exist. However, one should allow for enough time to collect an adequate amount of data in order to make generalizations about the effect of training on worker mishaps.

Nevertheless, other evaluation criteria exist that can be used to assess an **MRM** program. An alternative evaluation measure of safety-training involves the critical-incident method. The critical-incidents method involves the description of either observed unsafe acts or near-miss accidents that occur without observable or formally recorded consequences. This method of accident analysis is described in detail by Feggetter.[12] By looking at a system's potential for accidents, this method has two advantages over accident analysis. The first is that analyzing critical incidents allows an accident investigator to root out causal antecedents without further damage to the system. Secondly, because such incidents are more numerous than accidents (or reported accidents), it provides a rich source of data that accident reports may not have.[11]

Because of the greater proportion of critical incidents relative to actual accidents, statistical analysis has greater power and is able to be performed with greater precision. The critical-incidents method of accident investigation itself makes use of a variety of data collection techniques (e.g., questionnaires, interviews, behavioral observation), each with their advantages and disadvantages. (For a more complete review of this subject, see Feggetter.[11]) However, the critical-incidents method remains a vital tool both during the initial need analysis as well as in evaluating any behavioral changes after a training intervention has been implemented.

Behavioral-level criteria remain an attractive alternative to results-level measures. Though they often rely on the skill of those making the observations, large amounts of data can be collected over relatively (compared to results-level measures) short periods of time. In addition, tools such as behavioral observation scales can be utilized to create more systematic data.[13]

The preceding discussion presents some common evaluation methods. However, many other types exist. Among them are attitudinal, reaction, and learning measures. Behavioral criteria include job sampling measures and behavioral observations. The extent to which evaluation criteria are sufficiently relevant to both training program goals and training program contents determines their validity.[14] Due to the difficulties in making results-oriented evaluations, behavioral-level measures are emphasized and presented in the context of each specific plan. Nonetheless, we still advocate the use of performance-level evaluation criteria, in addition to behavioral measures, to assess the effectiveness of **MRM** III.

This chapter of the Phase Report serves primarily as a guide to help **MRM** trainers who may be shifting the development of their program from the needs assessment phase to that of training development. This chapter will serve as a primer that will ease the transition from determining what needs to be trained to how the training should be implemented. It will highlight the advantages and disadvantages of a series of training delivery systems and allow the trainer to choose the most appropriate plan for their particular situation.

3.4 TEAM COORDINATION AND SAFETY

Teams have become increasingly important to organizations in recent years. Because of such things as decentralization, employee empowerment, and the rising complexity of work, the role of teams and their component members has increased in number and the power they wield in organizations.[15] Yet, despite the increased visibility of teams in organizations, they remain difficult to define for most people. Some teams are temporary, such as a company softball team or a product-oriented team created solely for the purpose of achieving a single, short-term goal, while other teams are longer-lived and require a greater level of commitment from its members. Regardless of the nature of the team, every team is unique, each made up of its own set of components, experiences, and variables.[16] However, some commonalties do exist, or are assumed to exist among teams.

What is the nature of these commonalties? First, teams are defined as groups that consist of members who seek to complete a common goal, but contribute an individual set of knowledge, skills, and abilities that enable the team to advance through each of the subtasks that make up the common goal. However different these subtasks are, their integration leads to the completion of the final goal.[17]

Second, a review of the existing team literature by Cannon-Bowers, Tannenbaum, Salas, and Volpe has identified a core set of skill dimensions or behaviors common to most investigations.[18] Among these skill dimensions are coordination, communication, adaptability, shared situational awareness, leadership, performance monitoring, and interpersonal relations. These skills, at varying levels, are required to integrate a complex goal's subtasks. Finally, in order to perform these behaviors in a team context, interdependence must exist between team members, adding yet another team-related constraint when examining the aforementioned behaviors.[17,19]

Hoffman and Stetzer performed a cross-level analysis of organizational and individual-level factors as antecedents of an accident.[20] Using 222 individuals in 21 teams, group-level factors, such as communication and coordination, intention to approach others regarding unsafe behavior, and safety culture, using 21 teams and 222 individuals, were measured in an industrial setting. In addition, an individual-level variable, perceptions of role overload, was also measured. Results support Hoffman and Stetzer's hypothesis that both individual and group-level variables would be significantly associated with unsafe behavior, as measured through both self-assessments and the company's own accident database.

Despite Hoffman and Stetzer's success in demonstrating cross-level antecedents of mishaps, the environmental complexity that most teams were created to address tends to hamper efforts to derive generalized principles about teams.[20] Therefore, closer examination and subsequent manipulation of any team must take into consideration that team's natural environment.[19]

Finally, team skill dimensions exist independently from what is known as "taskwork" skills, i.e., team skills are often times functionally different from the technical skills required to complete a task. Those who participate in team activities are often taught and are competent in the technical aspects of their work, but are often not trained to work as a team. In this case, the entire team's effectiveness is lost. **AMT**s are not an exception to this phenomenon. **MRM** seeks to address this discrepancy.

3.5 TEAM COORDINATION IN A MAINTENANCE ENVIRONMENT

Fuller et al., also proposed specific strategies for improving safety in ground handling operations.[21] They contend that the "adaptability" of maintenance crewpersons must be trained to compensate for failures in a system. This assertion was again developed through the analysis of accident data. In their study of 580 accidents, Fuller et al., found that the majority of accidents were due to either behavioral (performance) failures, in which standard procedures were followed, but not done well, or because of a failure to follow proper procedure from the start. The authors conclude with a suggestion that training and safety programs should and could be more sophisticated than merely outcome-based incentive programs. They encourage a strategy that changes people's attitudes and establishes a sense of ownership of the trained behaviors.

Along with coordination and decision-making, another behavior identified as being necessary for a safe, "team-oriented" maintenance environment is assertive behavior.[22] Not to be confused with aggressive behavior, Stelly and Taylor define assertive behavior by using a series of "rights" to which a team member is entitled. Some of these rights include the right to say "no," the right to express feelings and ideas, and the right to ask for information. It has been shown that teams in cooperation openly discuss opposing views, critical for making cooperative situations productive.[23] Thus, assertiveness is a necessary skill for effective team behavior.

These and other ideas, all of which promote a team-orientation, make up the bulk of a training program Taylor and Roberston developed for Continental Airlines' technical operations.[24] The airline named this program "Crew Coordination Concepts" (**CCC**). Evaluation of this program, with pre-test, post-test and follow-up measures, showed an increase in communication, "willingness to voice disagreement," "goal attainment with own and other groups," and other scales developed to reflect the targeted behaviors as well as attitudes regarding those same behaviors.

Performance measurement also indicate a significant drop in injuries, damages, and repair costs due to maintenance-caused ground damage. Finally, this airline company's program possesses high face validity and is widely accepted by technical operations. In short, these researchers demonstrated the validity of creating a team-orientation among groundcrew personnel by targeting the behaviors that specifically improve communication skills, such as assertive behavior.[24]

The benefits of planning before a task is undertaken are also emphasized in accident prevention.[25] Planning is defined as evaluating a task at all levels and ensuring that the proper resources (e.g., the correct tools, adequate space, and clear and complete policies regarding the task) are allocated in order to complete the task safely and efficiently. Too often, a task is undertaken without making available the proper resources.

Planning and the ability to carry out a plan in a team context also depend on the ability of the team members to communicate with one another.[18] Ferry defines communication as the transfer of information, verbal, written or otherwise.[26] He goes on to state that communication deficiencies lie at the heart of many mishaps simply because of their role in disrupting plans. Consequently, it is safe to assume that the roles communication and coordination play in a safety-oriented, team context are highly important.

3.6 SUMMARY AND INDUSTRY EXPERIENCES

From the literature cited above, evidence has been found to support two assumptions:

- Assumption One: Team behavior is necessary in a complex environment, where safety and reducing maintenance-related errors are the prime goals. The aviation maintenance operations environment is one such place.
- Assumption Two: Specific behaviors are required for crew members to perform as a team. Among these behaviors are communication, assertiveness, planning, situation awareness, problem solving, and good decision making skills.

Displaying these and other team-oriented behaviors is necessary for coordination to occur among the many individuals who compose a typical maintenance crew. The remaining portion of the present needs analysis is designed to provide further support for these assumptions. By doing so, the specific team behaviors that can reduce maintenance error are identified and targeted for future **MRM** training.

3.7 CREW RESOURCE MANAGEMENT AND LINE-ORIENTED FLIGHT TRAINING

One of the most heavily and widely studied teams is air and cockpit crews.[27] Previous research has demonstrated that aircrew accidents could be traced to human error on the part of the aircrew.[28] Furthermore, it was determined that although each crew member possessed the necessary knowledge and skills for completing his or her job individually, the members of the crew lacked the coordination that characterizes team interdependence. These results became the basis for a systematic training program that identifies behaviors and teaches coordination among aircrew members. This intervention is commonly known as crew resource management (CRM).

CRM researchers identified basic skills necessary for coordination among aircrew members to occur. Among these behaviors are communication, situational awareness, decision-making, leadership, adaptation/flexibility, and assertiveness.[29] Overall, studies of CRM-type programs demonstrate that training these specific behaviors has a positive effect on performance and performance-related attitudes.[30]

Because **CRM** has been identified as a skill set necessary for the safe operation of aircraft, the Federal Aviation Administration (FAA) has outlined CRM training for all multi-crew pilots.[31] This training, as defined by the FAA, encompasses awareness training, practice, and continuous reinforcement. This is also the structure around which **MRM** was designed and implemented.

A review of the literature show a great deal of transfer of **CRM**-related behaviors and skills to **MRM**. Cannon-Bowers et al., conducted an extensive review of both theoretical and applied literature and summarized the behavioral skill dimensions that they found were common to almost all teams.[18] Though they vary in skill labels used in each study, Cannon-Bowers et al., generated eight core skills common to almost all studies.[18] These are listed below:

1. adaptability
2. shared situational awareness
3. performance monitoring and feedback
4. leadership/team management
5. interpersonal skills
6. coordination skills
7. communication skills
8. decision making skills

Both **CRM** and **MRM** are no exception to the list presented above. The following table is the result of additional reviews by these authors. **Table 3.2** presents a series of behavioral skills common to both CRM and MRM training. Initial research into CRM first identified these specific skills.[27,29,30,31,32,34] Follow-up research in the maintenance environment tested the validity, in terms of acceptance and effectiveness, of those skills for MRM.[22,24,33,35,36]

Table 3.2. Behavioral Team Skills Identified in CRM and MRM
Behavioral Team Skills
Communication & Decision Making • briefings • assertiveness • conflict resolution • communication
Team Building & Maintenance • leadership • team climate • interpersonal climate
Workload Management & (Team) Situational Awareness • preparation • planning • vigilance • workload management

To conclude, it must be noted that although team-related behavior and coordination remain the focus of both **CRM** and **MRM**, both programs encompass much more. Also included, though dependent on the syllabi of each specific program, are introduction to basic human factors concepts, training in human error recognition, and worker stress recognition and reduction among other things.

Line-Oriented Flight Training (LOFT) was a natural outgrowth of **CRM** research and training. LOFT is an application of CRM principles in a realistic, yet controlled cockpit environment. However, whereas previous simulator training focused primarily on individual, technical skills, LOFT scenarios are designed to include situations which require coordinated, team actions.[30] Taggart makes the analogy of a building; CRM is the foundation upon which the structure, namely LOFT, is built.[32]

In **LOFT**, trainees are placed in a simulated, though highly realistic environment, and are asked to react to a variety of pre-planned scenarios. Entire missions are run while mission variables, such as weather, "mechanical difficulties," etc., are systematically changed. This is done to facilitate the transfer of **CRM** concepts to the cockpit without placing trainees in a dangerous situation.[30] In addition, LOFT also enables trainers to gauge the levels of a crew's technical knowledge as well as the level of transfer of CRM principles to the cockpit. Finally, a vital component of LOFT is the post-mission debrief, in which trainers evaluate and discuss trainees performances both individually and as a group.

Because coordination skill dimensions (or variations of those dimensions) such as communication, decision making, and pre-planning were found to be common to almost all investigations of team assessments, those dimensions appear to relate to the performance of maintenance personnel.[18] Thus, as **CRM** applies to aircrew personnel, so too could programs be created to develop these skills for **AMT**s. This is the logic behind **MRM** I, II, and III.

3.8 AMT TEAM TRAINING

Gramopadhye, Ivaturi, Blackmon, and Kraus created a framework that incorporates team training into an aircraft maintenance environment.[33] Based on previous task analysis of maintenance activities which show a high need for coordination,[35] Gramopadhye et al.,[33] list a series of factors relevant to teams. These factors were categorized in terms of organization, task, equipment, and the knowledge, skills and abilities of individuals.

Following this initial task analysis, Gramopadhye et al., proposed and evaluated a training program based on these factors.[33] In this program, participants were taught either basic team training skills or placed in a control group. Their task consisted of the removal and installation of an aircraft engine, simulating a basic maintenance task. Pre- and post-test measures of performance and the perceptions of both trainees and instructors were taken. The results support the hypothesis that team-training 1) is possible in an aircraft maintenance environment, and 2) leads to increased performance. Although applied to a single task, the authors discuss how their results may be applied in a more general sense, emphasizing "coordination, communication, interpersonal, and leadership skills."[33]

Taylor and Robertson published a report that summarized three years of team-related training for maintenance personnel.[24] Taylor and Robertson compared this training to crew resource management for maintenance personnel. Once again, **CRM** training encompassed many team-related concepts such as communication, situation awareness, assertiveness, teamwork, stress management, and leadership, among other things. As mentioned previously, CRM in aviation remains well-documented in the literature, but the focus has been primarily on cockpit training and aircrews. Although CRM programs have been in use for over a decade, its application for maintenance crews has been limited at best.[34] This is unfortunate since many of the concepts addressed by CRM are crucial for a safe and productive maintenance environment. It is in this context that Taylor and Robertson introduced their training.[24]

An interdisciplinary design team assembled by a major airline identified what the training and learning objectives of the new **MRM** course were to encompass.[24] These goals were to:

1. diagnose organizational norms regarding safety.
2. promote assertive behavior.
3. promote understanding of individual leadership styles.
4. teach stress management.
5. enhance decision-making skills.

6. enhance interpersonal skills.

To achieve these goals, a **CRM** program in use for training cockpit crews was adapted for use by maintenance personnel. This included attitudinal measures regarding the above behaviors as well as the program itself. The training method chosen by Taylor and Robertson was the lecture format. The instructional team consisted of lead and assistant supervisors in technical operations, trainers, human factors specialists and academic researchers.

The results of a multiple time-sampled design show considerable and significant improvement in the use of the five targeted behaviors as well as in those attitudes regarding their use. They also demonstrated stability 12 months after participation in the training program. Taylor and Robertson also show a strong relationship between performance and its related attitudes for each of the follow-up surveys.[24] Performance was operationalized in terms of aircrafts' ground damage, lost time injury data, on time departures, delays from planned yet late maintenance, and the amount of overtime charged per week. The changes in attitudes demonstrated in these studies predicted improvement in performance and demonstrated a positive transfer from training to the job. This study laid the groundwork for future team-training programs and became the foundation upon which the resultant **MRM** initiative was built.

3.9 MAINTENANCE RESOURCE MANAGEMENT

Using a model derived from Reason, Wenner and Drury analyzed reports of preventable accidents among maintenance personnel.[3,37] They discovered that a significant number of incidents were the result of poor communication, mostly between crews. The importance of teamwork has also been discussed by others.[38,39] Wenner and Drury traced more incidents back to the lack of awareness of risks and hazards.[37] In addition, they found that equipment inappropriately chosen to complete a task accounted for the greatest number of incidents.

These conclusions suggest that most crew members are knowledgeable about their tasks. Unfortunately, they operate under a large number of rules and procedures, and it may be difficult to be aware of all of them.[37] Furthermore, these crew members are accountable to an airline's "on-time" policies. The large number of operating procedures coupled with the omnipresent scheduling pressure requires a certain flexibility in decision-making on the part of maintenance personnel.[22] However, the extent to which most crew members, during initial training, are made formally aware of external pressures, such as scheduling pressure and other factors that may lead to error, is minimal. Wenner and Drury also contend that many unsafe procedures become routine when placed in this context and are even "taught" in lieu of proper procedures.[37]

To counter these failures, Wenner and Drury suggest changes in not only policy and procedure, but also in the introduction of interventions that go beyond the technique of "reprimand, motivate, and train."[37] Instead, Wenner and Drury suggest that safety interventions must take into account factors typically not identified for change, and teach personnel to identify these factors themselves. These "hidden" factors, or latent errors, may be organization-level, such as insufficient shift rotation between crews, or workgroup-level, such as the perpetuation of a climate in which the productivity of the group takes precedence over its safety. The ability to identify the factors that lead to unsafe behavior becomes the impetus for changing them. **MRM** is the mechanism that enables airlines to make just such a change.

3.10 MRM I & II

MRM I and MRM II are the initial stages of **AMT** training in human factors. MRM I focuses primarily on teaching basic awareness of MRM-related skills. MRM II builds on this basic knowledge and introduces skill development in Team Situation Awareness.[40] MRM II utilizes group exercises and participation to a much greater extent than MRM I. Knirk and Guftafson outlined the characteristics of specific training methods whose goals are to teach job skills, but whose focus is primarily on the cognitive level (i.e., thoughts, ideas, and attitudes).[41] These training methods are presented in **Table 3.3**.

Table 3.3. Categories of Learning

Objective Categories	Examples of Individual Instruction	Examples of Small Group Training	Examples of Large Group Training
Cognitive (lower-order learning)	textbooks, workbooks, audio tapes, programmed materials	study groups, case studies	lectures, video tape, 16 mm film
Psychomotor (physical skills learning)	laboratory-directed practice	simulator/scenarios	demonstrations
Affective and cognitive (higher-order learning)	research fieldwork	discussion, simulation, gaming & scenarios, feedback training	on-site experiences

The model presented in **Table 3.3** classifies learning into three categories: lower-order (cognitive) learning, psychomotor (physical) learning, and higher-order (affective and cognitive) learning. Because the goal of **MRM** I is that of "awareness" of human factors principles, it is characterized by lower-order learning.

Instructional techniques vary in their effectiveness; their effectiveness is also contingent upon the goals and constraints identified by the needs analysis. However, when asked to rate the effectiveness of different training methods, training directors rated "programmed instruction" and the "case study" methods as the most effective, respectively, in knowledge acquisition and lecture (with questions) as the least effective of nine identified training methods.[42]

However, of the instructional techniques identified, the lecture method is the most widely used.[5] It is the most cost-effective training method. Despite criticisms about the passive role trainees play during a lecture, studies comparing the lecture method to the more sophisticated programmed instruction and teleconferencing methods show no differences in student achievement. There is, however, evidence of faster learning. This lack of differentiation among these training methods is especially true where the basic instructional task is the dissemination of information.[7] Based on these criteria (low cost, lower-order learning), a lecture-based intervention was chosen over other training methods for **MRM** I.

The lecture method can be further augmented when used in conjunction with other methods. One such method that is easily incorporated into a classroom atmosphere is the case study method.[7] The case study method is a paper simulation of certain organizational conditions. [5] In the classic case study method, a trainee is given a written report of an organization problem. The trainee then analyzes the problem and prepares a number of solutions. This portion of the case study is completed individually. Once the trainee has completed this section, he or she meets with a group that discusses each person's solutions. Critics of the case study method note its general lack of guided instruction. However, when used as a part of a larger training program, these criticisms may not hold true. For example, trainees participating in a case study simulation, preceded by a lecture, may use the information gleaned from the lecture to help guide their analysis of the case study material. In this case, the role of instructor feedback is critical to the effectiveness of the case study method.

In this sense, the structure of the **MRM** II training program follows the classic case study design. Briefly, the structure chosen for MRM II is lecture and adult inquiry learning with an examination of mishap incidents. Analysis of these sample mishap incidents requires the application of skill and knowledge dimensions taught during the lecture portion of the program. The chosen instructional technique for MRM II is much more interactive than MRM I. MRM II exercises provide the opportunity to practice MRM skills and knowledge in an active manner, while instructor feedback reinforces their correct usage. Therefore, it is expected that awareness of team behaviors will transfer to performance on the job.

It must be noted, however, that **MRM** II teaches more than just team coordination skills, although those remain a large part of the course. Whereas the tasks of an aircrew may be well-defined and the consequences of their actions immediate, the impact of maintenance personnel on public safety tends to fall in the domain of latent errors. Therefore, it is imperative that maintenance personnel be taught the processes that underlie the tendency to commit latent errors, even more than aircrew should be taught. As a result, **AMT**s should be taught the process behind maintenance operations, taking a systemic perspective, in addition to learning how to work as a team. This phenomenon has been termed Team Situation Awareness.[40]

Team Situation Awareness is defined as the degree to which all members of a team possess the situation awareness necessary to complete his or her responsibilities.[40] The difficulty of maintaining this level of awareness is compounded by the presence of multiple team members and multiple teams. Examples include those personnel employed in different departments such as "stores" and line maintenance. When one or more team members (or teams) do not maintain the minimum level of situation awareness, information gaps occur. In this case, poor communication results and the organizational "mission" is compromised.

In order to maintain Team Situation Awareness, **MRM** II also teaches maintenance personnel how to view maintenance operations from a systemic perspective and to understand basic human factors issues as they apply to their work.[1] These topics are as important as teaching team coordination skills for establishing a good safety culture within the organization.

3.11 MRM III

What training format is suitable to enable trainees to implement actual **MRM** skills? Ideally, a full simulation, one which incorporates many if not all of the intricacies of the aviation maintenance environment, is the best format to learn interpersonal and teamwork skills.[43] However, the costs of creating a high-fidelity simulated environment, as well as the lack of organizational support for such a project, generally prohibit its construction. Despite these constraints, the purpose of this research is to create a plan that takes into account organizational limitations, yet is still capable of sufficiently training MRM skills in a simulated maintenance environment. To this end, a plan is proposed that focuses on these following MRM skills: task planning, coordination, teamwork, communication, assertiveness, decision making, and situation awareness. This next phase in training MRM is tentatively called MRM III. In addition, an emphasis on the systemic perspective regarding the AMT's role in maintenance processes will remain a general theme throughout MRM III.

3.11.1 Instructional Design Model

In designing the next phase of **MRM** training, we incorporated and built upon the results of those previous needs analyses. Specifically, MRM I and II were assessed and deficiencies in training MRM behaviors were identified. In addition, deficiencies in training evaluation were also noted.

After integrating and using the development of **CRM** and **LOFT** as reference points, several goals and objectives were identified. They are as follows:

1. Opportunities for additional skill practice and development must be created.
2. The integration of technical training with **MRM** skills is necessary.
3. The ability to assess directly the use of any overt **MRM** behaviors is required for evaluation.

These **MRM** training objectives served as the basis for designing an instructional strategy for MRM III.

3.11.2 Design

Several factors affect the design of a training program and what is ultimately chosen. Among these factors are the content of the training (i.e., "what" is being learned), the target training population ("who" is being taught), and the trainers themselves ("who" is teaching).[7] For **MRM** III, the content and the targets are pre-determined by MRM II, while the trainers remain each organization's prerogative. Therefore, the development of MRM III must rely on other factors. Among these factors is an organization's ability to create maintenance simulations economically. These same programs, however, must still provide trainees with the opportunity to practice and integrate MRM skills outside of the classroom environment. The next section discusses three specific training strategies that take these factors into consideration.

3.11.3 Simulation Fidelity

Simulations range in their degrees of fidelity i.e., how close to the real situation they seem to be. However, there are two types fidelity that exist in training simulations. These are *physical fidelity* and *psychological fidelity*.[5] Physical fidelity refers to the degree that real-world operational equipment is reproduced. This is the type fidelity that comes to mind when most people think about simulators and simulations. Examples of these include aircraft simulators for pilots. Psychological fidelity, on the other hand, refers to the degree to which training tasks reproduce actual behaviors or behavioral processes that will be used on the job.

Physical fidelity also varies from simulation to simulation. Pilots are trained in full machine simulators, replete with motion, that immerse the trainee in an environment that is very close to their actual workplace. On the other hand, many simulations exist that do not, on the surface, resemble the workplace environment at all. Simulations such as business games are examples of simulations with low physical fidelity. Briefly, business games are simulated environments in which participants compete based on the rules and objectives of the business setting chosen. In the course of the game, participants learn and apply information on the operation of the simulated business.[5] Other variations of business games include "in-basket exercises," (though typically used for employee selection and assessment) and role-playing exercises.[6]

It is important to note, however, that even simulations with low physical fidelity maintain psychological fidelity by emphasizing the use of a behavioral skill, independent of its setting as long as the proper stimuli exist to elicit the desired responses. Caro presented a comparison between low and high fidelity cockpit simulators.[44] He found that precisely designed mockups which simulated the necessary cues and response opportunities of specific aircraft did not differ significantly from those trained in high fidelity simulators in the number of errors made when evaluated. It can be argued that a low physical fidelity, but precisely designed **MRM** simulation could achieve similar results.

Finally, a simulation may possess psychological fidelity without maintaining physical fidelity, but it may not have physical fidelity without maintaining psychological fidelity. *Psychological fidelity*, after all, is the primary goal of all simulations. For example, training a set of behavioral skills, even in a highly realistic environment, which would never be used would result in ineffective training. Therefore, maintaining psychological fidelity is also the primary goal of **MRM** III.

Table 3.4 shows the instructional strategies that follow, relative to their physical fidelity. As you review each proposed design in full, note that psychological fidelity, using and developing **MRM** skills, is maintained for all three types.

Table 3.4. The Physical Fidelity of Proposed Instructional Designs

Physical Fidelity	Proposed Instructional Design
High	Full Maintenance Simulations
Medium	Intelligent Tutoring Systems
Low	**TQM**-Based "**MRM** Teams"

3.11.4 Full Maintenance Simulations

One approach, and seemingly the most apparent, involves the recreation of the maintenance environment in a controlled setting of high physical fidelity. High fidelity simulations or "mockups" have proven to be effective in training not just task skills, but team skills as well.[7] A training environment such as this would be directed by the **MRM** trainer/observer. This trainer is comparable to the check-airman who evaluates performance in **LOFT** scenarios. Check-airman possess great technical proficiency and are specially trained in **CRM** principles and philosophy.[43] MRM III facilitators would be similarly equipped.

Specific maintenance tasks could be selected for use in **MRM** III. The validity of such maintenance simulations was demonstrated by Gramopadhye, et al.[33] The task chosen for their study was the removal and installation of an aircraft engine. This task was analyzed and divided into specific component behaviors. In addition to evaluating teamwork skills, each task behaviors were evaluated for an assessment of technical proficiency. In these ways, this study is quite similar to **LOFT**. A variety of maintenance scenarios can be developed, simulated, and evaluated in a hanger environment, creating a training system comparable to LOFT. MRM III facilitators can vary situations by introducing common **AMT** challenges, such as lack of adequate parts or manpower.

3.11.4.1 Evaluation of Mockups

Evaluation of mockups occurs in much the same way as with **LOFT**. Facilitators would rate trainees according to their proficiency in using **MRM** skills on the job. Behavioral observation would provide the mechanism for evaluation in this context. Peer review can also be included as a second evaluation measure.[33] Finally, videotaping these simulated maintenance tasks would provide more data for evaluation and feedback than naturalistic observation alone.[43]

3.11.4.2 Benefits of Mockups

The benefits of choosing such a task or another actual maintenance task in which to practice **MRM** skills is obvious. Using established maintenance tasks would have high fidelity and possess great saliency for an **AMT**. Use of such tasks would increase the probability of MRM being "bought into" and ease the transfer of MRM skills into the workplace. Indeed, after initial resistance, **LOFT** is widely accepted by most pilots.[32]

3.11.4.3 Issues to Consider

There are other issues to consider in instituting full maintenance simulations. First, by using specific maintenance tasks, the general ability of learned **MRM** skills may be limited in those scenarios not simulated. In other words, from avionics to airframe to powerplant maintenance, maintenance tasks contain a great deal of variability in the resources, tools, and context in which work is being performed. Given that there are a finite number of training hours and resources available, maintenance simulations must be equally limited. On the other hand, **LOFT** simulations, though varied, all occur in the same context -- that of the cockpit. As is the case, LOFT is continually challenged on a technological level by the wide variety of aircraft flown by today's pilots. These concerns may be unfounded, however, due to the generic teamwork quality of many of the MRM skills (coordination, communication, assertiveness, etc.) being taught. Because several of these skills are common to most teams regardless of context, transfer of MRM principles may occur despite the specificity of the training tasks.[18]

Another issue involving the implementation of full maintenance simulations involves the cost of such endeavors. Ideally, full maintenance scenarios would replicate a hanger and include all relevant materials and tools to maintain the highest degree of physical fidelity. Large organizations, such as aircraft manufacturers, that possess a surplus of both may be adequately equipped to handle such a situation. Indeed, Boeing has had such an operation in use for many years. The costs of simulating a maintenance task, however, may prove prohibitive to smaller organizations.

Added to the cost of instituting a high fidelity mockup is the cost of maintaining it. Should an aircraft change configurations or designs, the mockup would have to be similarly changed. This would require extra resources that smaller organizations may not have.

Finally, one must also recognize the role that training takes in the socialization of organizational newcomers. Gramopadhye, et al., found that control teams who did not receive formal team training still improved in coordination and performance, suggesting an intuitive use of team skills and influence from the organization.[33] Nevertheless, though these skills may reflect teamwork in the most fundamental sense, they may also result in the perpetuation of "bad habits," such as failure to follow standard operating procedure.[45] Using highly-realistic maintenance simulations within an established work environment may help perpetuate these work habits, unless they are closely monitored by a capable **MRM** III facilitator. In other words, poorly-trained or haphazardly-chosen trainers may actually socialize negative work norms into new employees, in much the same way as been documented during on-the-job training.[46] As Byrnes and Black stated clearly:

> Ironically but understandably, check airmen taken as a group can be the most resistant to the personal change suggested by a comprehensive **CRM** training program. They are the 'top of the food chain' of the pilot group and as such tend to believe that the skills which brought recognizable success are adequate. As 'captain's captains' suggestions for change can be interpreted as criticism of past performance. Therefore, since CRM is all about changing attitudes, one must first clear this hurdle of defensiveness…[47]

Because of the "defensiveness" described above, a poorly trained **MRM** facilitator may actually reinforce a newcomer's skills, based on their own experiences, that are contrary to the philosophy of MRM. Therefore, because the quality derived from using fully-simulated maintenance tasks as the vehicle for MRM III relies entirely on the skill of the facilitator, proper selection and training of these personnel are paramount.

The importance of check-airmen and their impact on the resulting quality of **LOFT** simulations are well-documented.[43]   Butler observed great variation among check-airmen and a corresponding variation in students' ability to grasp and integrate **CRM** concepts as well. The combination of a poorly trained facilitator with the "common sense" quality of many **MRM** skills may undermine the goals of MRM as a whole. Yet, MRM facilitator issues are not limited solely to full-maintenance simulations. As will be seen, the quality of the MRM facilitator affects the effectiveness of each of the proposed MRM III plans. However, facilitator errors are more salient in the context of full maintenance simulations than in others.

3.4.11.4 The Use of Mockups

In what context would full maintenance scenarios be best? Apart from large, well-established organizations and airline companies, Gramopadhye, et al., suggest that airframe and powerplant (**A&P**) schools would provide the ideal context for such training.[33] This training easily could be incorporated into school curricula. Because of the access to resources afforded most A&P schools, costs would not generally be prohibitive. The difficulty lies in training **MRM**-type skills within a particular learning window, specifically after a student gains technical proficiency but before work habits are established. This can be circumvented by the continuous training of MRM-type skills throughout an **AMT**'s tenure. However, given that many work habits or "norms" are passed from senior, established workers to less-experienced workers, the socialization of habits opposed to MRM principles presents a challenge to designing an "on-going" MRM course. Companies should consider these pros and cons, it is up to each particular organization to assess how full maintenance simulations could be incorporated into their own training structure.

3.11.5 Intelligent Tutoring Systems

A second approach for constructing a training program and its delivery systems focuses on the cognitive processes through which individuals transfer learned skills into the workplace. These cognitive processes differ among experts and non-experts.[48] Experts, for example, possess an extensive storehouse of knowledge and use that knowledge in unique ways based on previous experience. This ability to integrate knowledge and experience facilitates good decision making. Novices, on the other hand, possess a rudimentary knowledge of a system, and their understanding is less integrated than that of an expert. Clancy and Soloway present this as a model for computer-based training or, specifically, intelligent-tutoring systems (**ITS**).[49]

ITS not only contain a storehouse of specialized knowledge, they incorporate expert programs that approximate the decision making capabilities of human experts. In addition, ITS provide a tutoring model for students to guide them through these processes. Finally, ITS also possess full multi-media capabilities to demonstrate a variety of concepts through interactive audio and video, thereby giving any simulations presented in ITS added fidelity. For a more comprehensive discussion of ITS, see Norton.[50]

3.11.5.1 Evaluation of ITS

As with full maintenance scenarios, **LOFT** provides the template against which to structure **ITS** evaluation. Using behavioral observation, facilitators would rate **MRM** performance and provide feedback upon conclusion of each scenario. Furthermore, the ITS could maintain a database (using such criteria as "mistakes made," and time to elapsed between decisions, for example) of each group's progression over the course of time.

3.11.5.2 Benefits of ITS

All of the qualities of **ITS** make it an attractive alternative to full maintenance simulations for delivering **MRM** III. Although not as "realistic," i.e., possessing great physical fidelity, ITS is a satisfactory compromise between the benefits and criticisms of full maintenance scenarios. For example, ITS is much more cost effective, requiring only the purchase of computer hardware and the creation of relevant software. In fact, recent changes in **FAA FAR** Part 147 allows for the use of computer-based training for aviation maintenance.

ITS also avoids one of the downsides of full maintenance simulations by allowing for quick and relatively inexpensive maintenance and upgrading. A change in aircraft design would require only a change in software to maintain current. Costs, in this case, would be kept much lower than having to upgrade various types of hardware and/or the simulated mockup itself.

In addition to its low cost relative to creating full maintenance simulations, **ITS** is not location specific and can be instituted in a variety of locations. Finally, though the **MRM** III facilitator remains a vital component of training, the reliance upon the facilitator would be moderated by the ITS. In this way, the third criticism of full maintenance simulations is also addressed.

ITS training is already in use in aviation maintenance. One such example is the Environmental Control Systems (ECS) tutor. This program allows students to troubleshoot malfunctions of the air conditioning portion of the ECS through an interactive simulation of an aircraft's environmental control system. The student can ask for advice from the program at any time. Additionally, the system can detect if the student is encountering problems and may assist in helping to overcome them.

Though individually-based, such a framework can be modified to include other team members, and more complex maintenance scenarios. Maintenance variables, such as available resources, weather, etc., can also be easily manipulated. Similar to popular strategy-based computer games such as SimCity, such an **ITS** could prove to be extremely engaging as well.

3.11.5.3 Issues to Consider

Could **ITS** address an organization's propensity towards latent errors? The short answer is yes, but only if the ITS were designed to specifically tackle those issues. One possible strategy for addressing latent errors could be to introduce interactive, in-depth case study analyses of aircraft accidents via ITS. These analyses could be structured in two ways: the traditional, *post hoc* accident analysis or as a situational decision tree, in which the "actions" chosen by the trainees determine the next set of circumstances. Both strategies, used in conjunction with one another, could adequately convey a systems perspective of the maintenance process, thus training concepts that reinforce a culture of safety.

3.11.6 The Role of TQM in MRM

Though the heyday of quality circles seems to have past, many of the concepts taught and advocated in **MRM** training are similar to the principles of W. Edwards Deming's Total Quality Management (TQM) and quality circles, specifically. In fact, many of the initial MRM principles were derived from TQM.[51] Therefore, a review of quality circles is included in this report and is suggested as another possible strategy to include within the proposed MRM III training program.

In short, a quality circle (QC) is a group of between 5 to 15 employees who meet on a regular basis to discuss issues of quality and other related problems.[52] QCs address issues as varied as improving creativity to marketing to safety. The purpose of the typical QC is to create realistic and relevant solutions to workplace problems and suggest them to higher management. Though the term "quality circles" is the most widely used, organizations have been known to use other labels, such as "tiger teams" or "continuous improvement" teams.[53] Each of these groups are formed to address specific issues, but they similar to QCs in structure and goals.

Adequate training, especially those focusing on problem-solving skills, is the foundation for the **QC**.[51] Several researchers single out failure to train team participants adequately on interpersonal fundamentals, which are taught in **MRM** I and II, as the major cause for QC failure. In addition, management commitment is also necessary to ensure QC success. Management must enact the solutions suggested by the QC, lest members feel ineffectual.

The purpose of raising the issue of **QC**s is not to advocate their introduction into current organizations. That is beyond the scope of this report. However, a variegate of QCs can be incorporated into **MRM** III, and provide trainees with an opportunity to practice MRM skills as well as to apply them in a relevant, work-related context. (For lack of a more precise terminology, these modified QCs will herein be referred to as "MRM teams.") As an example, during MRM III training, students can be placed in teams comparable to existing workgroups. Afterwards, each team would be presented with a human factors-related safety problem and asked to generate solutions. These problems may be hypothetical or derived from the organization itself.

The methodology for creating these proposed **MRM** teams are most similar to implementing "continuous improvement" (CI) teams.[53] CI teams address specific problems identified in an organization, though they are typically not formed in response to them. Because of this specificity, CI teams maintain a narrow focus, with the goals of the team limited only to solving a constrained set of problems. MRM teams would differ from CI teams in that they would be formed in conjunction with initial MRM training. Therefore, the difficulties facing most **QC** or CI teams (a previous lack of interpersonal skills training, the failure to demonstrate managerial commitment, minimal training in problem-solving, etc.) is negated by MRM I and II.[52]

3.11.6.1 Evaluation of MRM Teams

Evaluation of performance in **MRM** teams would once again fall on the MRM facilitator. The MRM facilitator would observe each problem-solving session and provide feedback to each group after a designated amount of time. Feedback would encompass observations related to MRM skills such as communication, assertiveness, decision making, and leadership. Although it is suggested that **LOFT** check-airmen remove themselves from group interactions until feedback is to be given, the danger of this strategy is the "gripe" session. Facilitators must be aware of these tendencies and address them before and during training.

3.11.6.2 Benefits of MRM Teams

There are several benefits to employing **MRM** teams in MRM III training. First, they allow a chance for **AMT**s to use MRM skills in an applied way and practice their skills. Although this benefit of MRM teams is similar to that of maintenance simulations, the difference lies in which MRM skills are emphasized. MRM teams would encourage AMTs to practice problem solving skills that tap the global, systemic perspective taught in MRM I and II. This could be analogous to "organizational situation awareness." The resulting interaction among team members would allow for team skills to be practiced as well.

Secondly, as is the case with **ITS**, **MRM** teams are transportable from location to location. They are easily instituted in a classroom environment. In this way, MRM teams are extremely cost-effective.

Finally, there is an added side benefit to incorporating **MRM** teams in MRM III training. Using MRM teams may provide an organization with solutions to real problems that plague them. These solutions would be created as a minimal cost to the organization, and may even help recoup costs of the initial training if a solution proves successful. In addition, if management were to institute changes based on the real suggestions generated in these sessions, it would demonstrate managerial commitment both to MRM training and to employees in general.

3.12 SUMMARY

Currently, **MRM** is still in the classroom stage and is being piloted in a host organization. Initial reaction to this pilot program has been positive. In response to industry interest in furthering MRM training, the purpose of this report was to chart possible future directions for MRM. Using **LOFT** as a model, the researchers propose a more immersive approach that builds upon previous MRM training. This proposed course has been named MRM III.

Three possible strategies have been outlined for use in **MRM** III: full maintenance simulations, intelligent tutoring systems, and modified "quality circles." Each strategy has its benefits and drawbacks, just a few of which have been outlined above. There are cautions against using one strategy in favor of another. Because of the different advantages and disadvantages to each strategy, an ideal MRM III program would incorporate all three. However, logistically speaking, this is unlikely at best. Therefore, it is up to individuals in each organization to assess their resources and determine whether they can support a program such as MRM III or, based upon needs analysis, if MRM is even necessary at all. However, considering the need for airlines to find new ways of doing business, the future of MRM remains bright indeed.

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CHAPTER 4
SAFE MAINTENANCE IN AVIATION RESOURCE AND TRAINING CENTER

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4.1 INTRODUCTION

With the constant pressure of down-sizing, corporations and the government find themselves in positions of having to train their personnel to perform broader ranges of tasks. Airlines, repair stations, and **FAA** Flight Standards also face these pressures. Personnel are expected to be more skilled in more areas while fewer dollars are available to meet these training needs. Distance Education is enjoying a revitalization of interest among corporate and government leaders because they recognize the potential benefits as low-cost solutions to their training needs. Distance education is an instructional approach where people engage in educational activities without having to be at the site where the instruction is occurring. Instruction, resources, and students can be distributed across many different locations, and are usually connected together by technologies, such as computer networks, satellite dishes, and telephone lines.

One approach to distance education is to capitalize on the technical capabilities of the World Wide Web (WWW) to create resource and training centers for continuing education of professionals. The SMART Center (Safe Maintenance in Aviation Resource and Training Center) is an example of such an approach for the delivery of On-the-Job Training (OJT). The focus of the Center is to train aviation maintenance personnel issues in Maintenance Resource Management (MRM).

Human factors research in aviation has traditionally been concerned with the successful interaction between person and system, where system was generally considered to be a machine. In recent years human factors research has broaden the scope of the system to include successful interaction between individuals, groups, teams, and the environment in which personnel work. Accidents related to a breakdown of human communication and team work prompted the aviation industry to institute Crew Resource Management (CRM) to explicitly train flight crews to work together as a team. Industry is now recognizing that communication, situation awareness, and team work are essential to reduce errors and increase efficiencies in aviation maintenance operations.[1] Maintenance Resource Management (MRM) is a new training initiative promoted by the aviation industry to address shortfalls in communication, situation awareness, and team work among maintenance personnel.

A web-based training center, by virtue of being a central and public repository of research and training, lends itself to setting standards for **MRM** practice. The interactive nature of the Web can support live interaction, asymmetric interaction, and the dynamic evolution of information, and also can serve the aviation community as a forum for discussing issues unique to MRM.

The primary goal of the **SMART** Center project is to first create and service a web-based training center and then evaluate its feasibility and utility. The first phase of the research completed the development of the SMART Center infrastructure and the implementation of an on-line computer-based training course for **MRM** training. Access to the SMART Center and the MRM course is reached through the Human Factors in Aviation Maintenance and Inspection Web site at http://www.hfskyway.com.

A second goal is to develop standards for quality web-based training and delivery over the Internet. Web-based training is becoming pervasive as a training medium. The range in sophistication and quality between training products, however, varies greatly. At the close of the first phase of the project a classification system was developed. The classification system identifies a) types of features and level of sophistication in the delivery methods, b) course development standards, and c) administrative standards. This classification system was derived as a result of implementing the **SMART** Center infrastructure and observing the work of other developers attempting to create information centers on the Web. The classification system is presented and discussed throughout the body of this chapter.

4.2 DESCIPTION OF THE SMART CENTER

4.2.1 A Walk through the SMART Center

After entering the **SMART** Center, Aviation Maintenance Technicians (AMTs) find themselves looking at a map of a virtual school. The map (**Figure 4.1**) divides the school into four conceptual areas: Administration, Classes, Resources, and Recreation.

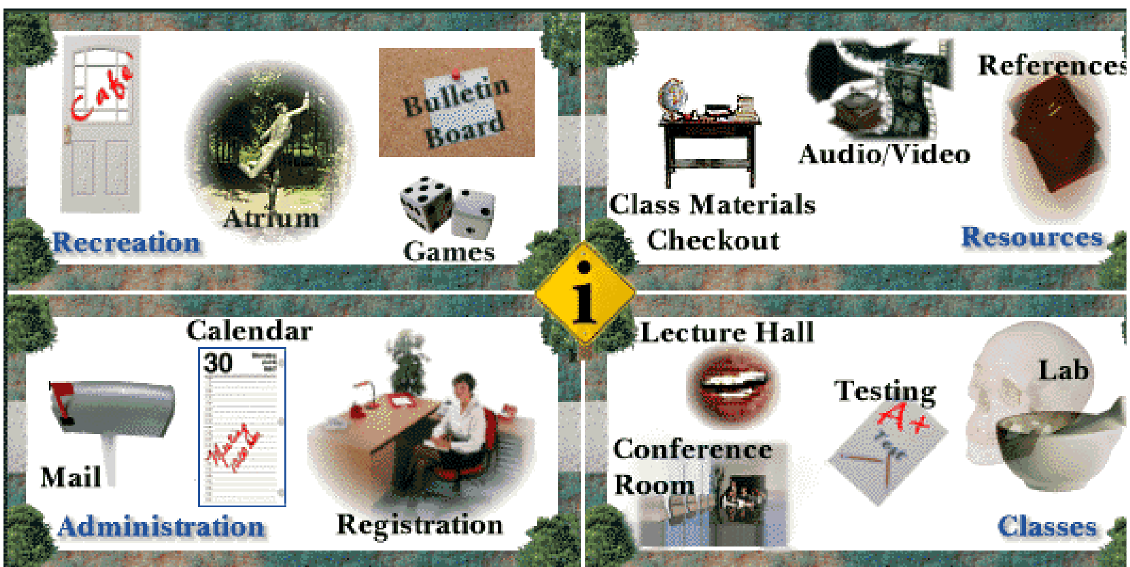

Figure 4.1. SMART Center Map

If an individual wants to participate in a course, he/she first goes to the administrative area (**Figure 4.2**) to see the courses offered and to sign up for a course. When an **AMT** registers for the **MRM** course, he/she is placed on the course mailing list. Once registered, the participant has access to class materials and activities. The class mailing list allows AMTs and instructors to send or receive mail and to submit or receive assignments. The Calendar facility informs AMTs of current events relevant to the course.

Figure 4.2. SMART Center Administration Area

AMTs visit the Resource Area (Figure 4.3) to pick up course materials, listen to prerecorded lectures, or view articles from online libraries. A typical lecture may be a Power Point slide-show with a prerecorded audio lecture or a video of the instructor. AMTs can browse other related sites and databases through links from the reference section of the Resource Area.

Figure 4.3. SMART Center Resource Area

Interactive classes occur in the Lecture Hall, Lab, and/or Conference Room of the Classroom Area (Figure 4.4). The CBT Lab is where interactive multimedia Computer-Based Training (CBT) can be found.

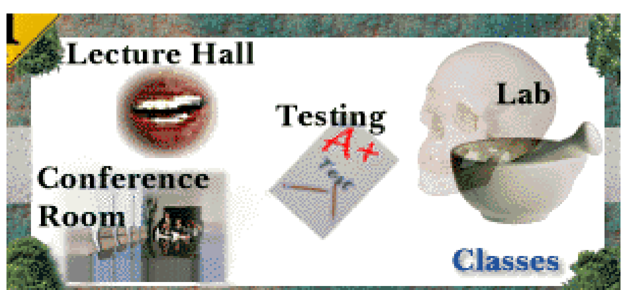

Figure 4.4. SMART Center Classes Area

The MRM-CBT, developed for the SMART Center and also available on the FAA/AAM CD98, is a prototype course that incorporates various multimedia tools bound together into an "electronic book."

The CBT provides course participants with a basic introduction to eight specific MRM concepts. The concepts are Airline Safety, Human Error, Human Factors, Worker Safety, Communication, Situation Awareness, Teamwork and Performance Management (Leadership).

A course participant can work her way through the basic concepts of the **MRM** course at her own pace. This is a good way to prepare prior to a class lecture or to review class material after the basic concepts have been presented in another context. For each unit a pretest is given followed with feedback showing how well the participant did. The participant can then review the material. He may review all the material for the unit or just the material he got wrong. Concepts are organized in outline form and the text and graphic displays are augmented with video and audio where appropriate. When the participant is ready he can be tested again. Once he has reached criterion that unit is checked off as mastered. Progress through the course is recorded so that when the participant returns to the **CBT** Lab he can continue where he left off.

Real-time lectures can be given through real audio-, video-, or text-based chat sessions. The type and sophistication of the equipment required for the class will change with the type of activity that is planned for the class. Text-based conference sessions require no additional equipment, while real-time audio or video sessions require additional equipment and protocols. Real-time interactive audio and video has not yet been implemented in the **SMART** Center. For the **MRM** course, a participant might be directed to first view an introductory video, followed by at least one pass through the basic concepts of the unit in the **CBT** Lab, before attending a live interactive chat session with the instructor. During the chat session participants can ask the instructor about specific concepts covered in the CBT Lab. After the chat session the participants are expected to reach criterion in the unit before the next unit is due to start.

The Recreational Area (**Figure 4.5**) is where more informal interactions may occur. The Cafe is a meeting place for interest groups to gather and chat. Announcements for new classes and other community activities can be posted on bulletin boards. Educational games can be launched from the Game Room, and in the Atrium participants can submit works of interest to be reviewed. If accepted these works will be posted in the atrium for public access.

Figure 4.5. SMART Center Recreation Area

4.2.2 What Makes the SMART Center Unique

Table 4.1 summarizes the key features that comprise the **SMART** Center. What makes the SMART Center unique is that it can function as both a training center and as a job aid. As a training center the SMART Center supports real time and asynchronous interaction as well as exploratory and structured learning. Lectures, conferencing, and interest groups are examples of real time interaction. E-mail is an example of asynchronous interaction. Lectures and testing could provide formal classroom structure, while a **CBT** Lab could provide an exploratory or troubleshooting environment. Decentralized collaborative teaching is possible with this type of instructional vehicle. The lectures in each unit in a course could be given by a different expert. And if recorded, that lecture can be accessed as needed. The continuity of the course can then be coordinated through CBT and an instructional administrator. If done well, this type of instructional vehicle provides a very consistent training resource worldwide. Finally, the training site is always open and available.

Table 4.1. Key Features of the SMART Center
On-line Registration
Calendar of Events
Real time or canned video and audio lectures
Informal discussions via chat groups, bulletin boards and email list server
Interactive Multimedia **CBT** and job aids (e.g. **FAR** glossary)
Archive and access important documents, articles, applications, class materials, media clips through direct display, email, ftp.
On-line testing with immediate feedback and record keeping.
Participant submission of candidate work for resource archives

As a job aid the **SMART** Center can function as both a central knowledge base and a communication center. Large databases, digital libraries, directories of services, and publications can be accessed. Information appears to be centrally located, yet can actually be distributed across many sites. Resources are not limited to the access of print information; resources can also be a location where ideas are exchanged through e-mail discussion groups, teleconferencing, or through video or audio. Knowledge is not easily lost. A class missed can be viewed at any time. Knowledge is not static. The body of information naturally evolves with the interests and perspectives of the participants as they interact, formally and informally, through different types of media. Training, communication, and the daily work routine are no longer distinct activities but become closely coupled with each other.

4.2.3 Limits to the Technology

Not everything about web-based training is a positive. The band-width expected to carry all this highly interactive multimedia material could be huge and costly or slower than mud if not well designed. Video beyond short clips of talking heads is generally impractical. Interactive video or text conferencing could be unwieldy if not carefully orchestrated. We must not lose the content for the technology. Often simple solutions can be very effective. High technology does not necessarily mean higher learning. Many relatively low technological activities have been found to be more effective in instructional activities than some of their high technology counterparts.[2] For example, electronic mail is a very successful educational medium, while satellite conferencing has had mixed reviews. Though satellite broadcasts are able to reach large numbers, the medium is lacking in the interactive aspects of a class that are important for sustained comprehension and skill development. Electronic mail is better suited to support the interactive aspects of a distance education class. Participation in e-mail based classes tends to be very high. Since e-mail is an asynchronous medium, participants have time to reflect on their correspondence. As a result, the quality of the interaction is also high. Administration of distance education courses in general require more overhead than traditional training. Participants of such courses need to be self-motivated individuals.

If these limits are taken into account and planned for, then the potential for consistent reusable training, a living growing resource, and a thriving communication center is a real possibility.

4.3 CLASSIFICATION OF WEB-BASED TRAINING

4.3.1 Web-Based Training Features

Table 4.2 shows the features that comprise a classification system for web-based training. Each higher level contains all the features of the lower levels. Most basic web sites found on the Internet fall into Level 2 of the classification system. That is, the sites have both text and graphics with non-linear links for navigating through the pages. Level 1 systems, found at some government sites, are all text-based with a simpler navigation mechanism consisting of a table of contents and page-turning navigation. As one moves higher in the classification system, the interactivity of the site increases. Level 3 provides participants with asynchronous interaction such as e-mail, bulletin boards, student registration, and an ability for full-text document search. Level 4 provides students with what most people would recognize as multimedia supported Computer-Based Training. Video, audio, or animation is supported. Real time text-based interaction, in the form of chat rooms and on-line testing or adventure games, is available. Students are tracked and a record of their progress is provided. This is the level where one would see the use of Java or Active X applications. Level 5 distinguishes itself in two ways. One is the ability to do real-time video or audio conferencing. The other is volume. The site is organized like a university or campus where complete certification or complete degree programs are possible. Finally, Level 6 adds intelligence to the operation. A word about what is meant by intelligence. In order for a developer to claim his/her system demonstrates intelligent behavior, it must exhibit the following features: it must collect and organize data; it must review that information and make modifications to its structure (e.g., modify its rule base) which in turn changes its conduct in response to its environment. Examples of such sophistication would be intelligent tutors, expert systems, or intelligent agents that help coach, organize, or administer instruction.

Table 4.2. Web-Based Training Classification System

Level	Features	Examples
1	• Text based HTML • Page turning links • Table of Contents	• Some government sites
2	• Level 1 + • Graphics • Hyperlinking	• Hyperlinked books • Most Web sites
3	• Level 2 + • Asynchronous interaction • Search capability • Student registration • Well structured navigation and site design	• On-line registration • Email, Bulletin Boards, List Servers • Site search full text document search • Ftp materials • Order forms
4	• Level 3 + • Automated multimedia Computer Based Training (CBT) with interactive database access • Real-time text interaction • Student tracking • Streaming video and audio	• On-line testing • Chat groups • MOOs, MUDs, adventure games (text) • Maintenance Resource Management CBT (Active X -interactive database access) • Ergonomics Audit Program (Java) • Turbine Repair Automated Control System (Active X) • Federal Aviation Regulations Multimedia Glossary (Java – multi-threaded database access)
5	• Level 4 + • Real-time interaction • Campus organization • Full degree programs with multiple courses	• Real-time lectures and demos • Virtual University

6	• Level 5 + • Intelligent Tutoring/ Expert systems • Intelligent agents for coaching/ site organization • Real-time interactive simulation	• Destributed simulation • Intelligent coaching • Ask the expert • Automate FAQ Maintenance

Based on this classification system, the **SMART** Center falls within Level 4. It is actually designed to accommodate a full training curriculum for aviation maintenance technicians but current lacks the requisite volume in terms of courses and administrative support to completely meet Level 5 classification.

In the next section the **SMART** Center, representing a Level 4 web-based training site, is described.

4.3.2 Administering a Web-Based Training Center

There are four management systems that need to be in place to administer a Web-Based Training Center (WBT) such as the **SMART** Center: System administration, Course development, Course delivery, and Course administration. Each system has its own automated work environment and set of procedures that facilitate the management of that aspect of the training process.

4.3.2.1 Course Development

Course development is the process by which the educator develops the course content of the material used in this new environment. This includes tools necessary to convert the current course material into a form which can be represented in this new environment. The course development environment should accommodate the tools (e.g., word processing, spread sheets, data bases, or slide presentations) instructors and trainers are accustomed to using. In some cases, instructional templates should be developed to facilitate course development and to ensure consistent quality in presentation of materials. More importantly, the course development environment should provide a straight-forward mechanism for posting course materials to the **WBT** Center. When real time lectures are part of a course, protocols for managing the interaction need to be developed.

Table 4.3 classifies the standards that need to be in place for course development. Level 1 is simple. One needs a mechanism for converting text-based electronic documents into **HTML** files. Many word processors now have this capability. Methods for converting and linking more sophisticated documents using a suite of HTML development packages are introduced at Level 2. In an effort to standardize instructional material, standard instruction templates should be developed. With the introduction of asynchronous interaction at Level 3, protocols for appropriate conduct and flow of information should be established. Also a standard template for developing and processing forms should be distributed. At Level 4, one now needs tools and protocols for developing and delivering multimedia **CBT**. At Level 5, because of the large volume, standardized production procedures, equipment and tools, as well as protocols for real-time interactions are all needed. At Level 6, implementation of standards for development and maintenance of intelligent features is necessary.

Table 4.3. Classification of Course Development of Web-Based Delivery	
Level	Course Development
1	• Convert text-based documents into HTML files
2	• Level 1 + • Convert and link text with embedded graphic documents • Instruction templates • HTML development packages • Graphic development tools
3	• Level 2 + • Protocols for asynchronous interaction • Forms development
4	• Level 3 + • Protocols for automated delivery • Multimedia development tools • Off-the-shelf or custom course development packages • Off-the-shelf or custom delivery system
5	• Level 4 + • Protocols for real-time delivery • Standardized production procedures • Standardized equipment and tools
6	• Level 5 + • Standards for development intelligent features

4.3.2.2 Course Delivery

The course delivery mechanism is the most developed aspect of web-based training. Many trainees are already familiar with the point-and-click environment of a Web browser. The **WBT** interface should present a coherent pedagogical structure that allows users to easily navigate and access information and to participate in the activities of the course. Typical questions that should be asked during the design phase of a web-based training course are: “How does one create an environment where a sense of active engagement is the norm?” “How does one insure both independent activity and joint participation are productive?”

The primary devices required for sending and receiving web-based training are the computer, a telephone line, and a modem. Because of the nature of multimedia information, the receiving computer must have graphics, sound, and telecommunications capability. The minimum requirements for a receiving computer are a 486 processor, 16 megabytes of memory, and at least 500 megabytes of disk space for storage of the operating system, communications software, and applications software. To accommodate the transfer of large data sets across the Internet in reasonable time, the modem should have a minimum speed of 28.8 KB.

4.3.2.3 Course Administration

Course administration consists of the tools necessary for the educator to properly administer the course activities. Additionally, the course administrator may develop, post, and, in some cases, present the course content in real time. Course activities also include posting assignments and tests, grading assignments and tests, and consulting with trainees. A large part of the design and implementation effort for a successful web-based training center is building functional components to support instructor posting of multimedia documents as well as the development of automatic updating of databases that store archived materials and test results.

Distance education courses tend to require more administrative time on the part of the instructor than traditional courses. This is due to the increased correspondence between instructors and trainees, and the more detailed feedback instructors tend to give trainees on assignments.[3] As distance education courses mature, the time spent on content preparation and presentation should diminish, since the course content will have been developed and posted on the site. Correspondence with trainees on assignments and tests will continue to be the central activity of instructors.

Table 4.4 outlines what is required administratively for our classification of web-based training. At Level 1, one only needs a system directory structure for the **HTML** files. At Level 2, minimum security should be implemented and protocols for posting materials developed. At Level 3, a moderately sophisticated registration and security system should be in place. Protocols for accommodating courseware developed by common office tools and a mechanism for maintaining full-text search capabilities should be in place. Level 4 introduces fairly sophisticated database capabilities. These facilitate the ability to automatically track student progress and post and grade assignments. Protocols for access to students records by instructors should also be in place. Level 5 requires the ability to handle large scale tracking of student and administrative information as well as protocols for administration of real time delivery. Finally, Level 6 requires protocols for maintaining intelligent features.

Table 4.4. Classification for Course Administration of Web-Based Training	
Level	**Course Administration**
1	• Post HTML pages to directory
2	• Level 1 + • Minimal security • Protocol for posting materials
3	• Level 2 + • Security, registration • Accommodate office tools (e.g. word, PowerPoint, e-mail) • Maintain search capability
4	• Level 3 + • Automatic tracking student progress • Posting/grading assignments • Protocol for access to student records
5	• Level 4 + • Protocols for administration real-time delivery • Large scale tracking student and administrative information
6	• Level 5 + • Protocols for maintaining intelligent features

4.3.2.4 System Administration

System administration keeps the **WBT** Center physically running. System administration makes sure the hardware and software can handle such things as simultaneous connections and information through-put. Other administrative duties include registration of students, tracking students for accounting purposes, and security.

High speed communications is a must to deliver **WBT**. The operating systems for these communication servers must be capable of handling multiple connections in order to efficiently disseminate the required material. For example, a T1 Internet connection can handle roughly 200-300 simultaneous connections from student PCs. The maximum number of connections could be higher for a more “text” based system and may have to be reduced for a system utilizing a large amount of video.

A typical distance learning class size will have a large effect on the type of system necessary to support the distance learning environment. The greater the number of students connecting simultaneously, the more important it will be to consider the system’s capacity. Typical systems are Unix systems, although a

Windows NT server can handle modest systems. The more powerful the communication system the greater the number of students that can connect to the **WBT** Center. For the **SMART** Center a Sun workstation with a communications capacity of 56 kilobytes is used. This is a minimum system capacity supporting a single class of 15-20 students.

4.4 FUTURE WORK

The first phase of the research completed the development of the **SMART** Center infrastructure and the implementation of an on-line computer-based training course for **MRM** training. During phase two of the research an on-line MRM seminar will be conducted. Participants in the seminar will be invited to evaluate the seminar and the SMART Center site.

A second goal is to develop standards for quality Web-Based Training and delivery over the Internet. Exclusive classification of web-based training is difficult because many sites will find they have features across classification levels. Developers will also find that they may meet one classification in the area of features but not in the area of course development or course administration. This classification system does give one a rule of thumb for assessing where the sophistication of a site primarily falls. With a classification scheme in place developers will be able to identify and implement training standards. Clients will be better able to identify their training needs as well as compare the costs they are incurring vs. the levels of sophistication and value added they will receive.

More important than classifying the features of a site, is the honest assessment of standards and protocols for developing and administering a site. How ad-hoc are the production procedures? For most of us the honest answer is pretty ad-hoc. The next step is to begin to define those standards and protocols (i.e., write them down) followed by a conscious effort to implement them. During the second phase of the **SMART** Center research project the classification scheme will be used as guidelines for developing production standards for web-based training.

4.5 FUTURE TRENDS

We are coming to realize that while the way we do business has changed, the nature of our work is not any easier. Computers and networks provide access to data which can be interpreted and manipulated by personnel from anywhere in the country. However, we are all experiencing information overload from too much, poorly organized, data. The next phase of the information age will be to create vehicles designed to make our information-intensive work seamless, efficient, less error prone and, hopefully, easier. Information will be organized so that it is easy to access specific information quickly. Job aids will be designed to facilitate both information access, entry, and analysis. Training will be task specific and completed as needed. One trend that will become more pronounced is the merging of information access and manipulation, job aids and on-the-job training. These separate enterprises will become less and less distinguishable. Job aids will facilitate information access and manipulation while training will become an elaborate coaching or help mechanism to the job aid. Sometimes one will be aware that one is progressing through an organized course. At other times one will only be aware that one has access to progressively more specific information or more complete guidelines. Electronic Performance Support Systems (EPSS) is the terminology used to describe these new emerging technologies tailored for the information age.[4] A web-based EPSS is seen as a viable technical approach to meeting the goals of these future work flow trends.

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CHAPTER 5
EVALUATION OF GROUND DAMAGE INTERVENTIONS

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5.1INTRODUCTION AND BACKGROUND: THE GROUND DAMAGE PROBLEM

This study continues earlier work on ground damage accidents, extending it from analysis of existing incident records to the measurement of the effectiveness of ground damage interventions.

Before we can examine how to intervene in ground damage, we must first define it and provide the historical background of attempts at ground damage control.

5.1.1 Definition of the Ground Damage Problem

In an airline maintenance environment, ground damage incidents (GDIs) refers to incidents in which airline personnel cause damage to an aircraft while it is on the ground. Ground damage can be caused by either maintenance or other ground personnel, and can occur at a maintenance facility or elsewhere on the ramp. Generally, maintenance personnel cause ground damage when they are using equipment near an aircraft to perform maintenance work, or while they are moving an aircraft. Ground damage caused by ground operations personnel generally occurs as an aircraft is being serviced, or as an aircraft is being moved into or out of a gate area. This category of incident only includes damage that is inherently preventable by airline personnel on the ground: damage caused by hail, bird strikes, part failures, or even by foreign object damage is not considered to be ground damage. Ground damage incidents also differ from **ASRS** reported ground incidents, which usually refer to miscommunications between pilots and air traffic controllers (e.g., runway incursions) which occur while the aircraft is on the ground.

The problem of ground damage incidents is one that is quite costly to airlines. In fact, one estimate puts the cost of ground damage around the world at twenty billion dollars per year.[9] Ground damage incidents result in both tangible (direct costs involved in repairing an aircraft plus indirect costs such as lost revenues) and intangible costs to the airline. One example, documented in Airline Equipment Maintenance describes a typical ground damage incident in which the cost of repairing a damaged aircraft was $39,300, while the total cost of the incident was calculated to be $367,500 due to lost passenger and cargo revenues.[1] McDonald, White and Cromie suggest that indirect costs are usually underestimated by airlines, and can be five times as high as the direct costs of an incident.[7] Additional intangible costs from passenger inconvenience, affected flight schedules throughout the entire maintenance system, and increased maintenance workloads are difficult to calculate, but also contribute to the cost of an incident.

5.1.2 Past Research Efforts Addressing Ground Damage Incidents

In recent years, the problem of preventing ground damage has garnered much attention throughout the airline community. For example, Transport Canada is developing a Ground Crew Dirty Dozen poster series, to parallel the Maintenance Dirty Dozen series, to alert ground crews about potential error-causing situations in their environments.[12] This series recognizes that ground operations personnel can help prevent future ground damage incidents by being aware of, and avoiding, these potentials for error.

The Aerospace Psychology Research Group (APRG), at Trinity College Dublin, has been investigating safety on the airport ramp for many years. The APRG has been concerned mainly with ground crew operations, and the possibility of reducing ground damage incidents through a human factors approach. Their analyses have identified that operations on the airport ramp rely on the ground crew being flexible and adaptive to deal with deficiencies on the ramp. Some of the deficiencies identified include congested work areas, time-pressures, and various types of equipment which each operate differently.[6] They also point out that deficiencies on the ramp generally result from design, operational, and organizational deficiencies that have been passed down to ramp operations from elsewhere in the airline system.[3]

APRG also worked with the **IATA** Ground Handling Council's Ramp Safety Group to develop an international ramp accident database, which has been used to document some common safety concerns in a typical airline ramp environment. Problems in the system were organized using the **SHELL** model of human factors.[4] Results from analyzing incidents collected in this database indicate that airlines have been generally ineffective in planning, developing and evaluating countermeasures to address recurring safety concerns in the ground operations environment.[8] Thus, the APRG, in conjunction with other university and airline industry partners, developed a training initiative to address some of the safety issues identified. This program, SCARF, (Safety Courses for Airport Ramp Functions) is a safety training program which promotes safe and cost-effective airport ramp operations.[6] The training program includes four sections for different members of the organization, recognizing that any changes on the ramp must be supported at all levels within an organization.[9] SCARF is being marketed to airlines and ground service companies as a tool to help ground crews and managers become aware of recurrent safety problems in the system, as well as to help deal with acute, one-of-a-kind incidents.

In 1995, a research team at **SUNY** at Buffalo, funded by the **FAA** Aircraft Maintenance Human Factors Research Program, investigated ground damage incidents in a maintenance environment as part of a study into how incidents are investigated and recorded in airline maintenance operations.[13] Researchers examined 130 technical operations ground damage incidents, representing three and a half years of data, in an attempt to identify the causes for each incident. The incidents were first sorted into hazard patterns according to the specific action that caused the incident. Only twelve distinct hazard patterns were identified, indicating that the same types of incidents occurred over and over (see **Table 5.1**). Next, the latent failures, or those errors that derived from decisions made by supervisors and managers who are separated by both time and space from the physical system, were identified for each incident (see **Table 5.1**). As in the research from the **APRG**, latent failures were organized according to the **SHELL** model. Finally, the relationships between hazard patterns and latent failures could be closely examined.

Such an analysis lends itself to the development of targeted interventions to prevent additional ground damage incidents. A matrix of hazard patterns and latent failures was developed, allowing the effect of an intervention to be evaluated. If an intervention were chosen to address a particular latent failure, the matrix would allow the effect on hazard patterns to be identified. For example, problems with painted guidelines, lines painted on taxiways and aprons for pilots to line up their aircraft, were associated with 10 percent of all ground damage incidents. Thus, if an intervention to improve the guideline problem was introduced and was 60 percent effective, then there would be an impact on 60 percent x 10 percent = 6 percent of ground damage incidents. This methodology provides a means of justifying the implementation of a specific intervention.

In addition, Chi-squared analysis showed significant associations between specific latent failures and specific hazard patterns (see **Table 5.1**).[14] Thus, it is possible to use this information to guide the choice of interventions that address particular latent failures, which in turn will prevent future ground damage incidents from the associated hazard patterns.

Table 5.1. Summary of Associations between Hazard Patterns and Latent Failures from Chi-squared Analyses

Latent Failures	Associated Hazard Patterns
Hardware	
H1 Poor Equipment	1.1 Equipment strikes parked aircraft
H1.1 Poor Equipment: Inappropriate for Task	
H1.2 Poor Equipment: Mechanical Problem	
Environment	
E1 Inadequate Space	2.3 Aircraft under tow
E1.1 Inadequate Space: Congested Area	
E1.2 Inadequate Space: Ill-suited for Task	
E2 Problems with Painted Guidelines	2.3 Aircraft under tow
E2.1 Guidelines: Do Not Exist	
E2.2 Guidelines: Do Not Extend Out of Hangar	
E2.3 Guidelines: Not Suitable for Aircraft	
Liveware (Individual)	
LI Lack of Awareness of Risks/Hazards	1.2 Aircraft or part moves to contact object
Liveware-Liveware	
LL1 Poor Communication	1.2 Aircraft or part moves to contact object
LL1.1 Poor Communication: Between Crew	
LL1.2 Poor Communication: Between Shifts	
LL2 Personnel Unaware of Concurrent Work	1.2 Aircraft or part moves to contact object
LL3 Correct Number of People Not Used	(General)
LL4 Pressures to Maintain On-Time Departures	(General)
LL5 Pushback Policies Not Enforced	2.3 Aircraft under tow

As described earlier, there has been considerable effort expended to describe the types of problems that typically cause ground damage incidents. Previous research has also provided a methodology that can be used to examine future incidents. However, analyses of past incidents indicate that there are only a small number of incidents that continually recur, and causes of these incidents have already been captured in previous studies.[13,14] Thus, continuing to examine incidents without examining interventions does not help to prevent future incidents; it simply helps to strengthen confidence in the classification system and methodological approach to data analysis. Developing targeted interventions, and evaluating the effectiveness of these interventions is the next important step in preventing re-occurrence of typical ground damage incidents.

OBJECTIVES

Although previous research has pointed to interventions which appear to be effective in preventing future ground damage incidents, little effort has been made to objectively evaluate these interventions. Thus, the first objective of this study was to quantify the effectiveness of human factors interventions in ground damage incident reduction at one airline.

Although it is useful to measure the effectiveness of particular interventions, it is necessary to determine a methodology that can be generalized to other possible interventions. Thus, a second objective of this study was to establish a methodology for analysis of incidents, deriving interventions and measuring the effectiveness of interventions that can be used by other airlines and for other human error outcomes.

5.3 METHODOLOGY

There were three steps to our methodology. First, our earlier analysis was extended to non-maintenance ground damage to provide a larger database. Next, two studies were completed , each involved a different evaluation methodology.

5.3.1 Airline Partner Background

Our previous studies of maintenance-related ground damage incidents (GDIs) focused on identifying the root causes (latent failures) underlying the final incidents (active failures).[13] The current project goes beyond these analyses to evaluate interventions based, in part, on the causal structures we have developed.

The airline partner has, of course, an on-going program of responses to **GDI**s. **Appendix 1** presents the current initiatives at the airline. (Note that this list has been de-identified to preserve the anonymity of the airline). As typical in the airline industry, our airline partner keeps and analyzes data on GDIs for management purposes. A computerized data entry form is used to record specific information about each incident, and a detailed investigation is performed for most ground damage incidents. The data from the computerized data entry form is then brought into spreadsheets, which allows the data to be examined on a regular basis (e.g., monthly). These spreadsheets are used to analyze incidents by station, by fleet, by equipment involved, etc. While this type of analysis gives data on the magnitude and location of the ground damage problem, it does not relate to either causal factors or interventions. Although the detailed investigations of ground damage incidents include information about causal factors and recommended interventions, this information is less likely to be used when looking at the ground damage problem.

At our partner airline, records of ground damage incidents in ground operations are maintained separately from ground damage in technical operations (maintenance). Since the tasks performed by ground crews and mechanics differ significantly, it would be expected that ground damage incidents types and frequencies should also differ between the two departments.

5.3.2 Analysis of Non-Maintenance GDIs

Our initial analysis of the partner's maintenance-related **GDI**s (1995-96) has been supplemented by analysis of 315 additional incident reports from the ground operations area. GDI reports from January 1995 through November 1995 and from September 1996 through February 1997 were included in this analysis. Only 42 of these (13%) did not fit into our previous classification of active failures, or hazard patterns. Four new hazard patterns have been developed to cover these new incidents. The classification of ground damage incidents into hazard patterns has been summarized in **Table 5.2**. In addition, our partner airline allowed access to the spreadsheets summarizing the ground operations ground damage incidents from 1995, 1996, and January through June of 1997.

Table 5.2. Comparison of Technical Operations Ground Damage Incidents and Ground Oper Ground Damage Incidents

	Technical Operations Incidents	Ground Operations Incidents	ALI Inci

	Number	**Percent**	**Number**	**Percent**	**Tot**
1. Aircraft is Parked at the Hangar/Gate/Tarmac	**81**	**62**	**280**	**89**	**36**
1.1 Equipment Strikes Aircraft	51	39	239*	76	**290**
1.1.1 Tools/Materials Contact Aircraft	4	3	16	5	**20**
1.1.2 Workstand Contacts Aircraft	23	18	25	8	**48**
1.1.3 Ground Equipment Driven into Aircraft	13	10	63	20	**76**
1.1.4 Unmanned Equipment Rolls into Aircraft	6	4	36	11	**42**
1.1.5 Hangar Doors Closed onto Aircraft	5	4	2	1	**7**
1.1.6 Jetway Contacts Aircraft			17	5	**17**
1.1.7 Employee Contacts Aircraft			2	1	**2**
1.2 Aircraft (or Aircraft Part) Moves to Contact Aircraft	30	23	23	7	**53**
1.2.1 Position of Aircraft Components Change	15	12	7	2	**22**
1.2.2 Center of Gravity Shifts	9	7	6	2	**15**
1.2.3 Aircraft Rolls Forward/Backwards	6	4	10	3	**16**
1.3 Cord/Hose Pulled out of Aircraft			18	6	**18**
2.0 Aircraft is Moving (Under Tow or Taxi)	**49**	**38**	**30**	**10**	**79**
2.1 Towing Vehicle or Towbar Contacts Aircraft	5	4	8	3	**13**
2.2 Aircraft is Not Properly Configured for Towing	2	2	1	0	**3**
2.3 Aircraft Contacts Object/Equipment	42	32	21	7	**63**
2.3.1 Aircraft Contacts Fixed Object/Equipment	13	10	2	1	**15**
2.3.2 Aircraft Contacts Moveable Object/Equipment	29	22	19	6	**48**
3.0 Service/Maintenance Error Caused Damage to Aircraft			**5**	**1**	**5**
	130	100	315	100	**44**

NOTES ON TABLE 5.2:

*** Totals for hazard pattern 1.1 includes 78 incidents that could not be broken into subcategorie lack of information**

Data for Technical Operations represents 3.5 years of data, while data for Ground Operations represe years of data

It is important to note that there were 78 ground damage incidents (or 25 percent of the ground operations incidents) that could not be classified more specifically than hazard pattern 1.1 (Equipment Strikes Aircraft). In most of these incidents, ground personnel discovered damage to the aircraft while working around the aircraft, and the exact cause and time of the incident was unknown. However, due to the nature and location of the damage, it was possible to determine that something contacted the aircraft causing the damage, but exactly `what did contact the aircraft could not be determined.

Our previous set of **GDI**s (from technical operations) was further analyzed to identify the interventions that had been recommended based on the ground damage incident investigation. Generally, the recommended interventions were based only on the information uncovered during the investigation, and were not concerned with the entire ground damage problem. A similar analysis was not performed on the ground operations incidents due to incomplete data for many incidents. The interventions recommended by the ground damage incidents analysts were heavy on changing procedures documents, training and counseling, although a number of hardware changes were also recommended. A summary of the recommended interventions is presented in **Table 5.3**, and the complete list of interventions is presented in **Appendix 2**. These interventions have been organized according to the **SHELL** model to match the categorization of latent failures in the ground damage incident analysis. Note that there were over 500 recommended interventions for 130 incidents, indicating that investigators often are able to identify multiple potential solutions to a problem. Our previous analysis indicates that the 130 incidents fall into only 12 distinct categories, implying that the same events keep re-occurring to cause ground damage incidents. Thus, we can infer that many of these recommendations were either not implemented or ineffective, since had they been implemented and effective, later incidents would have been prevented.

Table 5.3. Summary of Recommended Interventions for Ground Damage

	Number	Percent
Software	**73**	**14**
Placards/Warnings	10	2
Changes to Procedures	63	12
Hardware	**112**	**22**
Changes to Hardware	54	11
Supply and Use Correct Equipment	30	6
Improve Maintenance of Equipment	28	5
Environment	**51**	**10**
Improve Lines/Markings	28	6
Use Traffic Cones	3	.5
Improve Lighting	3	.5
Better Use of Space	17	3
Liveware (Individual)	**209**	**41**
Training/Coaching	79	15
Hazard Awareness/Alerting	39	8
Ensure Procedures are Followed	91	18
Liveware/Liveware	**64**	**13**
Improve Situation Awareness/Coordination	9	2
Improve Supervision/Management Support	10	2
Improve Communications Within Team/Shift	21	4
Establish New Policies	24	5
TOTALS	**509**	**100**

Table 5.3 shows one set of data from our airline partner, i.e., interventions recommended by ground damage incident investigations.

We have already seen in Appendix 1 a list of ongoing interventions in the ground operations department at our partner airline. Both the recommended interventions and the on-going interventions have been classified using the same **SHELL** model (see **Table 5.4**).

Table 5.4. On-going Activities (Interventions) to Address Ground Damage at Partner Airline

	Number	Percent
Software	**3**	**8**
Placards/Warnings	2	5
Changes to Procedures	1	3
Hardware	**8**	**21**
Changes to Hardware	4	10
Supply and Use Correct Equipment	1	3
Improve Maintenance of Equipment	3	8
Environment	**0**	**0**
Improve Lines/Markings	0	0
Use Traffic Cones	0	0
Improve Lighting	0	0
Better Use of Space	0	0
Liveware (Individual)	**11**	**29**
Training/Coaching	11	29
Hazard Awareness/Alerting	0	0
Ensure Procedures are Followed	0	0
Liveware/Liveware	**16**	**42**
Improve Situational Awareness/Coordination	1	3
Improve Supervision/Management Support	10	26
Improve Communications Within Team/Shift	0	0
Establish New Policies	5	13
TOTALS	**38**	**100**

Thus, we have two sets of interventions: those actually implemented and those proposed. Comparisons between **Table 5.3** and **Table 5.4** indicate that the partner airline is currently concentrating more on liveware and liveware/liveware interventions than was suggested by past incidents (71 percent to 54 percent). Also, the partner airline is currently not focusing on any environment interventions, though these were recommended during the investigation of past incidents. A Chi-square test on the **SHELL** category totals confirm that the difference between recommended and on-going interventions is significant (X^2 (4) = 31.1, $p < 0.001$).

There is less data available on the relationship between recommended interventions and actually implemented interventions. For example, in many cases it is unknown whether a recommended intervention was ever implemented or if an implemented intervention caused additional problems in the system. From these two sets we have chosen a number of interventions for evaluation so as to demonstrate the effectiveness of different interventions. We are also collecting before-and-after data on a new intervention that was proposed by the **SUNY** at Buffalo Team.

Thus, there are effectively two projects: one to evaluate management-initiated interventions retrospectively using archival data and one evaluating a jointly initiated intervention using prospective data. These are referred to as the archival study and the prospective study.

5.3.3 Study 1: Use of Archival Data

The airline partner maintains records of both ground damage incidents and dates of implementation of interventions. We used both data sets to determine the effectiveness of interventions by counting incidents before and after each intervention. At present, our airline partner performs occasional informal evaluations by tracking incidents immediately following particular interventions, but it has no mechanism for performing statistically valid evaluations on an on-going basis.

First, we chose interventions specifically to demonstrate the range of applicability of this technique. From our analysis of recommended interventions using the **SHELL** model, we found each of the five model components represented, although the emphasis is on procedures [software and personnel (Liveware)]. We have chosen interventions that are expected to have quite different characteristics:

- A liveware/liveware interaction using a training intervention targeted at first line supervisors, specifically training of crew chiefs through the Equipment Service Chief (ESC) training program.
- A liveware/liveware interaction using a training intervention targeted at first line operators, specifically training on jetbrige operations for Customer Service Agents (CSA) and cleaners.
- A procedure intervention, where a specific procedure change has been implemented, in this case the canopy procedure modification for a specific aircraft type.

The training interventions were chosen as being relatively inexpensive and rapid in their implementation. However, any training intervention may be expected to have decreased effectiveness over time due to personnel forgetting the training and/or re-assertion of less effective norms. In contrast, a procedure intervention may be expected to have more permanent effects, even though it is often slower and more costly to introduce. Note that the first two interventions represent changing the operator to fit the task, while the third is an example of changing the task to fit the operator. In any human factors program, both types of interventions are needed, so we need ways of evaluating the effectiveness of each.

Most interventions at airlines are programmed for a phased implementation due to resource limitations. Thus, not all personnel can be trained on the same day, or even in the same month. Hardware and procedure changes may take even longer, where they require site-by-site and even gate-by-gate changes to ground-based equipment and procedures. Some procedural changes (software) can be implemented rapidly. For example, manuals can be changed quickly, but the full effect of these changes on operator behavior may still take some time to appear. Thus, in using archival data, we must take into account the progressive rather than instantaneous nature of changes.

In this archival study we combined the existing data from ground damage incidents and intervention records to develop measures of effectiveness despite phased introduction. The month of introduction of an implemented change was used as a constant starting point for measurement. Prior and subsequent months then had negative and positive values, respectively. All sites (stations, areas or even specific gates, depending on the intervention) were matched to the implementation date of the intervention at that site. Note that existing records of who was trained on what date are not always easy to match to records of personnel on duty at specific gates over specific periods. Ground damage incidents were then recorded according to the number of months of both pre- and post-interventions, as far as the data allowed. Since ground damage is fortunately a rare occurrence, most sites will have zero in most cells (indicating that no ground damage occurred during that month), with some having one and rarely two or more.

5.3.4 Study 2: Use of Prospective Data

The intervention for the prospective study, regular behavioral feedback, was one that is relatively new to airlines, relatively inexpensive, yet well established in the literature. In this technique, the occurrence of well-defined safe and unsafe behavior is counted on a regular basis, and visual feedback based on these counts is provided weekly to the personnel involved. Sulzer-Azaroff and De SantaMaria concluded that feedback accompanied by approval of, and suggestions for, improvement is an effective intervention strategy in industrial settings.[11] Behavioral feedback has a long history, for example in improving safe operations of forklift trucks in warehouses, or improving manufacturing safety.[2,11] In fact, a similar system was being used currently at the partner airline (in conjunction with Liberty Mutual) to help control injuries in ground maintenance operations. In this project, we analyzed the effects regular behavioral feedback to impact the specific behaviors which contribute to ground damage incidents.

From our previous analysis of the active and latent failures we developed a set of safe behaviors which, if followed, will eliminate particular latent failures that contribute to ground damage incidents. Thus, for one hazard pattern, vehicle moves to contact aircraft, one strongly-associated action was leaving the engine running or the parking brake unset, so that the vehicle was able to move, e.g., by wind gust or inadvertent gear shift. The safe behaviors associated with this action were “setting the parking brake” and “switching the engine off.” A set of safe behaviors was developed from the **GDI** analysis, and is shown in **Table 5.5**. The items on this checklist represent behaviors that have been shown to contribute to ground damage incidents in the past. They provided proven cause-and-effect relationship between operator behavior and the costly outcomes of ground damage.

Each safe behavior had defined for it a visible indication, such as parking brake position or engine running for an unattended ground vehicle. Others, to address specific latent and active failures, were holding a brief team meeting before each arrival (the departure “huddle”), and having the correct number of personnel available as wing walkers for each push-back. The safe behaviors checklist was developed in conjunction with the partner airline ramp personnel to ensure that it was practical as well as technically accurate. In fact, some of the same visible safe behaviors were already included in the partner’s current safety study.

The partner airline has made results from its on-going safety audits available for inclusion in this analysis. Behavior patterns common between the safety audits and on the safe behavior checklist (**Table 5.5**) have been used to determine baseline performance, and to evaluate the effect of previously implemented interventions on the behaviors of ground operations personnel.

Table 5.5. Safe Practices Checklist

		YES	NO	N/A
General				
1	Taxi lines properly marked?			
2	Vehicles parked in assigned place?			
3	Safe zone lines painted at gate?			
4	Engine turned off when vehicle is left unattended?			
5	Parking brake set when vehicle is left unattended?			
6	Gear selector in neutral when vehicle is left unattended?			
7	Vehicle chocked when left unattended?			
8	Jetway bumper 1” to 3” away from aircraft?			
9	Jetway rubber bumpers and canopy in good condition?			
10	Loaders correctly positioned to aircraft on first approach?			
11	All loader guide rails in position?			
12	Loaders properly positioned against aircraft?			
13	Ground equipment positioned at least 4 feet from aircraft?			
14	Proper equipment used to service aircraft?			
15	Guideman used as vehicle was backed away from aircraft?			
16	Tugs and carts driven too close (within 6 feet) to the aircraft?			
17	Tugs and carts hand-pulled too close (within 4 feet) to the aircraft?			
18	Less than maximum number of carts/trailers (4) used at any one time?			
19	Correct approach/departure made with trailing carts?			
20	Handbrakes set on unattended carts/vehicles?			
21	Guideman used when maneuvering equipment close to aircraft?			
22	Vehicles driven under any part of the aircraft?			
23	Unused equipment/parts accumulated in work areas?			
24	Beltloader driven with boom in lowered position?			
Vendors				
25	Use guideman while positioning their vehicle to/from aircraft?			

26	Use truck chocks?			
27	Position vehicle in correct location?			
Aircraft Specific				
	Aircraft type A			
28	Jetway canopy lowered on aircraft?			
	Aircraft type B			
29	Beltloader inserted into rear cargo bin?			
30	Proper 3-step towbar disconnect procedure followed?			
Arrival				
31	Is ramp crew at gate prior to aircraft arrival?			
32	Is gate area set up prior to aircraft arrival?			
33	Jetway pre-positioned at a marked position?			
34	All pre-positioned equipment in designated areas?			
35	Aircraft parked on proper stop mark?			
36	Both main gears chocked?			
37	Aircraft chocked before equipment positioned at aircraft?			
38	Cones properly placed at wingtips or engines?			
39	Equipment positioned correctly at aircraft?			
40	Wingwalkers used in congested areas?			

Departure				
41	All doors and access panels closed?			
42	Chocks in place until all equipment removed?			
43	Communications maintained until all engines started?			
44	Pushback crew meets (huddles) before beginning pushback?			
45	Proper hand signals and wands used by pushback crew?			
46	Jetway in designated safe zone before aircraft departure?			
47	Wingwalkers correctly positioned?			
48	Correct number of wingwalkers/guidepeople used?			
49	Area visually checked for clearance before aircraft departure?			
50	All equipment in jetblast area secured?			
51	Equipment backed into proper parking position?			
52	Ground power cords disconnected?			

Observers must be trained, by **SUNY** at Buffalo and the partner airline, to make reliable and consistent observations of each indication on the Safe Practices Checklist. An initial, baseline, level can be found for the fraction of safe behaviors using a standard occurrence sampling technique. This defines the number of each behavior to be sampled, and the sampling plan to ensure effective coverage of gates, shifts and aircraft fleets. Using the baseline level of safe behavior probability, ramp management can set future target levels. For example, if the current level was .81 (81 percent of behaviors are safe), a first-month target level of .90 may be chosen, with expected safe behaviors ramping up to .95 for the next two months and .98 for the time period up to six months in the future.

The data from this type of study can be analyzed on a regular basis, usually weekly. Data can be presented to all personnel as a graph, or control chart, showing actual and target levels. As weeks pass, all personnel can see progress towards the target levels. In similar studies, the data is aggregated across natural units, such as the set of gates serviced by each team, as well as by stations. In other studies, two enhancements have been used. First, if an observer sees an unsafe behavior, he/she may be asked to tell the person involved immediately and provide reasons for, or coaching in, safe performance. Second, the weekly graphs may have additional data on the top three unsafe behaviors. Both of these enhancements provide directive feedback (or cognitive feedback) in addition to the performance feedback provided by the graph of safe behaviors.

5.4 RESULTS

The results of each study, archival and prospective are presented in turn.

5.4.1 Study 1: Use of Archival Data

Procedural Intervention: Canopy Procedure Modification

This intervention was targeted at a specific aircraft fleet at our partner airline. This aircraft type differs from other aircraft types in height and door operation, which results in a reduced clearance between the aircraft and jetbridge canopy when the canopy is lowered. The canopy contacting the aircraft caused many ground damage incidents. Thus, a new policy/procedure was implemented to prevent this type of incident. Airline management instructed all personnel not to lower the jetbridge canopy on this particular aircraft type. A placard was provided for each gate reminding jetbridge operators of this policy. Placards were provided simultaneously to all stations, and station management was told to install the placards immediately. Airline management believes that at least 99 percent of stations have complied with the requirement to install the placards (Personal Communication, 12/97).

One expected problem with this procedural change is that the jetbridge canopy protects passengers and crewmembers, as well as the floor of the jetbridge, from getting wet in bad weather. Thus, the policy not to lower the canopy may oppose airline personnel's overall objectives to keep passengers safe and comfortable. In addition, this policy/procedure requires airline personnel to use a different procedure for adjusting the jetbridge on this particular fleet than is used for all other fleets. Thus, airline personnel may be susceptible to capture errors, where routine, well-learned patterns of behavior take over and prevent a newer procedure from being performed.[10]

To examine the effectiveness of this intervention, a before/after approach was used in the statistical analysis. This allows us to determine whether there were different numbers of incidents before and after the intervention was implemented. An effective intervention should reduce the number of incidents that occur after it is implemented. However, caution in interpreting the data in this analysis is needed. The occurrence of a ground damage incident, even one caused by lowering the jetbridge canopy on this aircraft type, is infrequent. It is also impossible to know whether the modified procedure was followed each time an aircraft of this fleet was parked at a gate. Thus, changes in the number of incidents may not actually represent an improvement caused by the intervention itself, but rather be due simply to the infrequency of the occurrence.

Results from the statistical analysis indicate, as expected, that the number of incidents differ significantly by stations. This represents the differences in fleet usage throughout the airline system with busier stations contributing more incidents. Examination of ground damage incident patterns at each station indicates that there is no statistically significant effect on the before/after factor, meaning the intervention has not affected the occurrence of ground damage incidents.

Liveware/Liveware Intervention: Jetbridge Training Program

Jetbridge training was provided to **CSA**s and cleaners in June/July 1996. CSAs are often responsible for positioning the jetway at the aircraft upon aircraft arrival and for retracting the jetway once the passengers and crew boarded. Cleaners may position the jetbridge to gain access to an aircraft parked at a gate. The jetbridge training program had two phases; first, a classroom session that reviewed a "bullet list" of points concerning jetbridge safety was conducted, followed by a hands-on demonstration of safe and correct operation of the jetbridge.

The ground damage incidents were reviewed to determine which incidents were caused by problems operating the jetbridge. Data was analyzed for 1995, 1996 and January through June 1997. **Figure 5.1** summarizes the incidence of jetbridge incidents across the system. There were jetbridge-related incidents at 33 stations during this time period, with the highest number of incidents at the two busiest stations in the airline system.

Data was summarized using two methods: the trimester approach and the before/after approach. The trimester approach was intended to detect the presence of trends, and whether this trend was modified by the implementation of the intervention. In the trimester approach, the number of incidents in three-month blocks was counted. Then, data could be analyzed according to the duration of time between the incident and the implementation. It was necessary to collapse data into the number of incidents in a trimester (instead of using number of incidents per month) due to the infrequent nature of ground damage incidents.

Month	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	A	B	C	D	E	F	G	total
Jan 95																									1									1
Feb 95									1	1													1											3
Mar 95																																		0
Apr 95																																		0
May 95										2					1		2											1						6
Jun 95																	1																	1
Jul 95									1																									1
Aug 95																							1											1
Sept 95															1	1							1											3
Oct 95							1						1							1										1		1		5
Nov 95																																		0
Dec 95										2				1								1												4
Jan 96										1										1			1				1		1					5
Feb 96									1	3								1					1		1									7
Mar 96										1																								1
Apr 96										3																								3
May 96		1								2													2		1									6
Jun 96			1		1					2										1			1											6
Jul 96	1	1		1						2										1											1		2	9
Aug 96	1										1					1			1							1								5
Sept 96										1											1									1				3
Oct 96										1																								1
Nov 96										1																								1
Dec 96						1																	2											3
Jan 97										4														1	1									6
Feb 97												1												1										2
Mar 97										2													1										1	4
Apr 97										1																							1	2
May 97											1																	1						2
Jun 97								1			1				1																			3
Jul 97										2										1														3
TOTAL	2	2	1	1	1	1	1	1	3	31	3	1	1	1	3	2	3	1	1	5	1	1	11	2	3	1	1	2	1	2	1	1	4	

Figure 5.1. Monthly Summary of Jetbridge Incidents

The before/after approach was intended to simply determine whether the implementation was effective in preventing ground damage incidents. In the before/after approach, the data was simply coded as to whether it occurred before the intervention was implemented (assigned a “zero”) or whether it occurred after the intervention was implemented (assigned a “one”).

Statistical analyses were conducted using time (separate analyses were performed for the trimester and before/after approaches) and location as the two factors. As expected, location was found to be significant in both analyses, reaffirming that operations are different at each station in the system. Stations differ in terms of number of flights per day, the different aircraft fleets which must be accommodated, the number of jetbridges which are utilized, the number of personnel available, the time available for turning an aircraft, etc.

Since there is such variation between the stations, it is necessary to examine the effect of the intervention at each station individually. Additional statistical analyses were conducted for each station using both the trimester and before/after approach. Using the before/after approach, there was a significant effect at only one station (Station 32, p=.025). However, closer examination of the data at this station indicates that all of the incidents at this station occurred after the intervention (the training program) was implemented.

Lack of significant effects of the before/after approach indicates that the jetbridge-training program did not affect the number of jetbridge ground damage incidents at this airline. Thus, although providing such a training program did not increase the number of jetbridge incidents, it did not prevent any jetbridge incidents either, so could be considered neffective.

The previous analysis looked at all jetbridge related incidents in the reviewed time period. However, this analysis included incidents that were caused by personnel other than **CSA**s, who had not received this additional training. Therefore, a second analysis was performed, looking at only those incidents which could be attributed to CSAs. In the before/after analysis, there was a marginally significant effect at only one station (Station 73, p=.084). Four incidents occurred before the intervention and two occurred after the intervention. This is the only location where there is some indication that the intervention was effective.

There were 101 jetbridge related ground damage incidents in the data analyzed (1995 through July 1997). Examining the ground damage incident reports for each incident allowed us to classify these incidents into primary incident types, which can be mapped onto the hazard patterns described in **Section 5.3.2**. **Table 5.6** summarizes the number of jetbridge related ground damage incidents in each incident type. Note that the number of incidents in this table represents ground operations ground damage incidents from 1995 through July 1997, which is a different (though overlapping) data set than that described earlier.

Table 5.6. Summary of Jetbridge-Related Ground Damage by Incident Type

Incident Type	**Definition**	**1995**	**1996**	**1997**	**Total**
Jetbridge Contacts Aircraft					
Jetbridge Operation	Operator violates prescribed procedures while operating jetbridge	1	4	3	**8**
Jetbridge Malfunction	Jetbridge equipment malfunctions while it is in use at an aircraft	5	6	7	**18**
Jetbridge Movement	Jetbridge contacts aircraft while being moved into position	1	6	4	**11**
Jetbridge/Aircraft Movement	Miscommunications between aircraft personnel and jetbridge operator causes jetway to contact aircraft	2	2	0	**4**
Environment - Wind	Windy conditions cause jetway to be blown into aircraft	0	2	1	**3**

Aircraft Contacts Jetway					
Jetbridge Position	Jetbridge is parked in wrong location when aircraft approaches	4	3	1	**8**
Aircraft Movement	Aircraft contacts jetbridge while jetbridge is being moved into position upon aircraft arrival	1	6	1	**8**
Aircraft Rolls	Aircraft rolls into jetbridge	1	1	1	**3**
Other					
Special Cause	Mismatch between jetbridge and specific aircraft configuration causes aircraft to be damaged.	1	10	0	**11**
Found	Aircraft is found damaged, and the investigation determines that a jetbridge caused the damage	6	7	7	**20**
Unknown	Cause is unknown, but is attributed to the jetbridge in the incident database	2	5	0	**7**
	Totals	**24**	**52**	**25**	**101**

An initial Chi-square analysis showed a significant difference between the three years (X^2 (1) = 14.99, p < 0.01), and that this pattern did not change across the different incident types (X^2 (4) = 4.09, p > 0.25).

A second set of statistical analyses was performed to determine whether the jetbridge-training program had any affect on a particular incident type. Both the trimester and before/after approaches to counting incidents were utilized. Results indicated a significant effect only for the jetbridge movement incident type under the trimester approach (p = .007).

This analysis was also repeated for incidents that could be attributed to **CSA**s. Only one incident type, jetbridge operation (p=.047) showed a significant before/after effect. A closer look at the data shows that there were more incidents before the intervention than after, indicating that the intervention was effective in reducing this particular type of jetbridge-related incidents.

Liveware/Liveware Intervention: ESC Training Program

In 1996, safety and leadership training was provided to most Equipment Service Chiefs (ESCs). ESCs are first line supervisors who work alongside ground operation personnel on the ramp. This training program aimed to raise awareness of safety considerations on the ramp, and to make supervisors aware of possible risks and potential hazards that contribute to ground damage incidents.

Ground damage reports were reviewed to determine whether this training program had any effect on the incidence of ground damage on the ramp. In contrast to the jetbridge training intervention discussed previously, this training was provided to first line supervisors, who were expected to use the information to guide their supervision of subordinates. Thus, the effect on ramp personnel was not direct; that is, the effect of the training program on ramp behaviors was dependent on the information passed from **ESC** to the crew, and the ESC's supervision of his/her crew. Such information would further clarify the effectiveness of general training programs on actual ramp performance. However, the ground damage data collected by the partner airline does not allow this information to be easily obtained.

Each ground damage incident report consists of two parts: an electronic data form, which is submitted immediately after the incident occurs, and a written, detailed report compiled by a team of incident investigators. The electronic form consists of basic information as to where an incident occurred, who was involved in the incident, what were the environmental conditions, and what equipment was involved. This information is kept in a database that can be queried for specific information. For example, the database can be queried to determine how many incidents occurred on rainy days at one specific location. Only the employee numbers of personnel involved in an incident are recorded in this database. These employee numbers do not provide any indication of the job of the employee (e.g., baggage handler or customer service agent). The written report may include narrative information that describes the job of the employees involved, but not necessarily.

The partner airline was able to provide information on which **ESC**s had undergone training, but the data did not allow conclusions as to which ESC was responsible for the crew involved in any particular ground damage incident. Thus, it is virtually impossible to determine the effect of this training intervention on ground damage incidents.

5.4.2 Study 2: Use of Prospective Data

Our partner airline has made results from its on-going safety audits available for inclusion in this analysis. A total of 340 audits, conducted at 120 stations over a six-month (July – December 1997) period have been analyzed. Behavior patterns from the safety audit that also occur on the safe behavior checklist have been analyzed (see **Table 5.4**). **Table 5.7** summarizes the behaviors used in this analysis.

Table 5.7. Behaviors from Safety Audits Used in this Analysis

	Safety Audit Behavior Measured at Airline	Corresponding Safe Behavior from Table Y-[illegible]
1	Lead-In Lines Visible	1
2	Safety Zone Lines Visible	3
3	All Equipment and Jetbridge Outside Safety Zone	2
4	Cones and Chocks Safely Stowed, Not Lying on Ramp	32
5	Jetbridge Pre-Positioned for Aircraft Type (Height) – On Parking Spot	33
6	Spacer Bar Does Not Touch Aircraft (1” – 2” Space)	8
7	Jetbridge Not Moved into Position and Equipment Remains Out of Safety Zone Until “Wheels Chocked” Signal Given	37
8	Top of Canopy Does Not Touch Aircraft (Canopy Not Lowered on Fleet X Aircraft)	28
9	Marshaller Uses Approved Wands	
10	Wingwalkers Positioned in View of Marshaller at Wingtips During Arrival (As Required)	40
11	Both Main Gears Chocked After Aircraft Stops on Proper Mark	36
12	Cones Placed in Proper Position	38
13	Gear in Neutral/Parking Brake Set/Conveyor Not Touching Aircraft	6
14	Conveyor Belt Wheel Chocked Forward and Aft	7
15	During Idle Operations, Conveyor Backed Away from Aircraft, Boom Lowered and Engine Turned Off	24
16	Conveyor not Positioned Inside Cargo Bin of Fleet V Aircraft	29
17	Vehicles Not Driven Within 6’ of Aircraft or Manually Positioned within 4’ of Aircraft	16,17
18	Jetbridge Positioned Safely Away from the Aircraft before Departure	46
19	Towbar correctly disconnected from Aircraft for Fleet V Aircraft	30
20	Wingwalkers using Approved Wands During Departure	45
21	Wingwalkers Positioned in Full View of Marshaller at Wingtips During Departure	47
22	Employees Demonstrate Proper Hand Signals for Departure	45
23	Motorized Equipment and Carts Staged in Designated Parking Spots, with Brakes Set and Motors Off	51
24	Canopy in Good Repair and Rubber Spacer in Good Order	9

The first analysis performed on this data set was to consider the pattern of behaviors over the six months of data collection. Analysis of an aggregate measure of performance (percentage of observed safe behaviors) was not significant. Thus, each behavior was considered separately. Results indicated that Behaviors 1, 4, 14, 17, and 23 had a significant effect over months (corresponding p-values of: .021, .005, .063, .005, and .052). However, closer examination of means indicates that there are no trends that indicate that behaviors have either improved or worsened over time, just that the monthly totals were different.

Next, the correlation between observed behaviors and actual ground damage incidents was examined. This was done by considering first only ground damage incidents that occurred during the period of data collection (July – December 1997), and then considering ground damage incidents for three complete years (1995 – 1997). The first analysis determined whether observed unsafe behaviors contribute directly to ground damage incidents, while the second analysis took a larger view of whether observed unsafe behaviors make it more likely for ground damage incidents to occur.

There was a significant correlation for Behaviors 3 (p=.080), 4 (p=.047), and 9 (p=.001) and the number of incidents that occurred during the data collection period. However, each of these has a very low R-squared value, indicating that they are not good predictors of the actual occurrence of incidents. Interestingly, the regression equation for the total of all 24 behaviors and the number of incidents during this time period is also significant ($p < 0.01$) and has an R-squared value of 88.9 percent (Adj. R-squared is 81 percent). This indicates that looking at a combination of all of these observed behaviors gives a better prediction of actual incidents than individual behaviors.

Examining the correlation between the number of incidents in the three previous years with the observation of safe behaviors gives similar results. 1995 data shows that there is a significant correlation for Behaviors 4 (p=.036) and 9 (0.0) with the total number of ground damage incidents. 1996 data shows a significant correlation for Behaviors 4 (p=.032), 9 (p=0.0), and 19 (.068). Finally, 1997 data shows significant correlation for Behaviors 4 (p=.052) and 9 (p=.001). In addition, the regression equation for all 24 behaviors and the number of incidents in all of 1997 is significant (p=0.0), and has an R-squared value of 94.4 percent (Adj. R-squared is 90.4 percent). Thus, the same behaviors (4 and 9) give significant results consistently across the three years.

These results indicate that Behavior 4, properly stowing cones and chocks, and Behavior 9, using the correct wands during aircraft arrival, are important in preventing ground damage incidents. Both of these behaviors are indications of preparedness on the part of the ground crew, which may explain their importance in predicting ground damage incidents. Crews that are set-up in advance for an aircraft arrival may have more time to ensure that the arrival is performed carefully and properly, since the crew does not have to spend time and attention resources obtaining the proper equipment as needed. In addition, the significance of the regression equations for all 24 observed behaviors indicate that these behaviors together can be used to predict the occurrence of future ground damage incidents.

We also examined the data from each station separately. One-way Analysis of Variance analyses were performed for observation of each safe behavior at each station. Results indicated that there were significant differences between stations for Behaviors 1 (p=.002), 2 (.005), 5 (p=0.0), 8 (p=.048), 12 (p=0.0), 14 (.097), 16 (p=0.0), 19 (p=.001) and 24 (p=.002). However, there are no clear patterns that indicate that any one station is consistently worse than other stations. Some stations score poorly on one specific measure, but others score poorly on quite different measures.

The behaviors considered in this analysis consist of only half of the behaviors included on the safe practices checklist which linked behaviors directly to actual ground damage incidents (see **Table 5.5**). Thus, many behaviors that have previously contributed to ground damage incidents have not been considered. It is expected that observations of these additional relevant behaviors would further improve the ability to predict, and thus prevent, future ground damage incidents.

5.5 DISCUSSION AND CONCLUSIONS

Before we discuss the findings of the two studies, important observations about error reporting must be made.

5.5.1 The Role of Effective Error Reporting Systems in Evaluations

An inadequate error reporting system can prevent meaningful evaluations of the data collected by an airline. However, defining an adequate, or appropriate, error reporting system can be quite difficult. It is often the case that a considerable amount of information concerning an incident is collected, but yet it is still impossible to draw any conclusions as to its cause, or to answer other questions about the incident. For example, some checklist-based error reporting systems have little or no space for a narrative description of the incident, and it is often difficult to piece together, from the answers on the checklist, the actual scenario surrounding the incident.

This is a significant problem in using error-reporting systems to determine whether a particular intervention has been effective. The error reporting systems in place at many airlines, including our partner airline, make it quite difficult to ascertain the effect of the intervention on the occurrence of incidents. For example, it was impossible to determine whether the **ESC** training program was effective since no data is collected that records which ESC was on-duty during an incident, or which employees have worked with that ESC prior to being involved in an incident. Thus, more consideration has to be made to the type of data that is necessary to allow an intervention to be properly evaluated.

5.5.2 Evaluation of Interventions

The analysis of an accumulated set of ground damage incidents using human factors principles provides justification for the introduction of interventions. Once a suitably large set of incidents had been evaluated, it became apparent that there were relatively few patterns that keep repeating. Continuing to collect data simply helps to reinforce the patterns and latent failures that typically occur, but does not help to prevent additional incidents. The past incidents allow us to determine the hazard patterns and the associated latent failures, and the relationship between these indicates interventions that may be suitable and effective for preventing future ground damage incidents. In fact, at the latent failure level, interventions that may be effective across multiple hazard patterns become apparent.

However, once an intervention is chosen for implementation, it is necessary to evaluate whether the intervention is effective. Airline management must determine whether the intervention actually prevents additional ground damage incidents at a reasonable cost, without introducing additional problems into the system. Obviously, cost-effectiveness is simply one way to measure the suitability of an intervention. Adding costs to the hazard pattern/latent failure preliminary analysis may also help to provide some insight, by providing a methodology to evaluate the potential savings from introduction of an intervention. For example, if a latent failure of "inadequate guidelines" is known to have caused ten ground damage incidents, then the expected savings from fixing this problem (i.e., implementing an intervention to paint additional guidelines) is equal to the cost of these ten ground damage incidents.

Using the methodologies described in this study, it is possible for an airline to measure the effectiveness of any intervention strategy. Both retrospective evaluations and prospective evaluations are possible. The retrospective evaluations performed in this study indicated that in general interventions recently implemented by the partner airline had not been effective in reducing ground damage incidents. However, it is important to consider how these interventions were chosen by the partner airline. It appears that these interventions were chosen to address problems that represented only a small percentage of the overall ground damage problem. Thus, the incidence of these ground damage incidents were so infrequent to begin with, that the interventions could not be shown to prevent future incidents. Note that the criterion for a statistically significant difference is stricter than that usually applied in business decisions. In many business decisions, *any* reduction in incident rate is typically seen as good, even when there is no evidence to differentiate this reduction from chance fluctuations in the incident rate. However, for application beyond a single airline, or as a basis for national good practice, the criterion should be the stricter one of statistical significance.

In addition, there did not seem to be differences in the types of interventions. That is, the training interventions were no more or less effective than the procedure modification intervention. This may be reflective only of the particular interventions analyzed in this study, and may not be generalizable to other interventions. It would be expected that training interventions would have an initial effect to reduce ground damage incidents, with a return to pre-training levels after some time had elapsed. On the other had, procedure or equipment modifications may elicit a more permanent effect.

Finally, evaluation of interventions increases participant confidence in using human factors techniques and interventions. Using the **SHELL** model of human factors provides an aviation specific and consistent framework in which to compare hazard patterns, latent failures, and interventions. Performing evaluations reinforces the successful interpretations of past incident data into meaningful patterns, and using this information to choose suitable interventions. Obviously, it is also possible to use the methodologies described in this study to other error types, e.g., Foreign Object Damage, Operational Incidents, On-The-Job Injuries, etc.

5.6 REFERENCES

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5.7 APPENDICIES

5.7.1 Appendix 1: On-Going Activities to Prevent Ground Damage at Partner Airline

Training and Awareness

Annual and Recurrent

Manager Safety Training
Jetbridge Training
Loader Training

Slide Deployment Prevention Training Program
Quarterly Station Safety Audits
Ground Safety Training for Flight Crews

One-Time/Initial and Contribution Programs

New Hire Safety and Ground Damage Prevention
Towbar Disconnect Procedures
ESC Safety and Leadership Training
Station Management Training for New Managers
Ground Damage Investigation Policies and Procedures

Equipment Programs

Annual/Recurrent

"Car Wash" at hub stations
Introduction of a Formal Prevention Maintenance Program
Towbar Inspections/Modifications
Jetbridge Canopy Modifications
Jetbridge Modifications

One-Time

Luggage Cart Tire Program
"Set Brake" Placard
Glycol/Sweeper
Wide Spacer Bar on Beltloaders

Policy and Procedures

Canopy Procedure Modification
Vendor Safety Program
Safety Zones
Vehicle Chocking Policy
High Wind Program
Cart Towing Policy
Torque Link Pin Verification/Placard
Investigation Revamping
Changes in Reporting Process
Database Audit and Accuracy Improvements
Changes in Discipline Policies
Corporate Audit/Goal Tie-In
"Found on Arrival" Awareness
Wingwalker Review

Other Miscellaneous Programs

Work with **SUNY** at Buffalo
Airline/ATA Benchmarking and Best Practice Identification
Airline Human Factors Committee
Executive Safety Team

5.7.2 Appendix 2: Recommended Interventions from Technical Ground Damage Incident Reports (1992 - March 1995)

SOFTWARE

Placards/Warnings

Enforce use of “caution” and “danger” tags to identify out-of-service equipment.
0Install decal advising lift driver to check for clearance.
Placard operating pendulum with warning to close aircraft doors.
Use placards and safety devices on any job requiring them.
Stencil warning near hangar door controls to remind operators to check for clearance.
Install placard in vehicle that microbrake is supplemental and should not be used instead of hand brake.
Install signs to warn against driving between aircraft and jetways.
Placard tail dock operating box with reminder to check clearance and use spotter.
Placard hangar door controls warning operators to check clearance. (2)

Changes to Procedures

Review manual to ensure guideman policy is applicable to all operations
Review manuals to ensure good maintenance and safety procedures are included. (2)
Review manuals for pushback and towing procedures. (2)
Incorporate use of spotters into MM. (5)
Ensure all workcard procedures are written correctly.
Require fueler to use vehicles with hoses of sufficient length.
Review Fleet B manual on towing.
Change towing procedure for icy conditions - have wingwalkers next to wheels with chocks ready.
Ensure belt loader is down fully before being moved.
Place inventory list on top of engine change kit.
Include requirement for communication of door light status in pushback procedure.
Revise ramp manual to implement procedures to remove ground equipment before pushback.
Revise captain procedures to insure all ground equipment is clear before pushback.
Change MM to reflect exceptions to existing policies to always turn off unattended vehicles (if this is to be permitted).
Update MM to show how to get elevators to move -- there is an error in manual.
Use guide person when maneuvering ground equipment around aircraft. (7)
Write new procedure for bungee spring removal and installation (include installation of gear pin).

Check clearance before moving ground equipment. (2)
Use spotter when moving aircraft component.
Establish procedure to check both tires, especially in bad weather.
Mechanically connect each set of chocks.
Consider using chocks whenever vehicle is left unattended.
Reduce excessive aircraft moves.
Have mechanic reinstall screws immediately after removal when access is difficult.
Revise procedure for nose landing gear retraction to include precaution to close and lock nose gear door.
Perform PDAU check outside.
Observers should have copy of PDAU check in hand.
Review ramp area cleaning procedures.
Review SOP of using tugs as workstands.
Revise job cards to include safety precautions abut working with flight controls and hydraulics. (2)
Review MM manual about using "Do Not Operate" tags. (2)
Establish policy for specific communications between pushback drivers and wingwalkers prior to pushback.
Ensure personnel and area are clear of nose wheel before releasing brakes and/or moving tug.
Establish procedure to remove tow bar from tow hitch first.
Insert safety precaution into written procedures requiring aircraft component movement.
Slow down on aircraft movement.
Use largest tug practical for all pushbacks.
Test tug steering/brakes before tow bar hookup.
Ensure aircraft is powered during move/parking in order to read brake pressure gauge and to power hydraulic pumps.
Chock tires before removing tow bar.
Ensure chocks are properly placed for bad weather.
Develop aircraft shoring checklist and procedure.
Review tow procedures to remind everyone about their responsibilities before starting tow.
Develop procedure to be accomplished prior to turning on hydraulic power.
Write jacking procedure to address clearing of dock.
Lock airstairs in down position before removing aft jack.
Develop pre-operational checklist, or appoint person to be in charge, to assure area is clear.
Prepare written docking procedure for hangar bays at Station A.

HARDWARE

Changes and Hardware

Install safety pin on Fleet B tow bar.
Investigate feasibility of improving flexibility of movement of jetway.
Modify equipment by installing rubber bumpers.
Install safety rail on all workstands.
Return modified tow hitch to original configuration.
Utilize new hitch on vehicles used to tow large aircraft.
Install mirror so driver can see platform/rails from cab.
Modify wing workstands to enable handrails to collapse.
Hang orange streamers from forward end of de-ice truck catwalk which are long enough for driver to see.

Paint first 6” of catwalk a fluorescent color.
Remove portions of structures and modify switches to facilitate easier aircraft movement.
Paint left forward side of belt loader a bright fluorescent color.
Rework pallet platform/safety railing to provide unique work areas for task.
Provide positive, visible, indication on forklift that it is in neutral.
Install positive locking control on brake system
Install “gate” on all tow tractors to prevent shift lever from drifting.
Paint top of A-frame red and stencil “top heavy” as visual indicators of its imbalance
Vehicles should all have keyed ignitions so only authorized personnel can use.
Equip vehicles with reverse warning horn.
Determine feasibility of balancing Fleet A engine sling.
Determine feasibility of adding slower speed to crane.
Modify deadman switch on equipment to prevent accidental slip-off.
Need lighting systems on all vehicles.
Mount cowl pump to workstand.
Allow sufficient hose on each pump for ease of use. (2)
Install toe rail on stand to prevent tools from falling.
Modify safety rails on workstands.
Install gear safety pins whenever work is performed on landing gear.
Modify control protection plate on belt loader to eliminate sharp protruding point.
Install and maintain warning lights for hand brakes, for visual indication that brakes are set.
Modify parking brake to conform to later manufactured tugs.
Paint vertical indication mark on outside of cowl so gap between the two halves is obvious.
Paint lip and forward edge of bottom roll of cowl red, so gap can more easily be seen.
Purchase new motorized work platforms.
Remove windshields from tugs if they are going to be used as work platforms.
Have PM cut angle on lower surface of lift bed so it cannot cause puncture.
Develop system of ropes/pulleys to raise and lower tools from lift bed.
Install safety restraints on vehicle doors.
Redesign wing/engine stand so jacks can be used to shore aircraft while in check.
Review justification for improved Fleet X rudder access equipment.
Install safety bumpers on stands.
Install better swivel wheels on workstands.
Investigate possibility of installing sensors with alarm warning system.
Workstand should have locking device to prevent sagging.
Equip tugs with “hands free” radios.
Modify lower tail dock platforms to allow for rudder travel.
Install pigtail control box to allow operator to stand at edge for better view of dock movement. (2)
Install permanent locks on flap boards on upper level of workstand, instead of using ropes to hold boards back.
Modify tail stand to fold out of way during tow in/out.
Review cost of installing power cable routing to north wall of hangar for hangar reorganization.
Lower safety railing on lift truck bid.
Install rubber bunkers around opening in tail dock.

Use Correct Equipment/Have Equipment Available

Use right equipment to do a job. (5)

More ladders from hangars to ramp areas.
Ensure proper amount/type of equipment is available on the ramp. (2)
Locate equipment at gates/locations where maintenance is performed.
Purchase proper pin insertion tool for nose gear.
Purchase sand for traction augmentation and make available to mechanics.
Remove substandard short tow bars from service on ramps.
Provide safety cones to be used adjacent to O/B edge.
Place operating manual in each dock control box.
Increase number of lift trucks available for overnight maintenance.
Provide fixed/semi-mobile maintenance platforms unique to aircraft and tasks, to minimize movements near aircraft.
Allocate additional airstart unit to stations that need it.
Use proper equipment.
Avoid using non-standard equipment to do maintenance work. (4)
Make 8-foot ladders available.
Use as short a ladder as possible that is still adequate.
Have all required tooling available.
Ensure an adequate supply of chocks is available.
Ensure proper quantities of proper equipment are available.
Replace temporary scaffolding with permanent docks.
Purchase single channel radios for aircraft moves.
Fabricate "j" hook with red warning streamers and attach to main electrical shutoff switches on hangar doors.

Better Maintenance

Initiate preventive maintenance program for tow bars.
Repair mechanical problems on vehicles. (2)
Develop periodic maintenance checks for all ground equipment. (2)
Develop daily service checks of all ground equipment.
Unserviceable stands/safety rails should be removed from service. (3)
Encourage preventive maintenance to improve service/turn around time on repairs of defective equipment. (3)
Develop preventive maintenance for docks.
Replace brake microswitch and master cylinder in vehicle.
Perform incline brake tests before returning vehicle to service.
Establish preventive maintenance program for all vehicles. (3)
Replace broken mirror on vehicle.
Install anti-slip type brake pedal in all equipment.
Remove inoperative equipment from service and send for repair.
Ensure all defects are repaired before returning equipment to service.
Inspect deck supports to ensure sagging won't lead to collapse.
Troubleshoot and repair brakes so pressure doesn't bleed off.
Inspect and repair all vehicles for proper operation of parking brakes.
Have PM inspect all brake pedals for worn anti-skid, and replace as necessary.
Improve daily ground equipment inspection, reporting and corrective follow-up procedures.
Do not use tug with inoperative power steering.

ENVIRONMENT

Lines/Marking

Clearly mark stop lines for all aircraft types on all lead-in lines.
Paint reflection lines of aircraft outer dimensions. (2)
Paint centerlines between concourses in Station B.
Redraw tow-in line in hangar bay X to provide more clearance.
Repaint all existing towlines, equipment storage lines, and fire lane lines. (5)
Move painted stop line back 2 feet in hangar X.
Establish nose gear stop lines for all aircraft in a hangar.
Reposition nose gear spot.
Install clear (safe) zone markings at Station D gate X.
Designate equipment storage areas in which to park equipment when not in use. (2)
Paint guidelines at each gate. (2)
Paint lines for correct positioning of ground equipment near aircraft. (2)
Park aircraft on painted guidelines.
Plow ramp after snow, especially near alignment lines.
Repaint guidelines, extending them out of hangar. (4)
Establish boundary markers for nose/tail limits.
Eliminate use of solid guidelines; use only dotted lines.

Traffic Cones

Use wing tip cones at all times.
Use cones at wing tips.
Permanently position traffic cones in area of jetways.

Lighting

Improve lighting in terminal/alleyways.
Request Station E to install outerway taxi marker lights.
Install lighting on either side of tail dock.

Spaces Better Use of Space

Establish and enforce safe zones.
Establish safe zone around refueling station.
Establish area where to park jetways.
Relocate refueling station to more accessible area.
Locate equipment in operations area, rather than parking area.
Review hangar organization as to proper positioning of stands and support equipment. (2)
Move equipment in hangar to provide more storage space for extra work equipment.
Establish specific storage areas for all equipment.
Establish and communicate hangar utilization (organization of hangar).
Relocate dumpster from Station B gate X.

Open hangar doors completely when moving aircraft in or out.
Redefine width of taxiway Y at Station E to allow wide body aircraft.
Increase turning radius ramp markings between taxiways at Station E.
Monitor ramp areas for snow piles - where located and how high.
Create and utilize designated areas for equipment storage.
Establish wider approach to ramp area.

LIVEWARE

Training/Coaching

Mandatory training on how to handle paperwork.
Mandatory training for all air cargo ramp employees on proper procedures.
Mandatory training on proper use of equipment. (2)
Recurrent training for all pushback and towing operators. (2)
Mandatory training on choosing and using proper equipment. (4)
Only qualified mechanics should service engines with oil.
Restrict brake operator, tow-driver duty to those with specific training. (3)
Document all taxi-tow training in airline computer system. (2)
Emphasize safety in preventing ramp damage. (6)
Only training personnel (in towing and/or taxiing) should participate in moving aircraft. (2)
Have all employees review rules and procedures for towing. (2)
Initiate first level of discipline concerning work performance. (2)
Review operating procedures with employees.
Establish training and procedures for moving aircraft in/out of dock.
Discourage use of belt loaders as work platforms.
Counsel employees on incorrect actions.
Tell employees to watch door for obstructions while opening.
Provide training (initial and recurrent) on equipment used and safety procedures. (4)
Retrain mechanic for safe operations.
Provide training on equipment staging and removal.
Recurrent run-up/taxi training as needed.
Need training for safety procedures. (5)
Need training for reporting procedures of malfunctioning equipment. (2)
Train in towing policy as it relates to safety.
Emphasize safety in towing policy and procedures. (6)
Develop orientation/familiarization program for new employees.
Coach employee involved. (2)
Provide instruction for need to use proper equipment.
Review training requirements on run up/taxi to ensure completeness.
Monitor time elapsed between training and actually performing run-ups.
Review training on jetway procedures.
Provide instructions for awareness of effects on systems when hydraulic power is applied.
Continue emphasis on ramp safety-promote through performance development programs. (6)
Ensure all new employees receive adequate training and supervision.
Develop training program about employee roles and responsibilities during docking.
Emphasize importance of surveillance and clearing area prior to push back. (2)

Emphasize policy of turning off door switches and installing warning streamers.
Increase awareness of procedures. (3)
Tow driver must be made aware of responsibility to determine the number and location of personnel needed.
Continue training review of lift procedures.
Retrain employees involved in incident.

Hazard Awareness/Attention

Managers must raise awareness on safety features of tow hitches.
Manager must raise awareness of tow drivers' responsibilities. (3)
Managers must raise awareness of problems with secondary locks on fleet B tow bars.
Managers must raise awareness of how and properly select right equipment. (2)
Managers must raise awareness of procedures (keeping vehicles/equipment clear) relating to safe zones. (3)
Managers must raise awareness of need to improve housekeeping standards. (3)
Managers must raise awareness of importance of working as a team.
Managers must raise awareness of aircraft ramp damage. (7)
Managers must raise awareness of need to perform pre-arrival preparation.
Issue memo to employees about safe use of jacks.
Raise awareness of tow drivers' responsibilities.
Shut down aircraft if jetblast will interfere with equipment on ramp.
Tell employee to be more aware. (2)
Issue bulletin to all maintenance personnel to remind everyone to use safety pins.
Emphasize caution when working in bad weather.
Establish awareness to check aircraft security before disconnecting.
Keep eye on clearance when working around aircraft.
Don't leave ladders unattended.
Stress to everyone to be alert and conscientious
Disseminate information about ground damage incidents to all personnel.
Issue bulletin to all employees driving equipment to assure proper use of equipment.
Raise awareness of maintenance personnel to maintain adequate clearance between aircraft. (4)

Ensure Procedures Followed/Enforced

Recommend two wingwalkers.
Tow driver must assign adequate number of personnel. (3)
Aircraft won't enter gate area without necessary personnel in place.
Wingwalkers must use correct hand signals. (2)
Check landing gear pin before performing work where landing gear handle may be disturbed.
Delete airline developed landing gear pin insertion tool from inventory.
Remove all equipment from around aircraft prior to raising/lowering aircraft.
Workers must use safety rails
Use hangar checklist to install/remove aircraft from a hangar.
Mechanics must follow maintenance manual when operating Fleet A stairs.
Follow all Standard Operating Procedures (9).
Observe all warning placards.
Ensure pre-arrival preparation is performed.

Use 2 ESEs when installing /removing jack.
Use 2 ESEs while towing. (3)
Ensure jack is all the way down when removing from aircraft.
Ensure manual policy regarding number of wing/tail walkers is followed during any aircraft movement. (5)
Prepare for job at hand.
Promote and enforce all policies.
Establish and enforce safety zones. (3)
Pull aircraft into hangar further.
Repost requirement to use spotter when moving equipment. (3)
Meet with ground operators to assure equipment is not staged under wings.
Emphasize need to move equipment in order to gain access to area.
Enforce all safe pushback procedures. (2)
Engage brakes on all equipment not being moved.
Bring tow to complete halt prior to entering hangar to ensure everyone/everything is ready.
Remove unserviceable equipment from ramp.
Adopt standard signals and commands for spotters.
Chock wheel of unattended, running vehicles.
Maintain safe distance between equipment and aircraft. (2)
Ensure all policies and procedures are enforced. (11)
Issue bulletin for all employees to be properly seated when driving.
Promote and enforce safe operation of all ground equipment.
Mechanics should review procedures before beginning task.
Tell employees to keep attention on controlling ground equipment.
Ensure mechanics review workcards for content and versions before starting work.
Always use wingwalkers. (2)
Only qualified personnel should perform tasks.
Clear all stands/objects around aircraft. (2)
Ensure all fuel on board is in #2 center tank.
Use spotter when moving dock in/out or up/down.
Use only airline personnel during pushback/tow.
Clarify requirements for wingwalkers to be in position and to use hand signals. (3)
Tow driver must watch wingwalker at all times and should stop when not looking at wingwalker. (3)
Position tail walkers to be in visual contact with tow drivers.
Don’t use only one jack to raise aircraft, follow SOP of using two jacks.
Prepare properly for job at hand by clearing area and getting necessary equipment. (2)
Investigate possibility of having ramp services clear area under engines requiring line checks.
Never force anything.
Get help when difficulty arises.

LIVEWARE-LIVEWARE

Situational Awareness/Briefings

Maintain awareness of loading and refueling of aircraft.
Wait until fueling is finished before working around area.
Use headsets to ensure proper verbal communications with flight crews. (2)

Have briefing at start of shifts to review work assignments. (2)
Raise awareness of working as a team. (2)
Ensure all personnel are aware of inoperative equipment.

Supervision/Management Support

Airline must perform or supervise all work done in airline facilities.
Set up de-ice teams who always work together.
Assign supervisor whenever cherry picker is being used around aircraft.
Make sure personnel know where to get support.
Ensure employees unfamiliar with a task are supervised.
Provide trained personnel to assist as safety observers when operating aircraft controls--safety observer should be in contact with mechanic.
Review accident/incident reporting policies with managers.
Assign lead mechanic to oversee docking process.
Manager should review late evening shift staffing, reassign mechanics as necessary.
Use additional personnel on field trips, if necessary to adhere to staffing task policies.

Communication with Shift/Teams

Encourage communication between all employees working in an area. (7)
Implement turnover log: shift/shift, crew/crew.
Encourage communication between all employees working on aircraft. (3)
Improve between shift communication.
Improve inter-shift (team) communication. (3)
Require greater communication between wingwalkers and pushback drivers - verbal and visual. (3)
Have quick briefing before each aircraft movement to coordinate assignments.
Establish policy to have ground personnel in communication with lift operator when moving around aircraft.
Use radios during pushback.

Establish Policy

Restrict access of particular aircraft types in particular station gates.
Use different aircraft doors to load passengers at particular station gates
Establish rules pertaining to arriving vehicles under wing.
Establish pool agreement for procuring equipment.
Change manual to require inspection of hitches for all vehicles.
Develop Station A airfreight procedures manual.
Develop action plan for chains to be installed when needed.
Develop plan to clear ramp of snow.
Establish policy to use left wingwalkers during tractor removal
Establish local procedure for general housekeeping and equipment placement to be done before aircraft arrives.
Establish policy for de-icers to spray only 1/2 of aircraft where truck is positioned.
Establish local policy for minimum tow speed.
Establish remote parking policy.
Require proper footwear for all mechanics (shoes should have significant tread).

Establish procedure to notify all personnel when hydraulic systems will be activated.
Develop facilities plan for Station C to promote more regular operations.
Establish policy of proper disposition and loading of late baggage.
Establish verbiage for disposition of passengers after door closure.
Restrict double parking of aircraft at gate.
Develop procedure for maintenance personnel to physically check ramp in bad weather.
Establish policy to “get help” whenever a question of clearance arises.
Begin using “light-duty” personnel as guidepeople.
Establish SOP for towing aircraft into hangar.
Revise MM reference to caution tugs, when tug is installed the workcard should have entry made in job status section denoting installation of tag and the reason for installation.

CHAPTER 6
A STUDY OF AMT NORMS AND WORK HABITS

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6.1 INTRODUCTION

Awareness of maintenance-related factors in aircraft mishaps has expanded considerably over the past ten years. Similarly, the application of human factors research to aviation maintenance technicians (AMTs) has risen as well.[1] Once reserved for flight crews, attention is now given to personality and organizational factors that may influence the safety and quality of work performed by AMTs. Maintenance resource management (MRM) addresses these issues.[2] Little attention, however, has been given to social factors at the workgroup level, which may also contribute to human error. Indeed, a great deal of anecdotal evidence exists suggesting that a workgroup may apply social pressure on an AMT to ensure conformity to locally established procedures, even if those procedures contradict those officially established by the organization.[3] These workgroup pressures emanating from one's peers are called norms.[4] Despite the preponderance of anecdotal evidence, few have attempted to quantify the extent to which norms may negatively impact the quality of maintenance work. The purpose of this study is to gauge, quantitatively, the extent to which norms may exist in the AMT workplace. Because of the lack of previous research, this study remains largely exploratory in nature.

6.2 NORMS

Norms are omnipresent in society. Norms dictate fundamental rules of dress, speech, and basic interaction. In this way, norms can be defined as expected, yet implicit rules for behavior.[4] Because these rules for behavior define others' expectations, norms facilitate interaction by reducing the number of surprises one may encounter in a social context. On the other hand, a violation of norms can prove distressing. Dressing inappropriately, for example, may be not only a source of concern for the norm "breaker," but may also elicit negative reactions from those who conform.[5] In this case, the norm breaker may be sanctioned by others in the surrounding group.

Norms usually develop as a answers to problems that have ambiguous solutions.[6] When faced with an ambiguous situation, an individual may use others' behavior as a frame of reference around which to form his or her own reactions. As this process continues, group norms develop and stabilize. Newcomers into the situation are then socialized into the group norms. Very rarely do newcomers initiate change into a group with established norms.

In the context of the present study, norms are also defined as expected rules of behavior. Norms, particularly the extent to which norms may impact compliance with standard operating procedure (SOP) remain the focus for this study.

6.3 POLICY AND PROCEDURE

Degani and Wiener[7] described a model for understanding deviations from established procedure. Despite the uniformity **SOP**s dictate, pilots tended to deviate from them in actual practice. Degani and Wiener attempted to isolate factors that might encourage such seemingly reckless behavior. The result was a hierarchical model in which an organization's "philosophy" -- as driven by or perhaps in spite of other external forces such as economics, technology, etc., dictates the policies that specify operations in that organization. Finally, these policies influence the procedures that govern the actual behavior of employees.

However, as Degani and Wiener[7] note, employees can (and do) deviate from procedure when put into practice. They identify four specific reasons why a pilot deviates from **SOP**: individualism, complacency, humor, and frustration. Each of these reasons may also impact the **AMT**. This study, however, contends that norms may also play a role in deviation from SOP. The next section explores this contention more fully in the context of on-the-job training (**OJT**).

6.4 OJT AS NORMATIVE INFLUENCE

Zohar[8] showed that a reciprocal relationship exists between an organization's culture (or climate) and its employees' perceptions regarding safety. Specifically, he found that an individual formulates his or her perceptions of an organization's safety commitment based on how that organization functions and the expression of safety-related programs, rules and regulations. Therefore, as common sense would dictate, an employee's personal regard for safety is based directly on the priority the organization places on it. However, Zohar specifically measured attitudes regarding employee safety. An organization's safety culture may also be expanded to include those of the customer as well.

What factors should a culture that promotes customer safety encompass? First, a change in organizational culture should favor one that reflects continuous operational reliability. Weick[9] differentiates an "operationally reliable" organization from others in that it requires a culture dedicated towards error-free performance. Thus, a major learning strategy, trial-and-error, is unavailable to organizational newcomers. According to Weick, a newcomer in an "operationally reliable" organization must be incorporated and socialized into its culture quickly and without error. This socialization is accomplished by creating a culture that substitutes trial-and-error learning with stories, imagination, and symbolism. By socializing newcomers in this way, the underlying attitudes of organizational members are manipulated and the errors that might occur while learning essential job skills are minimized.

Weick and Roberts[10] expand on this theory by asserting that as a culture which encourages safety in this way develops, it becomes reminiscent of a "collective mind." This "collective mind" is characterized by interdependence and coordination. Maintaining the "collective mind" is required to maintain a truly safe and “reliable” environment, such as can be found on flight decks. The components of the collective mind, interdependence and coordination, show up in other research in which the level-of-analysis focuses more on the work group or team than on the organization.[11]

However, a highly interdependent organization intensifies the effects of the actions of all of those within the organization. In other words, high interdependence between team members makes the consequences of decisions made by those at even the lowest level of an organization more far-reaching than the consequences of those decisions made in a *low* interdependent environment.[12] Therefore, in an organization characterized by *high* interdependence, it would be necessary for all members of the organization to possess good decision-making skills. In order for a structured environment such as a flight line to exist where interdependence is maintained and yet remains “operationally reliable,” coordination and considerable decision-making skills among groundcrew personnel are necessary.

Roberts[13] documents such a situation in an extensive study of U.S. Navy aircraft carrier operations. In Roberts’ study, three researchers went to sea intermittently for up to ten days on two aircraft carriers. During this time, they observed and collected data on the operations that most likely contribute to “reliability.” Among the safety strategies observed by Roberts is the “buddy.” In the buddy system, an experienced deck hand is assigned to closely monitor another. By doing so, a form of redundancy is built into the system, a redundancy that is assumed to ensure operational reliability.

Despite the relative reliability of these operations, accidents do happen. In fact, a review of deck operations from 1977 to 1991 traces 91% of deck mishaps involving aircraft to “human causal factors.”[14] In addition, the mishap rate for Naval operations seems to have stabilized over the past few years.[15] These two studies suggest that current strategies for safety have reached their potential.

Anecdotal evidence supports this assumption. Interviews with officers familiar with Naval line operations showed that the training of behaviors that may encourage safety and a minimization of error are implied at best.[16] Indeed, the current buddy system relies solely on the skill of the experienced “mentor.” If the mentor does not display behaviors that contribute to crew safety, then the “buddy” will be equally lacking. In addition, even if mentors are skillful in their jobs, they may lack the communication skills necessary to maximize a “buddy’s” learning. And even if the mentor is capable in both the job and communication skills, it may not be possible to slow the pace of the job, appraise performance and provide feedback in an environment where performance is the criterion for success.[17]

As was described by Wieck and Roberts,[10] reliance on the “collective mind” is greatest in an environment in which **OJT** remains the most salient training tool for newcomers. This is the case with Naval Air maintenance operations.[18] Accordingly, previous needs analyses suggest that commercial air groundcrew operate in much the same way as the military by relying heavily on OJT.[19] OJT, in most cases, was used to “refine” technical training obtained elsewhere. In describing training in a commercial environment, Walters[19] identified five separate ways in which current systems may degenerate. They are as follows:

- Experienced workers are not always knowledgeable.
- Without an outline to follow, valuable skills get left out.
- Mistakes are perpetuated.

- There is no consistency from employee to employee.
- Shortcuts develop due to lack of understanding.

Walters[19] continues by proposing a training system that addresses the concerns identified by the needs analysis. This study's primary purpose is to assess the extent to which group-related problems such as norms are perpetuated in industry. It is not the contention of this study that **AMT**s consciously violate **SOP**. Instead, we examine the extent to which norms may be perceived by AMTs as well as assess possible reasons why negative norms may be accepted by individuals.

As stated previously, the structure of this study is driven primarily by its exploratory nature. Therefore, it is difficult to make specific hypotheses regarding the data. However, certain assumptions did drive the creation of the survey instrument. First, norms exist and are a function of the incongruity between procedures and the "real world." Second, the creation of norms is also guided by an **AMT**'s ability to access and/or understand **SOP**. In addition to these two assumptions, instances of a specific, well-documented norm is measured: the use of a "black book" or personal references to complete one's work. This was done to assess the prevalence of a well-recognized norm that does not follow SOP. Furthermore, measuring individuals' reactions toward a specific (and well-documented) norm allows for a frame of reference to be developed regarding attitudes towards norms themselves. In addition, certain demographic data were also collected. This was done to assess how experience and job type might affect one's acceptance and use of norms.

6.5 DATA COLLECTION

6.5.1 Test Site

Data collection occurred during a human factors workshop conducted at an aviation maintenance engineer (AME) conference held in Canada. The purpose of the workshop was to introduce and familiarize AMEs with norms and their promulgation. The test site was far from ideal for data collection. Participants had great difficulty in completing their surveys due to lack of tables and writing surfaces, and discussion occurring during the actual data collection itself. These factors could have been a factor in the quality of the data collected.

6.5.2 Test Subjects/Data Collection

One hundred forty-five people completed and returned surveys to the experimenters. The majority of these respondents were Canadian; American respondents were sought, but data collection on a second group within the allotted timeframe proved impossible. Data were missing from some of the returned surveys, though not in a systematic fashion. Because cases were deleted when missing data, sample sizes in certain analyses are not equal. In all, 138 individuals fully completed their surveys.

Subjects varied greatly in age and experience. Ages of those who provided the data (N=144) ranged from a minimum of 16 years to a maximum of 70 years (M=40.5 years). Experience (N=141) varied as well, though not to as great a degree (min=0 years, max=50 years, M=18.3). **Table 6.1** displays these data clearly.

Table 6.1. Descriptive Statistics of Age and Experience				
	MIN.	**MAX.**	**MEAN**	**SD**
AGE in years (N=144)	16	70	40.5	13.2
EXPERIENCE in years (N=141)	0	50	18.3	13.1

Data indicating "type of work performed" were also collected. The majority of respondents checked more than one category demonstrating that they were not limited to one specific area of aircraft maintenance. In order to facilitate analysis, worktype data were recoded to reflect a ranking order. That ranking included, in this order, students, light check personnel, heavy check personnel, and then management. In doing this, a basic assumption was made: participants who listed themselves in a "higher" rank had experience in the "lower" ranks, while the reverse would most likely not be true. For example, an **AMT** who indicated "management" or "upper management" was coded simply as management, despite also having included himself in another group such as "hanger maintenance." Though this remains a generalization done only for the purposes of data analysis, correlations between worktype, experience and age bear this assumption out. Both work and experience are significantly correlated to worktype (1="manager," 2="heavy check," 3="light check," 4="student"). See **Table 6.2** for the correlation matrix.

Table 6.2. Correlation Matrix of Age, Experience, and Worktype, *p<.05			
	AGE	**EXPERIENCE**	**WORKTYPE**
AGE	--	.92*	-.49*
EXPERIENCE	--	--	-.50*
WORKTYPE	--	--	--

Worktype was restricted mainly to two groups, management (*n*=57) and "Light check" (*n*=55). The remaining individuals were divided between heavy check personnel (*n*=16) and students/"Other" (*n*=14). Aircraft inspectors/regulators (ASIs) were coded as "others," though their low numbers (*n*=3) made it prudent to collapse them in with another category.

Data collection occurred during a safety seminar. Prior to survey distribution, participants were given a brief, 20 minute primer on "norms," so as to ensure a standard definition among respondents. During this time, participant anonymity was also ensured. Subjects were given a total of 20 minutes to complete the survey, after which all responses were collected for later analysis. The norms survey is presented in **Appendix A**.

The Survey

The norms measure was created using an *a priori* scale structure, i.e., specific questions were created based on past research and subject matter input. Questions were then grouped together accordingly to create *a priori* subscales.

The survey was divided into five subscales. Each scale was intended to reflect a facet of workplace norms. However, subsequent calculation of Cronbach's alpha indicated unreliability in two of the scales, Scales II and III.   Cronbach's alpha is a statistical calculation performed on a survey to test the extent to which its observations are consistent both among the respondents and within the survey itself. A low alpha score, <.50, indicates that the scale factors are not consistent among respondents. See **Table 6.3** for a list of each scale and their associated reliability coefficients.

Table 6.3.   Listing of Subscales and Associated Reliability Coefficients

Subscale	Subscale Name	Cronbach's Alpha
Scale I (n=144)	**"Procedures Are Not 'Real World'"**	**.52**
Scale II (n=138)	"There is a great Degree of Pressure to conform to the workgroup"	.38
Scale III (n=138)	"Norms Positively Impact Safety"	-.18
Scale IV (n=142)	**SOP** is accessible and easily understood."	.69
Scale V (n=139)	"I use a Black Book or Private References"	.69

Subscales were created to assess the degree to which norms factored into an employee's work environment. A score of 5 indicates highest agreement with each subscale. A score of 1 indicates highest amount of disagreement with a statement.

In addition to the attitude survey, a second measure was included to gather critical incidents of "positive," "negative," and "neutral" norms. Because of the qualitative nature of these data as well as the lack of standardization among participants, these critical incidents were not analyzed systematically. They were, however, collected for future presentation and to guide further research.

6.6 RESULTS

Because of the exploratory nature of this study, analysis of the data was driven primarily by the *a priori* scale structure. Comparisons were made among respondents in terms of worktype and experience.

Descriptive statistics revealed interesting trends within the data. Overall, the sample (N=138) demonstrated greatest agreement with Scale III (“Norms impact on safety”) with a mean=3.4 (*SD*= .68); note that a score of 5 indicates “greatest agreement.” Scale V (“Use of blackbook”) showed the least amount of agreement (n=139, *M*=1.9, *SD*=.64). Most interestingly, however, was the general lack of agreement in the sample with all of the subscale items. In other words, respondents did not generally agree with any of the subscale factors, demonstrating that the norms identified in the survey may not be perceived by **AMT**s as impacting work performance. These results are explored more fully in the discussion section of the report. **Table 6.4** lists the means and standard deviations of each scale for the entire sample.

Table 6.4. Descriptive Statistics of Subscales I-V

Scale	Valid N	Min.	Max.	Mean	SD
Scale I	144	1.0	4.67	2.72	.80
Scale II	138	1.2	4.4	2.85	.60
Scale III	138	1.0	5.0	3.4	.68
Scale IV	142	1.8	4.2	2.8	.44
Scale V	139	.67	3.3	1.9	.64

Two multivariate analyses of variance (MANOVA) were conducted. The first MANOVA showed significant differences at the .05 alpha level among worktype categories for Factor II ($F(3,126)=2.71$, $p<.05$). Specifically, Student Newman-Kuels *post hoc* analysis showed that shop/component personnel scored significantly lower than any of the other worktype groups. These were the only significant results obtained through MANOVA.

Closer examination of each worktype reveals that, in general, managers were more apt than the other worktypes to show agreement with all factors, particularly Scale III (“Norms impact on safety”) (*n*=55, *M*= 3.5, *SD*= .76). Other types of personnel did not demonstrate any systematic deviation from the overall mean for any scales. For example, students and light check employees agreed less with Scale V (“Use of blackbook”) than managers and heavy check personnel. However, students and heavy check personnel agreed less with Scale I (“Procedures are real-world”) than did managers and light check employees. **Figures 6.1-6.4** provide a summary of each worktype’s data.

Highest Agree

Lowest Agree

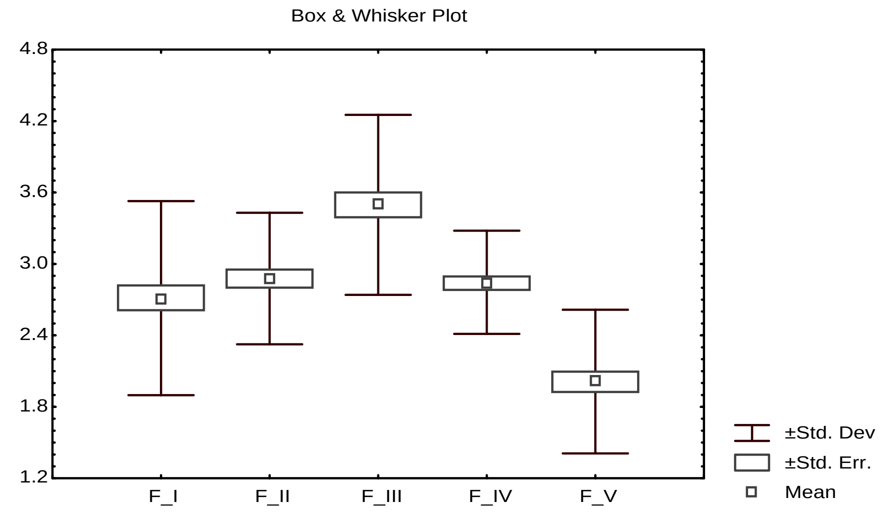

Figure 6.1. Means and Standard Deviations of Manager Scale Scores

Highest Agree

Lowest Agree

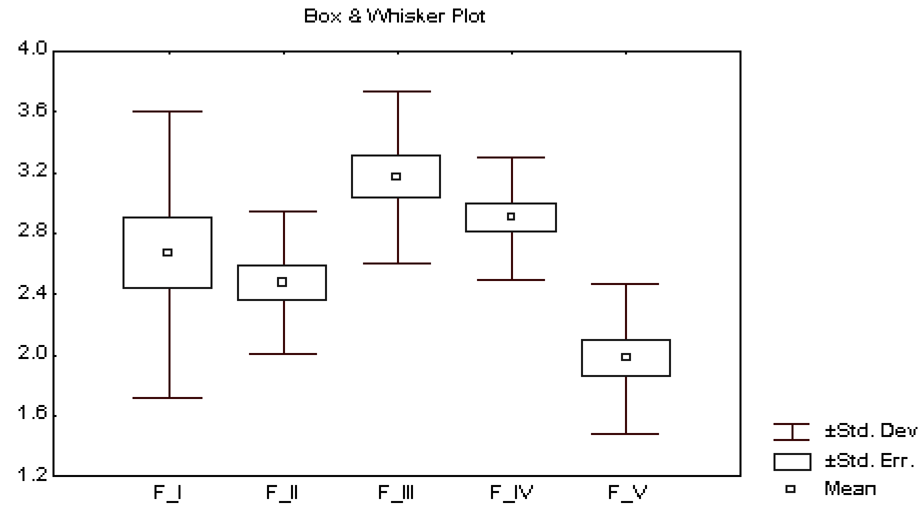

Figure 6.2. Means and Standard Deviations of Heavy Check Personnel Scale Scores

Highest Agree

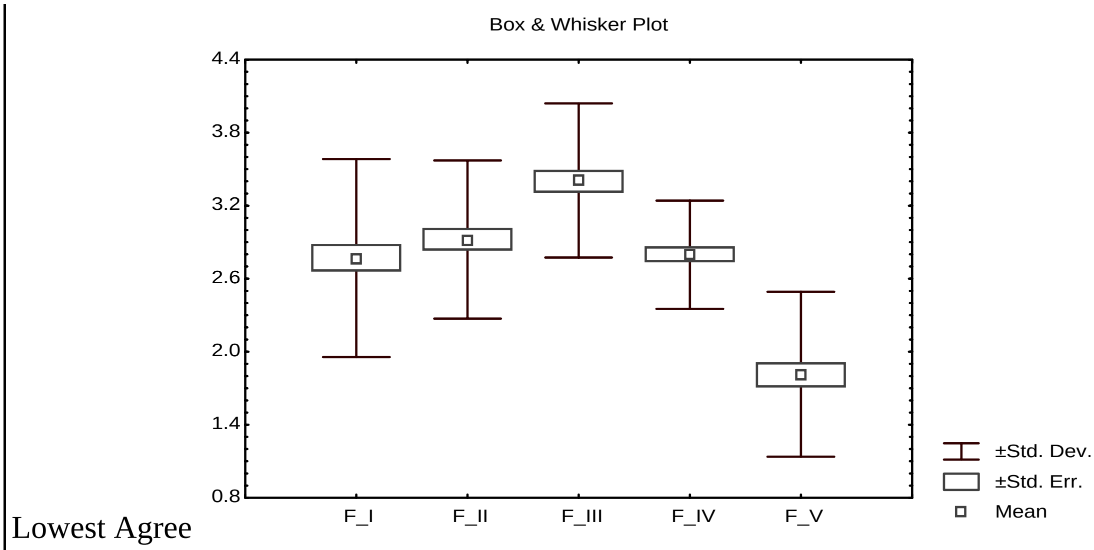

Figure 6.3. Means and Standard Deviations of Light Check Personnel Scale Scores

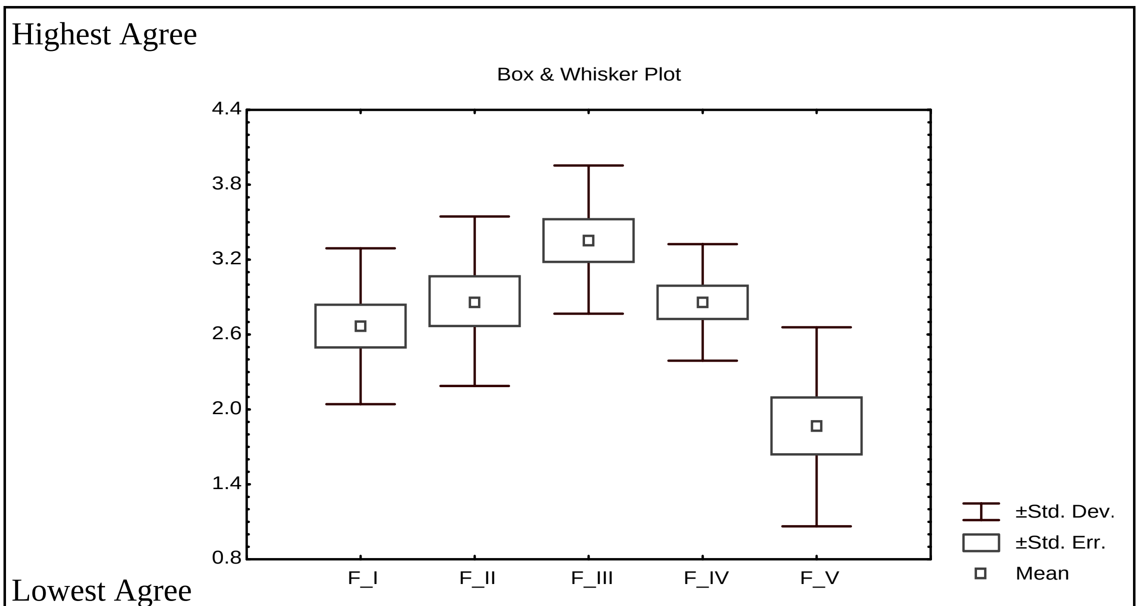

Figure 6.4. Means and Standard Deviations of Students' Scale Scores

Effect of work experience was also investigated using a second **MANOVA**. Because work experience was listed by subjects in terms of years, it was recoded and divided into quartiles. These quartiles are as follows: *n*=37 "<8 years," *n*=33 "8><18 years," *n*=37 "18><27 years," *n*=38 ">27 years of experience." MANOVA was conducted using the recoded work experience as the independent variable. Results indicate that differences due to work experience exist at the .05 alpha level for Scale V(F(3,129)=2.70, p<.05). Student Newman-Kuels *post hoc* analysis indicated that those employees with the most experience scored significantly greater than the second most experienced employees for Scale V ("Use of blackbook"). However, this difference is only at the .1 alpha level (p=.07).

6.7 DISCUSSION

Overall, with one exception, the results indicate no significant differences among worktype. Similarly, with one exception, there were no significant differences attributed to experience level. Interpretation of the lone significant difference due to worktype leads one to conclude that shop/component personnel are affected by workgroup pressures to a lesser degree than other personnel. One may theorize that a "slower" pace, relative to line or hanger work, may buffer component personnel from the effects of workgroup pressure. Similarly, managers also seem more vulnerable to workgroup pressure than component personnel, due to the "buck stops here" nature of their position. In other words, managers are accountable to many different organizational members, creating more pressure to conform. However, it must be noted that examination of the means shows that all worktype groups indicated some level of disagreement to being pressured by their peers. These data do not support the notion of workgroup pressure factoring into one's job.

The results derived from the "experience" **MANOVA** are more difficult to interpret. The mean of the most experienced employees (Group 4) is significantly greater than the mean for the second most experienced group of employees (Group 3), implying that the most experienced employees were more apt to use personal references. Perhaps as one gains more work experience, certain habits, such as consulting a "blackbook," become more ingrained. Curiously, distribution of the means across all four is bimodal. The lack of systematic increases or decreases makes data interpretation difficult at best. However, as was the case with the worktype group data, means of all experience groups indicate overall disagreement for Scale V ("Use of blackbook"); respondents did not rely on personal references to as great a degree as anecdotal evidence seemed to indicate.

Examination of the means themselves showed low agreement with all scales, with the notable exception of Scale III ("Norms impact on safety"). In other words, as a group, respondents felt that norms positively impact safety. However, as a group, respondents felt that **SOP** do reflect the "real world" (Scale I), are easily accessible and understood (Scale IV), and do not require the use of personal references (Scale V). In addition, respondents did not feel that they were negatively pressured by existing norms (Scale II).

When categorized by worktype groups, managers seemed the most inclined to show agreement with any of the factors, scoring greater than the means for the entire sample. However, they also showed greater variation in their answers, as a group, than did most of the other worktypes, demonstrating a lack of overall agreement in the factors. In addition to this result, students and light check personnel indicated more understanding and accessibility to **SOP** than other more experienced personnel. This could be due to the relative "newness," compared to older, more experienced workers, of the training on SOP for this population. Accessibility, especially when computer-based, may also contribute to this. No other systematic trends seem to be apparent with regards to worktype.

However, interpretation of the means must be performed with a caveat. Because **MANOVA** indicated few, if any, significant differences among the factors, all groups gave equivalent answers, in a statistical sense. But does the lack of any significant findings have a value? Possibly. If these results were borne out through repeated testing, these data could prove encouraging. For example, the sample's overall disagreement with all factors may indicate that norms may not be as great a problem as once believed. The lack of significant differences shows that these feelings are widespread and are not dependent on experience or type of work.

Once again, however, one must be careful when interpreting a lack of statistical significance. The lack of significant differences may be due to effects separate from the independent variables. For example, it is equally likely that sample characteristics may have driven the results. The sample surveyed for this study were all attending a safety seminar; therefore, respondents' work habits may not reflect those of the **AMT** population as a whole. In addition, difficulties occurred in data collection, such as lack of adequate time to complete the survey, which may also have affected individual's responses.

Due to the exploratory nature of the study, the survey's subscales could not be fully defined before data collection; this may have affected some of the resulting data. The scales themselves possessed only moderate reliability. This calls into question their statistical validity, especially Scales II ("Degree of workgroup pressure") and III ("Norms impact on safety"). Barring the general disagreement with the factors among the sample, the lack of systematic results, even among the means, supports this conclusion.

How could further research into maintainer norms benefit from the current study? First, because this research project was an initial, exploratory effort into a field that lacked previous research, this survey amounted to a pilot effort. Pilot testing rarely reveals "good" data. Instead, it identifies areas for survey modification should data be collected in the future. Second, other demographic information could have been collected. The present study's independent variables may not have been sensitive to differences among the scales. In addition, the recoding of the worktypes, though necessary for analysis, may have introduced an artifact not present before the data transformation. Finally, the researchers may have overestimated the extent to which norms are identified and accepted in the general population. In such a case, the pre-survey primer as it was designed may not have addressed some of the specific conceptualizations of norms individual respondents may have possessed.

Research into norms, especially potentially destructive ones, may require behavioral observation in the field. Collecting critical incidents, for example, may provide more detailed and valid data that attitudinal research could not. However, attitudinal research is a legitimate and cost-effective first strategy for initial data collection.

6.8 CONCLUSIONS

It is difficult to make conclusions from these data. At best, they represent directions of research that need further study. For example, are norms omnipresent, as anecdotal evidence indicates, or are they not, as the survey results show? Examination of the qualitative data collected from the participants show that norms are present in the maintenance environment. Many of the norms cited are identical across respondents. A sample of them are listed below:

> "Keeping schedule, even though [the] aircraft is not ready."
> "We don't have it, so don't worry about it."
> "Using shortcuts to stay in [the] time limit."
> "Fill out paperwork days after work is carried [out]."
> "Using the wrong tools for job."

"Non-critical items signed off without checking."

Because of the contrast between the quantitative data and the qualitative data, it is difficult to reconcile the two. One possible explanation could be that the quantitative data created demand characteristics that elicited responses contrary to the critical incidents. Participants could be trying to "put on a good show" for experimenters. Another likely explanation could be that the critical incidents are the result of the 20 minute norms primer given prior to data collection. Many of the responses are similar to the examples given in the primer. Respondents could be "parroting" the norm examples provided to them minutes earlier. Finally, the identification of these norms could be an example of the "Not Me" syndrome (i.e., everyone else, other than the respondent, conforms to workgroup pressure). This is likely as well. Could future surveys be structured to compensate for this?

On the other hand, the results of the survey are extremely encouraging. The universal lack of agreement with the factors, for example, may indeed be evidence of safe work habits. In this we can take some comfort. Also, according to these data, procedures were accessible and understandable, which implies organizational support for the **AMT**. This is also encouraging. Even the listing of negative norms emphasizes that critical components and tasks are not taken lightly. The following sample of positive norms listed by the respondents demonstrates also an undercurrent of safety present in the AMT environment:

"Independent checks required on maintenance actions."
"Two people working together all of the time regardless of task."
"We would do a final walk-around just before the aircraft was pushed back."
"After doors closed, do a final walk-around with nothing else in mind."

Some of the data made intuitive sense. It might be expected that less experienced personnel might be more familiar and willing to use **SOP** than more experienced employees who may not consult written SOPs to an equal degree. This would be especially true of managers who may not consult written SOP as often as those on the line. Indeed, the data bear this out. Other results are more perplexing. The lack of use of personal references was surprising. Would a broader, more representative sample respond the same way? One could only guess.

To conclude, though the authors were constrained by the exploratory nature of the research, it has provided an interesting first look into a previously unexplored area. This study has laid the groundwork for additional research into the difficult field of attitudes and employee norms. However, the data as it currently stands not only provide some evidence of the need for maintaining a safety culture, but they provide those tasked with such endeavors with a "gameplan" to guide them through it.

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APPENDIX A

Norms Survey

Dear Fellow Aircraft Maintainer:

Thank you for taking the time to answer a few questions. Your answers will be strictly confidential and anonymous. This worksheet will only take a few minutes to complete. Your candid answers may help prevent an aircraft accident by aiding us in understanding one of the leading causes of maintenance error: *norms*.

Norms are unwritten rules followed by the majority of a group. (In other words, "the way we do things around here . . .") Norms can be positive, negative, or neutral as they relate to safety/compliance standards.

Examples of norms:

- How fast people in the group usually work (Can be positive, neutral or negative)
- Number of coffee/smoke breaks taken per day (positive, neutral or negative)
- Doing the "extra" inspection to insure quality work (positive)
- Number of casual conversations during work time (neutral or negative)
- Use of private reference lists (the "little black book") rather than using manuals (Likely negative)
- Usual quitting time for the day (Likely neutral)
- Making sure that work areas are cleaned up before leaving (positive)

Thank you in advance for your valuable time.

Demographics (Your answers are strictly anonymous)

Age: ______

Years as AME/AMT or in aviation work: ______

Area of Maintenance:

- ☐ Line Maintenance
- ☐ Hangar Maintenance
- ☐ Component/Support Shop
- ☐ Management
- ☐ Upper Management

Please indicate your agreement with the following questions using the following scale.

1 = Strongly Disagree	2 = Disagree	3 = Moderately Agree	4 = Agree	5 = Strong

1.	My workgroup would not get work completed on time if all written procedures were followed exactly.	1 2 3 4 5
2.	There is pressure from my workgroup to take shortcuts from the formal procedures.	1 2 3 4 5
3.	Norms that contradict written policy usually compromise safety.	1 2 3 4 5
4.	Most norms in my workgroup are aligned with my company's goals and policies.	1 2 3 4 5
5.	Most norms in my workgroup have a positive impact on safety.	1 2 3 4 5
6.	I usually follow the norms of my workgroup.	1 2 3 4 5
7.	Others in my workgroup have made negative comments when I don't follow workgroup norms.	1 2 3 4 5
8.	I am rewarded for following my workgroup's norms.	1 2 3 4 5
9.	I value the opinions of my fellow workers more than the opinions of senior supervisors.	1 2 3 4 5
10.	The formal procedures of my company do not reflect what happens in the "real world."	1 2 3 4 5
11.	Many formal procedures are outdated.	1 2 3 4 5
12.	I have difficulty accessing written policies and procedures.	1 2 3 4 5
13.	The formal standards and procedures of my company are difficult to understand.	1 2 3 4 5
14.	I am very familiar with the standards, policies, and procedures that apply to my job.	1 2 3 4 5
15.	The formal procedures that apply to my work are communicated adequately.	1 2 3 4 5
16.	I have difficulty getting the information I need to do my job.	1 2 3 4 5
17.	I have kept a personal reference list to help me in my job.	1 2 3 4 5
18.	I need to use private references to keep up with my workload.	1 2 3 4 5
	Has your company ever provided you with any training to recognize norms?	Yes No

Please describe three norms that exist in your work environment now or at some time in *your past. Describe a positive, a neutral, and a negative norm. If you need more room, please use the reverse side.*

Positive Norm

Description of the norm:

How did you learn the norm?

What happens if you don't follow the norm?

Neutral Norm

Description of the norm:

How did you learn the norm?

What happens if you don't follow the norm?

Negative Norm

Description of the norm:

How did you learn the norm?

What happens if you don’t follow the norm?

Thank you for helping to make our industry safer.

CHAPTER 7
ENHANCING AVIATION SAFETY THROUGH THE DEVELOPMENT OF ADVANCED TRAINING MODELS

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7.1 INTRODUCTION

The goal of this research was to develop a framework for understanding and improving inspection performance. Following this step, the framework was used to define the functional specifications of a computer based inspection system to improve inspection performance. This report is divided into four major sections. The first section, Background, reviews the existing state of inspection. The next section outlines a general model for evaluating inspection tasks. The third section provides a functional description of a computer-based inspection system to support inspection training and minimizing inspection errors. The last section provides conclusions and plans for future research. The project was performed in close cooperation with a major maintenance repair facility and a partner airline to ensure that the results addressed the concerns of the aviation community.

7.2 BACKGROUND

In order for the **FAA** to provide the public with a continuing safe, reliable air transportation system, it is important to have a sound aircraft inspection and maintenance system.[1] The inspection/maintenance system is a complex one with many interrelated human and machine components. The linchpin of this system, however, is the human. Recognizing this, the FAA (under the auspices of National Plan for Aviation Human Factors) has pursued human factors research.[1,2] In the maintenance arena this research has focused on the aircraft inspector and the aircraft maintenance technician (AMT).[3,4,5] Since it is difficult to eliminate errors altogether, continuing emphasis must be placed on developing interventions to make the inspection/maintenance procedures more reliable and/or more error tolerant.

The aircraft inspection/maintenance system is a complicated one.[1,3] Moreover, it is affected by a variety of geographically dispersed entities ranging from large international carriers, repair and maintenance facilities, through regional and commuter airlines, to the fixed-based operators associated with general aviation. Inspection, like maintenance, is regulated by the **FAA**; however, while the adherence to inspection procedures and protocols are closely monitored, monitoring the efficacy of these procedures is much more difficult. Just as effective inspection is seen as a necessary prerequisite to maintenance safety, so inspector reliability is fundamental to effective inspection. Since 90% of all inspection in aircraft maintenance tends to be visual, it is critical that this visual inspection is performed effectively, efficiently, and consistently over time. Aircraft for commercial use have their maintenance scheduled initially by a team that includes the FAA, aircraft manufacturers and start-up operators. These schedules are then taken by the carrier and modified so that they suit individual carrier requirements and meet legal approval. Thus, within the carriers schedule there will be checks at various intervals, often designated as: flight line checks, overnight checks, A, B, C, and the heaviest (D) check. The objective of these checks is to conduct both routine and non-routine maintenance of the aircraft. The maintenance includes scheduling the repair of known problems; replacing items after a certain air time, number of cycles or calendar time; repairing defects discovered previously (e.g., reports logged by pilot and crew, line inspection, items deferred from previous maintenance) and performing scheduled repairs. If a defect is discovered by the inspection system, it often leads to repair/maintenance. In the context of an aging fleet, inspection takes a more vital role. Scheduled repairs account for only 30% of all maintenance compared to 60-80% in the aging aircraft, which can be attributed to an increase in the number of age-related defects.[1] In such an environment the importance of inspection can not be overemphasized.

Once the maintenance and inspection is scheduled on an aircraft, the schedule is translated into a set of job cards or work cards (instructions for inspection and maintenance) as the aircraft arrives at each maintenance site. Initially, the aircraft is cleaned and access hatches opened so that inspectors can view the different areas. This activity is followed by a heavy inspection check. As stated earlier, most of this inspection is visual in nature. Since such a large part of the maintenance workload is dependent on the discovery of defects during inspection, it is imperative that the incoming inspection is completed as soon as possible after the aircraft arrives at the inspection maintenance site. Furthermore, there is pressure on the inspector to discover critical defects that necessitate long follow-up maintenance times early on in the inspection process. Thus, there is a heavy inspection workload at the commencement of each check. It is only after the discovery of defects that the planning group can estimate expected maintenance workload, order replacement parts and schedule maintenance items. Frequently, maintenance facilities resort to overtime, resulting in an increase in the total number of inspection hours. This often leads to prolonged work hours. Also, much of the inspection is carried out in the night shift, including routine inspections on the flight line, which are scheduled to occur between the last flight of the day and first flight on the next.

During inspection, each defect is written up as a Non-Routine Repair (NRR) record. This is translated into a set of work cards to repair the defect. The defect is rectified by the maintenance crew. Once the defect is repaired, it may also generate additional inspection to ensure that the work meets necessary standards. These subsequent inspections are typically referred to as buyback inspections. Thus, it is seen that initially the workload on the inspector is very high with the arrival of a aircraft. As the service on the aircraft progresses, the inspection workload decreases as the maintenance crew works on the repairs. The inspection load again increases towards the end of service. However, the rhythm of the work changes towards the end of service as there are frequent interruptions as **AMT**s call in inspectors to conduct buybacks of completed work.

Task analysis of aircraft inspection has revealed inspection to be a complex task wherein the inspector has to visually search for multiple defects occurring at varying severity levels and locations.[3] In performing the inspection task, the inspector has to be sensitive to efficiency (speed measure) and effectiveness (accuracy measure). These performance measures are impacted by task factors and others, as seen in **Figure 7.2**. The inspector needs to be sensitive to these factors if he or she is to optimize his or her performance. Thus, it is obvious that the inspection is a complex system and as such can be expected to exert stress on the inspectors and other personnel.[6]

The inspection task is further complicated by the wide variety of defects that are being reported in older aircraft. Consequently, a more intensive inspection program is required for older aircraft. The introduction of newer aircraft does not strictly reduce the inspection workload, as new airframe composites create an additional set of inspection variables. Nevertheless, the widespread use of older aircraft is expected to continue in the future. Thus, the **FAA** Office of Aviation Medicine and the Technical Center have recently concentrated their efforts in this area.

The problem of inspection is further compounded since the more experienced inspectors and mechanics are retiring and are being replaced by a much younger and less experienced work force. Not only do the unseasoned **AMT**s lack the knowledge or skills of the far more experienced inspectors/**AMT**'s they are replacing, but also they are not trained to work on a wide variety of aircraft. Since inspectors will continue to be a part of the inspection process for the foreseeable future, they must be trained to be effective and efficient. Training has shown to have a powerful effect on inspection performance when applied to both novice and experienced inspectors.[3,7,8] However, most of the training for inspectors tends to be on-the-job (OJT) training, especially for visual inspection tasks. We know from the literature that this may not be the best method of instruction.[1,9] Clearly, training is a critical issue because the reliability and safety of the aircraft fleet can be assured only when inspections are conducted properly.

Further, it is seen that the cost of inspection is rising.[10] As a result, there is increasingly greater competitive pressure to reduce maintenance/inspection costs (e.g., by maintaining minimum staffing levels and adhering to the mandated workload), without, of course, jeopardizing safety or disrupting flight schedules. Thus from an airline management perspective, two goals need to be achieved by a maintenance/inspection program: safety and profitability. While safety is of paramount concern, profitability can be achieved only when safety is achieved economically.

The two conflicting goals of safety and profitability are embodied in the inspection function in the form of *accuracy* and *speed*, respectively. Accuracy denotes detecting the defects that must be remedied for the safe operation of the aircraft while keeping false alarms to a minimum. Speed means the task must be performed in a timely manner without the excessive utilization of resources. In order to establish benchmarks for speed and accuracy and quantify the tradeoffs between them, behavioral models must be developed for inspector performance.

7.2.1 Problem Statement

The establishment of inspection performance benchmarks and the determination of the relative merits/consequences of speed/accuracy tradeoffs will improve the effectiveness of existing inspection and maintenance procedures. Although the scientific literature contains a number of models that have been developed to predict inspector performance, their application is limited to fairly straightforward tasks, and hence not appropriate here. Moreover, a higher degree of control is needed to bring about more systematic and extensive training than is currently possible with on-the-job training. While exploratory work in the area of computer-based training has been encouraging in this respect, this research is still in a preliminary stage.

Therefore, the goal of the research was to develop a framework to model inspection performance and use the framework/model to design a computer-based inspection training software system which will resolve the problems inherent to on-the-job Training (OJT). The objectives of this research are two-fold:

1) Develop a framework to model human performance to predict and benchmark visual inspection

performance.

2) Use the framework of visual inspection performance in developing an off-line computer-based training program to enhance aircraft inspector performance.

7.3 MODEL FOR INSPECTION

7.3.1 VISUAL INSPECTION

Inspection has been studied for many years, as evidenced by the work of investigators such as Tiffin and Rodgers, Harris and Chaney, Drury and Fox, Weiner, and Thapa, Gramopadhye, Melloy, and Grimes.[7,11,12,13,14] (The contemporary literature is the focus of this summary, and as such, only a brief historical perspective is presented here.) Originally, inspection performance was modeled as a vigilance phenomenon. However, the lack of evidence for a vigilance decrement in industrial inspection tasks suggests that other models may be more appropriate.

The inadequacy of the vigilance model motivated (in part) the application of Signal Detection Theory to this area.[15] This theory, first applied to inspection tasks by Wallack and Adams,[16] has since been used extensively by many researchers. However, while Signal Detection Theory captures the decision making aspect of the inspection task, it ignores the overtly visual aspects of the inspection task.

These shortcomings led Drury to propose a two-component model that considers the inspection task as a two-stage process consisting of visual search followed by decision making.[17,18] Therein, it is assumed that the search proceeds as a series of fixations encompassing small areas. When a flaw is located, a decision is made as to whether or not the flaw should be classified as a fault. If so, then the item is rejected; otherwise, the search continues until the time limit is reached, at which point the item is accepted. Of the two activities, searching has been shown to be the most time consuming and potentially highly error prone.[19] Thus, there is both a great need and opportunity for training intervention within the context of the search activity.

Accordingly, there has been an increased investigative effort in the area of search performance. Nevertheless, it should be noted that there were significant contributions to this area prior to 1988; e.g., as early as Lamar,[20] and subsequently by authors such as Bloomfield[21] and Greening.[22] From a modeling perspective, search performance depends primarily upon 1) the visual search strategy (random or systematic) and the inherent assumptions thereof with respect to memory, and 2) the speed. Modelers have typically treated the visual search as being composed entirely of eye fixations and have made one of two extreme assumptions about the manner in which the fixations occur. The first assumption treats fixations as random and independently distributed with any fixation point being equally likely on any fixation.[23] Under the second assumption, the whole area is searched systematically, i.e., fixations are restricted to fall on only those points that have not been fixated before.[24] Morawski et al.,[25] extended these two models of the human visual search process to multiple occurrences of a single fault within a search field, and then to the case of multiple faults.) However, human visual search is not a memoryless (random search) process, or one of perfect memory (systematic search). In reality, search performance lies between these extremes. To account for this, Arani et al.,[26] proposed a variable memory model of visual search that had a simple decay function of memory.

Secondly, it has been determined that at the level of individual performance on a fixed task, accuracy will generally decrease as speed increases.[27] In other words, for most inspection tasks, as the search time per item increases, the visual search activity becomes more successful in general, leading in particular to an increase in the probability of correctly detecting a target. This phenomenon, which has been documented in both field and laboratory studies, is referred to as the Speed Accuracy Trade-Off.[28,29]

Thus, from a practical point of view, the inspection speed (or, equivalently, the time) can be chosen to obtain a desired probability of detection. A primary question in inspection, then, is how much time should be spent inspecting an item before moving to the next item. If there are costs and values associated with the various parts of the inspection process, then determining an optimal time to inspect would result in maximizing the gains.[28]

Following several visits to our team partners hangar facilities and from previous analysis of inspection activities, the study identified the factors affecting inspection. **Table 1** shows a detailed breakdown of the inspector's activities and identifies the factors affecting the various sub-activities along with the appropriate performance measures. Analyzing **Table 1**, it is clear that speed and accuracy characterize the performance of inspection tasks. This relationship, which has been validated both in laboratory settings and under field conditions, is commonly referred to as the speed accuracy trade-off (SATO).[29] The trade-off between speed and accuracy affects the safety, dependability, and affordability of air transportation. These circumstances provide compelling motivation to analyze the SATO in quantitative terms. Such an analysis though, requires models of visual search that are capable of satisfactorily predicting inspector accuracy as a function of time in this domain.

Several different models have been employed previously to investigate the **SATO**.[25,26,34,38] These models, however, were designed expressly for two situations: 1) situations in which only one defect of a specific type could occur [34,38] or 2) situations wherein multiple defects could occur, but with the stipulation that the search would terminate when one or more defects are detected.[25,26] Moreover in these instances, an item is ordinarily classified as "defective" if even one defect is detected in the search field. Consequently, search accuracy has traditionally been defined as the proportion of defective items that are discovered.

In contrast, the models developed as part of this research and described in detail in Melloy, and Gramopadhye[30] were designed for situations in which the objective is to locate as many defects as possible on an aircraft structure, within a specified period of time. Accordingly, accuracy is defined in this case as the proportion of defects that are discovered in the search field. Since the design of these models and the associated measure of accuracy are more consistent with that of aircraft inspection tasks, there is cause to reexamine this issue. Therefore, the models developed by Melloy et al.,[30] will be employed to analyze the relationship between speed and accuracy in this specific context.

The process of searching an aircraft structure for defects is modeled as a series of fixations. The search field itself is represented as a set of uniformly sized cells. The size of these cells correspond to the *visual lobe*, or, in other words, "the area . . . which can be perceived in a single glimpse" or fixation. Any one of these cells may contain one or more defects. In order for a particular defect to be located, two events must occur in succession. First, the inspector must first fixate on the cell that contains the defect and secondly, the inspector must detect the defect.

Whether or not an inspector fixates on a particular cell depends on the search behavior and the number of fixations (i.e., the time engaged in search). The conditional probability that an inspector successfully detects a particular defect type, *t*, provided that the cell containing the defect has been fixated on, will be referred to as the conditional probability of detection, p_t.

Two complementary models of visual search are adopted here for the inspection of aircraft structures. These models were formulated under the exclusive assumptions of systematic and random search behavior in order to encompass the entire range of search performance. The performance measure of interest is accuracy, where accuracy is defined as the proportion of defects that are detected in a particular inspection area (e.g., an aft cargo pit) within a specified period of time (or equivalently, a given number of fixations). Since accuracy is a random variable, the expected value (mean) of the accuracy was employed as the actual measure of search performance.

Now, suppose that the number of fixations that occur is equal to an integer multiple, m, of the number of distinct cells that comprise the search field, c. For a defect of type *t*, Melloy et al.,[30] have demonstrated that the mean of the search accuracy is

$$\mu_t r(mHc) = 1 - [1 - (p_t/c)]mHc, \qquad (1)$$

in the case of strictly random behavior, whereas in the case of strictly systematic behavior the mean is

$$\mu_t s(mHc) = 1 - (1 - p_t)m, \qquad (2)$$

for (mHc) fixations, for m = 1, 2, . . . and c = 1, 2, ... (Note that under the assumption of strictly systematic behavior the search field will be completely scanned m times in (mHc) fixations, since the number of fixations required to make a complete scan corresponds to the number of distinct cells that comprise the search field.)

Then, since it can be shown that

$$\mu_t r(mHc) \# \mu_t s(mHc) \qquad (3)$$

(Melloy et al., 1997), it follows that the corresponding range for the mean of the search accuracy, $\mu_t(mHc)$, is defined by

$$\mu_t r(mHc) \# \mu_t (mHc) \# \mu_t s(mHc), \qquad (4)$$

since the accuracy yielded by any mixture of random and systematic behavior lies between the two extremes.

Thus, models for visual search that characterize aircraft inspection tasks were adopted to examine the specific relationship between speed and accuracy in this environment. The two models employed predict the mean accuracy as a function of time under the assumptions of either strictly systematic or random search behavior. In the absence of knowledge of individual search behavior, these two models encompass the entire range of mean accuracy for a given scenario. The magnitude of the difference between the two limiting values indicates the degree of improvement that could be achieved through training. The computer based inspection training system described in **Section 7.3** and to be developed as part of next years activities will provide a valuable tool to systematize the inspection process and improve both inspection speed and accuracy. Ultimately, the models along with the computer-based inspection training system will enable us to benchmark inspection performance.

7.4 ASSIST: AUTOMATED SYSTEM OF SELF INSTRUCTION FOR SPECIALIZED TRAINING

7.4.1 Objectives of ASSIST

The objectives of **ASSIST** are two fold:

(1) to provide basic general training on work organization, safety and procedures as it relates to aircraft inspection, and

(2) a system that provides inspection training using a computer simulation of aircraft inspection tasks.

7.4.2 System Specifications

The computer-based training program will be developed using Visual C++, Visual Basic, and Microsoft Access. The development work will be conducted on a Pentium 120 MHZ platform with a 17" high resolution monitor (0.28 mm dot pitch, non-interlaced), 32 MB RAM, 2 MB video RAM, ATI Mach 32 VLB advanced graphics accelerator card, 810 MB hard drive, multi-speed CD drive, 210 MB Bernoulli drive, and a Reveal multimedia kit. The training program will use text, graphics, animation, and audio. The inputs to the system are entered through a keyboard and a two-button mouse.

7.4.3 System Structure

ASSIST (see **Figure 7.2**) will consist of four major modules: 1) General Inspection module, 2) Inspection Simulation Training module, 3) Instructor's Utilities module, and 4) Start-up module. All system users will interact through a user-friendly interface. The user interface capitalizes on graphical user interface technologies and human factors research on information presentation (e.g., color, formatting, layout, etc.), ease of use, and information utilization.

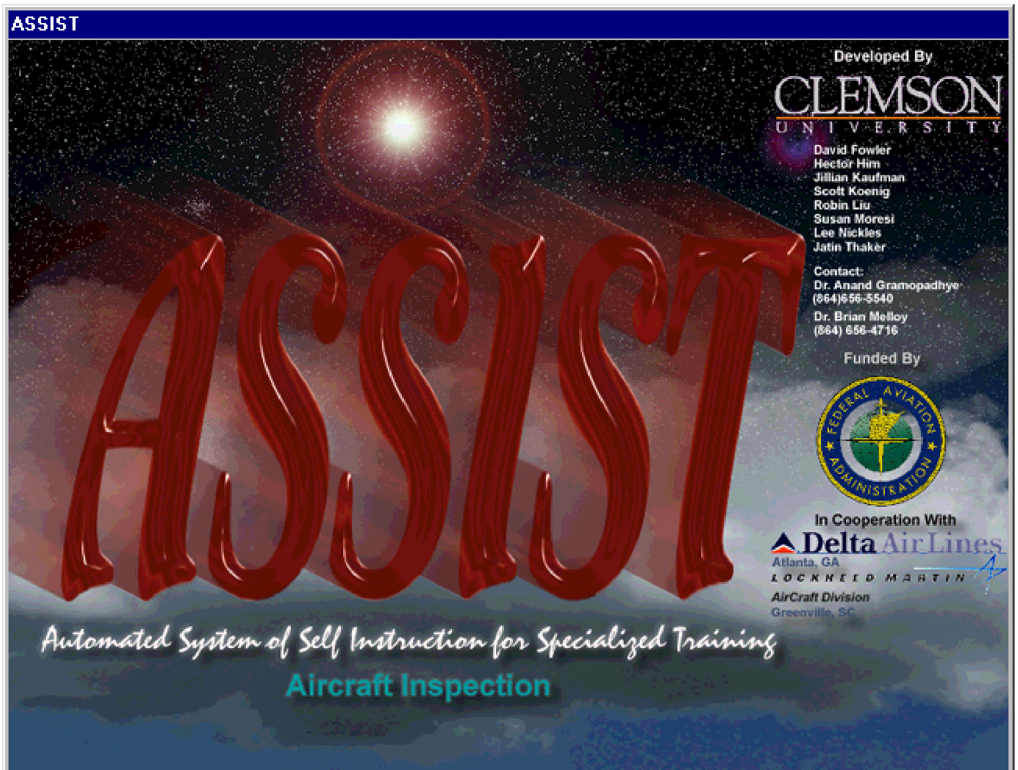

Figure 7.1. ASSIST Main Screen

General Inspection module

The objective of the general module is to provide the inspectors with a basic overview on the following topics: 1) role of the inspector, 2) factors affecting inspection performance, 3) safety, and 4) inspection procedure. These topics were identified following discussion with our team partners and based on the realization that often knowledge in these is lacking and is critical to successful inspection performance. The material covered in these topics will be cross-linked with the activities of the inspector as outlined in **Table 7.1** (see **Appendix A**). Thus, understanding of the material can have performance implications on each of the above mentioned activities. The module will incorporate multimedia (sound, graphic, text, pictures, and video) with interaction opportunities between the user and the computer. **Figure 7.3** shows a prototypical screen of the General Inspection module. **Figure 7.2** shows a prototypical screen from the general module.

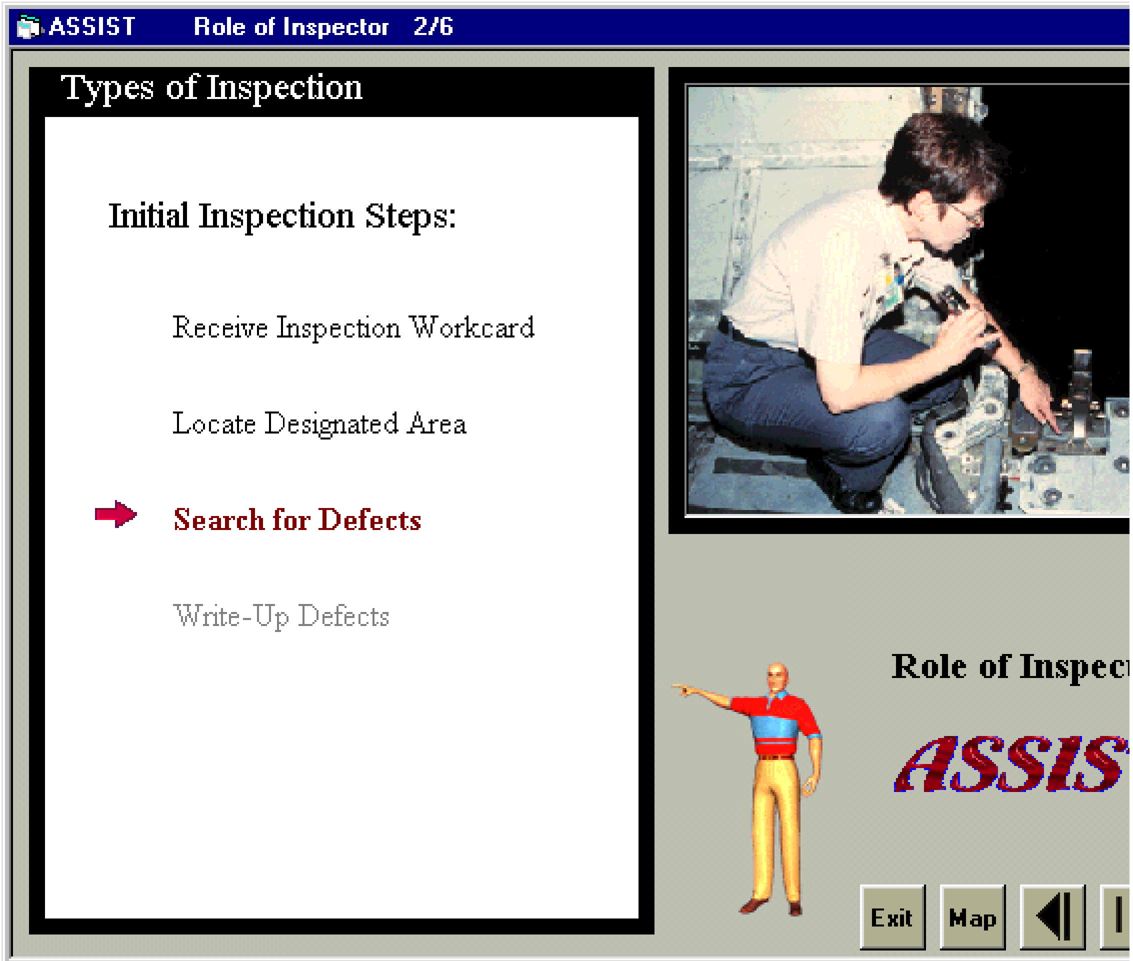

Figure 7.2. Screen from General Inspection Module

Inspection Simulation Training Module

This will be the module of the training program with which the inspector will interact to receive training on the simulated aircraft inspection task (Aft-Cargo Pit inspection of an L1011). By manipulating the various task complexity factors, the inspector can simulate different inspection scenarios. **Figure 7.4** shows a prototypical screen of the simulation training module. This training module will be further divided into four major sub-modules: introduction, search training, decision training, and testing. Each sub-module will use computer-generated images of the airframe structure.

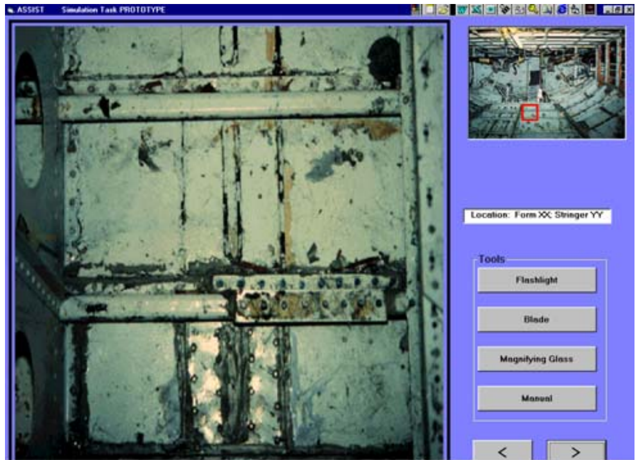

Figure 7.3. Protypical Screen from Task Simulation Module (aft-cargo pit inspection)

Figure 7.4. Prototypical Screen of the Simulation Training Module

Introduction

The introduction will be an animation that will provide the trainee with an overview of the various facets of the program. It will consist of the following:

Aircraft Inspection Terminology

This section will provide basic information on aircraft terminology. It also identifies for the trainee the associated information for which he/she should look.

Visual Inspection Defect Standards

This section provides the trainee with a graphical representation of various faults.

Overview

This section introduces the trainee to the search and decision making aspects of the visual inspection task. Each section is followed by a question and answer session wherein the trainee has to make an active response as each piece of new material is presented. The trainee is provided with immediate feedback as to its correctness. If an error is made, it is identified and the correct answer is supplied.

Search Training

This module will train the inspector only on the search component of the visual inspection task. The objective is to train inspectors to correctly identify and locate defects. This type of training is aimed at developing cues, knowledge of where specific defects occur, and the use of feed-forward information. The trainee is provided with immediate feedback on the following speed and accuracy measures: the time to locate the defect (search time) and the accuracy of the search process (the program lets the inspector know whether he/she correctly identified the defect and marks the defect on the computer screen).

Decision Training

This module will train the inspector on the decision making component. A series of aircraft structures are displayed with the faults marked. After each image is displayed, the inspector makes an active response. First, the trainee classifies the defect by defect name. Following defect classification, the trainee writes up a Non-Routine Report -- NRR report (if required) -- based on the number of defects, defect type, severity, and location. The inspector is provided with immediate feedback on his or her decision-making performance. The general objective of this module is to train the inspector on both the rule-based and knowledge-based aspects of the decision component of the inspection task.

Testing

The testing module will be designed in two separate modes: with and without feedback. The non-feedback mode simulates the actual visual inspection task (as it would take place on a hangar floor). In either mode, the inspector first locates the defect and indicates this by clicking on the fault. Subsequently, the inspector classifies the defect. In the feedback mode, the inspector is provided with immediate feedback on his/her performance on the search and decision-making components of the inspection task. The trainee is also provided with end-of-session performance feedback.

Instructor's Utilities Module

This module will allow the supervisor/instructor to access the results database, the image database and the inspection parameter modules. The module will be designed as a separate stand-alone tool that is linked to the other modules of the system. The results database allows the instructors to review the performance of a trainee who has taken several training and/or testing sessions. Performance data will be stored on an individual image basis and summarized over the entire session so that results can be retrieved at either level. The utility will allow the instructor to print or save the results to a file. The objective of the image database module is to provide the instructor with a utility wherein a specific image along with its associated information can be viewed on the computer screen. By manipulating the inspection parameters, the instructor can create different inspection scenarios. The inspection parameter module will allow the instructor to change the probability of defects, defect mix, the complexity of the inspection task, the information provided in the work card (thereby varying the feedforward information provided), and whether the inspection task is paced or unpaced.

Start-up Module

The start-up module will allow the instructor to select images from the image database and store them in a batch file. Thus, an instructor can create visual inspection tasks consisting of several batch files of images which can be used with the training and testing modules.

7.5 SIGNIFICANCE AND IMPACT OF PROPOSED RESEARCH

The centerpiece of the proposed effort is a computer-based inspection training system (**ASSIST**). The high degree of control that this system affords will create the opportunity to systematize the training. In addition, there are several other inherent advantages that will serve to alleviate the problems characteristic of **OJT**:

Completeness. Inspectors can be exposed to a wide variety of defects, with varying degrees of severity, at different locations, through the use of a library of defect images. Inspectors can also be trained on less frequently occurring critical defects.

Adaptability. **ASSIST** can be modified to meet the needs of individual inspectors. Batch files of images can be created to train inspectors on particular aspects of the inspection task with which they have the greatest difficulty**.** Thus, the program can be tailored to accommodate individual differences in inspection abilities.

Efficiency. Since the training will be more intensive, the trainees will be able to become more skilled within a shorter period of time.

Integration. The training system will integrate different training methods (e.g., feedback training, feed-forward training, and active training) into a single comprehensive training program.

Certification. **ASSIST** can be used as part of the certification process. Since the record keeping process can be automated, instructors can more easily monitor and track an individual's performance, initially for training and later for retraining.

Instruction. **ASSIST** could be used by instructors in **FAA**-certified **A&P** school for training. In this manner, for example, **AMT**s could gain exposure to defects on wide-bodied aircraft that they might not have otherwise.

Finally, this research has future implications as well. **ASSIST** could potentially be used for a wide range of controlled studies both to evaluate the effect of various task and subject factors on aircraft inspection performance, and to identify specific interventions to enhance inspection performance.

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7.7 APPENDICES

7.7.1 Appendix A

Table 7.1

Activity	*Assign Work/ Inspection tasks*	*Preparatory work*	
Description	Supervisor assigns tasks to the inspector	The objective is to conduct all activities that support inspection.	Ins the
Personnel Involved	Supervisor/ Lead Supervisor, *Inspector*, Planning personnel	*Inspector*, Cleanup crew, Stores	
Performance Shaping Factors	Subject Factors: • Inspector availability, availability of inspectors with specialized skills (e.g., NDI inspection) • Knowledge in assigning tasks, monitoring work and delegation of work • Knowledge to use information to complete tasks • Leadership skills, training Task Factors: • Planning information/workload status • Availability of resources (human, machine, system) • Aircraft schedules: arrivals, departures, types, number, types of checks • Availability of other personnel (e.g., cleanup crew) • Work disruptions: parallel tasks, interference from competing tasks • Safety issues	Subject Factors: • Availability of support personnel (cleanup crew, stores) • Training, Team approach Task Factors: • Availability and knowledge on the use of tools and equipment (e.g., NDI calibration, use of cherry picker) • Availability and knowledge on use of information (written and oral) • Safety issues (e.g., X-ray inspection) Environmental Factors: e.g., Temperature, humidity, lighting, noise level, time pressures, shift time	Su • • Ta • • • En e.g lig shi

Performance Measures	• OTD: On Time Departure • Quality of Work • Percentage utilization of personnel • Incorrect assignment of people → tasks	• Correctness in accomplishing preparatory work so that next task in sequence can proceed without delay • Time to complete preparatory work	• • •

Activity	***Inspection***		***Record item***	***Fix ite***
	Search	**Decision- Making**		
Description	Search the inspection area for potential defects	The objective is to decide on the severity of a defect once it is located	Write up the defect using a non routine card	Perfor mainte
Personnel Involved	**Inspector**	**Inspector**	**Inspector**	**Mech**

Performance Shaping Factors	Subject Factors: • Visual acuity, color vision, peripheral vision • Visual scanning strategy • Experience • Training • Knowledge of aircraft and defects Task Factors: • Task complexity (# of defects, defect types, defect mix, defect probability, defect distributions, search area, defect conspicuity) • Feedforward information and feedback information • Time available for inspection • Standards and job aids Environmental Factors:	Subject Factors: • Visual acuity • Experience • Training • Knowledge of aircraft and defects Task Factors: • Task complexity (rules in classifying defect severity based on extent, # of defects, location) • Availability and use of Feedforward and Feedback information • Time available for inspection • Job aids and standards (On-line, documented, none) Environmental Factors: e.g., Temperature, humidity, lighting, noise level, time pressures, shift time	Subject Factors: • Writing skills • Training • Knowledge of rules and procedures, aircraft and defects Task Factors: • Task complexity • Standards and procedures • Availability and use of Feedforward and Feedback information Environmental Factors: e.g., Temperature, humidity, lighting, noise level, time pressures, shift time	

	Factors: e.g., Temperature, humidity, lighting, noise level, time pressures, shift time			
Performance Measures	• Time to locate defects • Time to complete inspection • Percentage defects located • Number of times tools, equipment and procedures correctly applied	• Decision time • Decision accuracy (correctness of decision) • Number of times tools, equipment and procedures correctly applied	• Accuracy of information contained in non-routine card • Time to complete task	-

CHAPTER 8
EVALUATION OF DOCUMENTATION FORMATS

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8.1INTRODUCTION AND BACKGROUND: DOCUMENTATION DESIGN

Documentation errors continue to be a source of concern for airlines and regulatory bodies around the world. The Aviation Safety Reporting System (ASRS) is still finding procedure-related incidents running at about half of all incidents, with many of these involving written communications. This report details the latest of a series of projects aimed at reducing errors caused by poorly-designed documentation. The project first refines a documentation design job aid developed and tested in an earlier project, then proceeds to measure the performance of people working with the documents written using this job aid.

As has been noted throughout the **FAA** Office of Aviation Medicine's Human Factors in Aviation Maintenance projects, documentation plays a large and important role in aviation maintenance and inspection. Documents from an airframe manufacturer's manual, through an airline's general maintenance manual, to aircraft logbooks and inspection workcards, define what tasks must be accomplished, how to accomplish them and provide the data needed by the user. Some, such as logbooks and workcards, are also systems to ensure regulatory compliance and production control, requiring the user to have a two-way interaction with the document, both reading it and using it for recording responses. Such documents have been the focus of redesign efforts during the project, for example user-designed logbooks, and human factors guidelines for workcards.[9,11]

The importance of good document design in reducing errors was emphasized by an analysis of the paperwork errors made when a rather poorly-designed Campaign Directive (CD) was issued by an airline. It was found that *none* of the errors were made where guidelines for good human factors design were followed and *all* of the errors were made where the guidelines were not applied.

At present, the civil aviation industry is undergoing something of a documentation revolution as the information in documents is becoming available in computer-based form as well as the traditional paper-based form. This allows information to pass more easily between manufacturers, airline engineers, and document users such as Aviation Maintenance Technicians (AMTs). Standards have been promulgated (e.g. by Air Transport Association (ATA)) for formats such as Standard Generalized Markup Language (SGML) which facilitate this information interchange. But the ultimate requirement of the information remains unchanged: it must be usable by an end-user, implying that the user can comprehend the document and use it without error.

The **FAA** Human Factors in Aviation Maintenance Program has considered the unique needs of computer-based documentation over several years. For example, guidelines for design of workcards delivered by a portable computer were developed and tested by Patel, Pearl, Koli, Lofgren and Drury.[8] (A paper based on this work is currently in press: Drury, Patel, and Prabhu, 1998).[3] A commercial system for computer-based documentation using portable computers has grown out of the project, going well beyond the 1993 prototype demonstration of Patel, Pearl, Koli, Lofgren and Drury.[6,8] With many aviation companies moving to computer-based documentation, a unique opportunity has been presented to improve the quality of document design.

If airlines and others who produce end-user documents are to apply what is known of human factors good practice to the design of their own documents, simple tools are needed for document designers. During 1996, a Documentation Design Aid (DDA) was produced in cooperation with an airline partner to help meet this need.[4] This was either a Windows-based computer program or a paper checklist. The computer version of DDA could go beyond the guidelines presented in the paper-based version, to explain how each guideline was based on quantitative human factors research.

The Documentation Design Aid was evaluated by having engineers use it to make changes to an existing workcard. This usability test showed that even first time users could improve the quality of documentation quite rapidly using the **DDA**.

But neither usability of the **DDA**, nor even the usability ratings of documents produced using the guidelines are the ultimate test of documents designed to ensure safe aircraft maintenance.[9] The true test is to measure the effect of document design changes on maintenance errors.

An analogous set of tests was performed earlier on aspects of documentation design, the use of Simplified English. Chervak, Drury and Ouelette measured the usability of workcards written in **AECMA**'s restricted language of aviation maintenance — Simplified English.[2] Using a sample of 175 **AMT**s from across the **USA**, they found that comprehension was higher for Simplified English, particularly for complex workcards and for non-native English speakers. This study was extended to count errors made in task performance, using engineering students and automobile mechanics performing maintenance tasks on a small gasoline engine.[1] The Simplified English versions of the workcards produced less errors and performance hesitations than similar workcards not using Simplified English.

The current project extends this methodology to workcard design as a whole, and user errors made during actual maintenance task performance in airline operations, rather than errors made during a controlled experiment. First, however, changes were needed to the Documentation Design Aid itself based upon feedback during the usability trials and from human/computer interaction professionals.

8.2PROJECT OBJECTIVES

For the current project, we continued to work with the same airline partner used in earlier **DDA** development. This ensured airline user input into re-design of the DDA for ease of integration into the partner's on-going program of electronic documentation delivery. It also ensured that the ground work for DDA evaluation would be simplified through our organizational linkages developed during earlier DDA development. Finally, a second project with the same airline partner showed members of the airlines documentation team, and maintenance management, that progress was being made towards the deployment of improved documents.

Specific objectives of the 1997-98 project were:

- Objective 1: To modify **DDA** as required to ensure that it can be integrated with our airline partner's current and future documentation systems
- Objective 2: To provide a direct test of the operational error rates found with **DDA** and original (non-DDA) documents.

8.3 METHODOLOGY

To meet these two objectives, the project had a design component and an analysis component. These are described in turn.

8.3.1 DDA Integration

The Documentation Design Aid tested at the end of the 1996-97 project provided most of the information required by technical writers to apply human factors good practice to documents such as workcards. However, it lacked a major element, Simplified English, and the **DDA** user interface did not meet current good practice in human/computer interaction. Additionally, from the point of view of the airline partner, it was a stand-alone system, not integrated with their on-going electronic documentation efforts. The redesign/integration objective was designed to upgrade the DDA and help its integration into our partner's activities.

Simplified English has already proven useful in workcard design, so it should be incorporated into human factors good practice.[2] C. G. Drury attended a meeting of Association Europeenne des Constructeurs de Materiel Aerospatial's (AECMA) Simplified English Committee in May, 1997 to obtain information on the latest developments in Simplified English. We were thus able to use the current version of Simplified English, and to decide on the level of Simplified English support provided in the **DDA**. There are a number of advanced Simplified English computer programs available which will parse a document to detect deviations from grammar and word choice for Simplified English approved. Examples are the original prototype developed by Boeing, and MAXIT developed by Smart Technologies of New York. Rather than attempt to reproduce the functionality of commercial systems (an effort well beyond the scope of this project and difficult without specialist skills in linguistics), it was decided to incorporate only a Simplified English word checker within DDA. This could be accomplished relatively easily in the Visual Basic™ language used to program DDA.

To check whether a word is part of the approved Simplified English vocabulary, the word is pasted (or typed) to a dialog box within **DDA**. If the word is in the approved vocabulary the user is told this. If not, the program checks for synonyms of Simplified English words and, if a match is found, suggests the approved Simplified English word. If no match is found, the program tells the user that it cannot recognize the word. The DDA will also check words in a more extensive fragment of text for their compliance with Simplified English. It will not perform grammar checks, for example, the use of passive voice or for long noun clusters.

Although the original **DDA** interface had proven to have good usability, the knowledge of human factors in computer interface design is expanding rapidly, so that the opportunity was taken for a thorough overhaul. Three human computer interaction specialists from Galaxy Scientific Corporation provided a detailed critique of the DDAs interface and functionality. In addition, two human factors engineers who have taught human computer interaction at the graduate level provided input. Based on these inputs, the menu structure, functions available, and options for program navigation were all re-programmed.

Most of the specific changes made were to the wording of dialog boxes, the colors used for backgrounds, and to the program logic so as to ensure consistency between function in different pairs of the program. For example, the Simplified English checker was presented as a separate dialog box.

While the modifications to the **DDA** were being programmed, the opportunity was taken to update the sources of human factors good practice in document design. Several more recent compilations of guidelines were located and the appropriate changes made in the DDA content. [5,6,10]

An updated version of the **DDA** is now complete and is available through Human Factors site on Web (www.hfskyway.com) and 1998 Human Factors Guide for Aviation Maintenance CD-ROM.

8.3.2. Evaluation of DDA documents

The evaluation section is presented in some detail to serve as a model for other evaluation efforts. As human factors becomes embedded within many aviation maintenance and inspection organizations, formal statistical evaluation of interventions should become the province of the practicing airline engineer rather than the human factors researcher. Hence, a discussion of the considerations leading to choice of sample size is included. Additional material is supplied on how to measure comprehension and usability, and how to collect error data from maintenance records. Statistical analysis techniques are also presented as a model for evaluation by practitioners.

8.3.2.1. Measures

Operational Effectiveness means that the document should have high comprehension, high user acceptance, and low error rate. Comprehension by the user is measured using a short comprehension quiz on each document. User acceptance was measured by having the user complete a set of rating scales covering different aspects of document design. Both the comprehension quiz and the rating scales have been used in previous studies of document design. Error rate is the final outcome measure. Data on actual paperwork errors was collected from the Maintenance Records department by the partner airline in their regular manner and associated with each test document.

8.3.2.2. Overview of Studies

Two studies have been run: one to count paperwork errors and a separate study to measure comprehension and user acceptance. Campaign Directives (CD) were chosen as the test documents because they typically require immediate compliance. Two versions of each were tested, an original and one produced using **DDA**. A number of Campaign Directives were used, with each version of a particular Campaign Directive having effectivity for a specific set of tail numbers in the fleet. Total sample size was designed to be in the range of 400-800 completed Campaign Directives for counting paperwork errors. Comprehension and user ratings were analyzed to compare the two Campaign Directive versions in a separate study with a sample size of 100-200.

8.3.2.3. Evaluation Materials

A number of different Campaign Directives were used, to cover a range of length and complexity. Each Campaign Directive were produced in an original version, as supplied by the airline partner and a **DDA** version produced by the **SUNY** Buffalo team. The two versions were identical in content, differing only in documentation format and layout. For example, all the DDA versions used Simplified English and the formatting conventions approved by the DDA team at the partner airline in 1996. The two studies used the same set of Campaign Directives where appropriate, supplemented by Engineering Orders where needed. Two versions of one Campaign Directive are attached as examples. These have had the identity of the airline partner removed for publication.

An overview explaining the two studies was presented as a news item in the airline partner's house magazine in November 1997. This is good practice in any human factors study to ensure that potential participants are informed of research efforts which may affect their jobs.

8.3.2.4. Evaluation Subjects

The subject pool consisted of **AMT**s and/or inspectors at each station who normally perform Campaign Directives. Subjects were not chosen specially, and did not have any identifiers associated with their responses. (Age, gender, years of experience and other demographics were collected for the comprehension/ usability study.) All subjects were told in the magazine item that their responses are confidential, i.e., we are evaluating the document, not the user.

8.3.2.5. Sample sizes

Sample size depends upon the size of effect we want to measure, what the original value was, and how certain we need to be that we have found a real effect rather than chance variation. If we take error rates as our main criterion, then we can eventually compile a table counting the Campaign Directives with and without errors for each version. A Chi-Square statistical test applied to such a table will show the significance of the data, i.e. the probability of finding such an extreme result by chance. Thus if we used 300 original and 300 **DDA** Campaign Directives, with an original error rate of 6%, and found a 50% reduction in errors with the DDA version, we would have results shown in **Table 8.1**.

Table 8.1. Hypothetical Results for Sample Size 600, Original Error Rate of 6%, and 50% Error Reduction

	Number with Errors	Number without Errors	Total Number
Original version of CD	**18**	**282**	**300**
DDA version of CD	**9**	**291**	**300**

Performing the statistical test on this data gives a chance of 0.08, or odds of 92 to 8 (11.5 to 1), of finding such a result from chance variation in the data. Typically, a chance of 0.05 or less is the criterion for a statistically significant effect, but readers can draw their own conclusions given the odds. We calculated the probabilities for different original percentage errors and sample sizes, with the results shown in **Table 8.2**. Combinations, which would lead to a significant outcome, are shaded. Note that this table is based on a conservative estimate from the Chi-Square test. There are slightly more powerful tests but these depend on the actual distribution of errors. Thus, if anything, the sample sizes in **Table 8.2** are somewhat overestimated, and represent a worst case for planning.

Table 8.2. Probability of a 50% Reduction in Error Rates being Found Significant by Chance for Different Sample Sizes and Original Error Rates

Percentage Errors in Original	N = 400	N = 600	N = 800
2%	0.41	0.31	0.25
4%	0.24	0.15	0.10
6%	0.14	0.08	0.04
8%	0.09	0.04	0.02
10%	0.06	0.02	0.01

Table 8.2 shows that we really needed about 400 samples to be reasonably sure of a significant result, always assuming that the **DDA** is an improvement. These 400 samples could come from a number of Campaign Directives spread over a period of time.

Results from the comprehension quiz and the rating scales should show significance with smaller sample sizes. For example, both measures showed significant results on a test of Simplified English using 175 **AMT**s in a 1995 study. It was planned to use a total sample size of 100-200 for the comprehension/usability study.

8.3.2.6. Procedure

<u>Study 1: Paperwork errors</u>

The evaluation was set up at several stations, using the larger fleets for simplicity. The team communicated with the **AMT**s and supervision/ management to define the evaluation, how the station would benefit, and what the expectations were for the study. As each suitable Campaign Directive was sent to **SUNY** Buffalo, a **DDA** version was produced. Production time, including retyping, for average length Campaign Directives was 2-3 hours. Packages were produced and sent back to the partner airline for a final check for accuracy by the engineer who wrote the **CD**, and then distribution in the normal manner. Three Campaign Directives were finally distributed in both versions.

When the Campaign Directive was distributed at each station, the originals were submitted and collected in the usual manner. When these were eventually received by Maintenance Records, the errors were counted in the usual way by the Records clerks. **SUNY** Buffalo did not interfere in any on-going processes of error investigation and discipline associated with the Campaign Directives.

Study 2: Comprehension and usability

A comprehension test, a usability evaluation page, and a short demographic questionnaire were produced for each **CD** chosen. The examples in Appendix A show old and new versions of a typical CD, with these attachments. Multiple copies of each version (**DDA**, original) were produced and used for the study. The experiments followed the same protocol used in the Simplified English study in 1995, by visiting each station and administrating the material individually to **AMT**s and inspectors.

Each individual was given the package, timed for completion of the comprehension test, and then asked to complete the rating scales of the usability evaluation, and the demographic data. The comprehension test has ten questions. Five questions were on the content of the **CD**, for example, "What do you do if a delamination is found?" The other five questions asked where (CD step number) the answer to the content question could be found. Packages were collected and the comprehension test scored as percent correct.

8.4RESULTS

The results are in two parts to correspond to the design and evaluation objectives. Under evaluation, the main results are from Study 2 with results collected by the end of the project for Study 1. It is the airline partner's intention to complete Study 1 and provide **SUNY** Buffalo with the data for later analysis.

8.4.1 DDA Integration

Now that the DDA has been rewritten and tested, it is being integrated into the partner airline's operations. This is not as straightforward as it would appear because (a) the airline has existing standards which may conflict with **DDA** recommendations and (b) there is an on-going program of moving from paper-based to electronic publishing. Because both of these reasons are replicated at other airlines, they are worth consideration here.

All airlines have documentation standards, typically based on an **ATA** standard or guideline, and referenced in legal documents such as the general maintenance manual. Any change, even one which improves documentation, must pass through an approval process both at the airline and with the local representatives of regulatory authorities. Close cooperation is required between airline personnel and regulators (e.g., MIs in the USA) to ensure that this proceeds smoothly. A single person who wants to see the changes made should be given responsibility for implementing this aspect of change. Any change can be seen as a threat by some of those it affects, so there are natural tendencies to assign on such changes a low priority. Having a single committed change agent can speed the overall process.

Most airlines are moving towards electronic publishing of many maintenance-related materials, which provides a unique opportunity to incorporate good human factors practice into the final documents. However, most of the participants in electronic publishing are not trained in human factors, so that their main concerns are for electronic compatibility rather than user/document compatibility. Too often, human factors can be seen as just another restriction on "getting the job done." To take advantage of the opportunity inherent in this change, those responsible for human factors in airlines (and other maintenance organizations) will need to actively seek out electronic publishing initiations and ensure that human factors considerations are brought into the process early.

8.4.2 Evaluation of DDA Documents

As data was collected in the two studies, it was entered into a statistical data analysis package, MINITAB™. This allowed tabulation of results and performance of statistical significance tests on the data.

Study 1: Operational Effectiveness

For Study 1, counts of numbers of documents with and without errors for each **CD** were tabulated, similar to **Table 8.1**. When the maximum number of data points in the project period had been collected, a statistical analysis was performed to determine whether the improvements were beyond the chance level.

Three **CD**s were used in this study, differing in length and complexity. As shown in **Table 8.3**, the **DDA** versions had more steps, more words and a lower Fleish-Kincaid reading score. The **DDA** produces more explicit information, leading to more steps and words, but ensures that the document is easier to read, leading to the lower Fleish-Kincaid score.

Results collected so far (end of March 1998) are shown in **Table 8.3**. Note that overall, two errors were detected out of the 38 original versions and zero errors out of the 11 **DDA** versions. The error rate for the original version (5%) was in line with the historically-expected value, but the numbers are too low for statistical analysis using the Chi-square test. Our partner airline has agreed to continue making data available to SUNY Buffalo for analysis as all **CD**s are completed. This would give a sample size of well over 100 instead of the current sample size of 49, but may still not be large enough to provide an adequate test (see **Section 8.3.2.5**). Over three times as many original versions were issued as DDA versions, because the original versions were released earlier from the Engineering Department.

It is interesting to consider the types of errors made in the study, and also to analyze confusions as well as actual errors. Both errors were in one **CD** (coded "21") which required both part number and serial number to be recorded for left and right water separators. One error was that both numbers were incorrect, the other that the part number was incorrect. Both **CD**s were sent back to the station to be completed correctly.

In fact, there were two serial numbers on each part, one assigned by the manufacturer and one assigned by the airline. Neither version was specific on which was to be recorded. The original said:

"....... record manufacturer's part number and serial number....."

while the **DDA** version said:

"......find the manufacturer's part number on the data plate on the side of left water separator and record it. Then find serial number on the data plate or within close proximity to the data plate on the right side of the water separator and record it......"

Thus although in the original version "manufacturer's serial number" is implied, it is not stated. In the

DDA version, the description above leads the user to the airline's serial number. All six DDA-version users recorded the airline's serial number, whereas only 13 of the 22 original-version users did this. The others recorded either the manufacturer's serial number, or both, or differed between the right and left sides. While all are technically correct, the DDA version provided the uniformity which is so desirable in airline maintenance record-keeping. On the same **CD**, the original version had three other problems with specifying the replacement of the water separators, although none were considered errors of the records clerks.

For the **CD** coded "36" no errors were found but some difficulties were seen in the records. In the **DDA** version, one inspector did not stamp a block where he had written "**N/A**", and also had two digits transposed in the part number, but both were corrected. For the original version two inspectors had stamps which the team found illegible, although the records clerks could read them; one inspector had written N/A in spaces he should have left blank, and one recorded the airlines part number for the replacement part instead of the manufacturer's part number.

In summary, Study 1 was not continued long enough to produce statistically significant results. However, both of the two errors recorded and most of the problems encountered occurred in the original version and not the **DDA** version.

Table 8.3. Details of the Three CDs Issued, with Numbers of Errors

CD Code	Version	CD Steps	CD Words	Fleish-Kincaid Score	# without Errors	# with Errors	Total
36	Original	5	134	11.4	11	0	11
	DDA	7	259	10.1	5	0	5
21	Original	3	122	10.4	20	2	22
	DDA	6	294	9.7	6	0	6
25	Original	8	379	8.2	5	0	5
	DDA	11	442	7.1	0	0	0

Study 2: Comprehension and Usability

The comprehension and usability study was performed on a total of 101 **AMT**s at seven stations of our partner airline. All AMTs were line maintenance personnel who regularly perform the work required of **CD**s. The two versions of the three CDs were distributed randomly, giving the following total number of AMTs:

Table 8.4. Number of AMTs Tested

	CD1	CD2	CD3	Total
Original	17	18	17	52
DDA	19	14	16	49
Total	36	32	33	101

Age and experience distributions of the sample are shown in **Figures 8.1** and **8.2**. Median age and experience were compared to the population data collected by the Bureau of Labor Statistics (1988) using a Wilcoxon test. Both age and experience were different from the population values (t = 3918, P < 0.001; t = 4286, P < 0.001) showing that our sample was somewhat older and more experienced of the national population of **AMT**s was in 1988.

Analyses of variance were performed on the comprehension measures of Number Correct and Time Taken. (The model used was a two factor fixed effects ANOVA.) A significant effect of version (Original versus **DDA**) was found for Time Taken (F (1, 91) = 12.59, p = 0.001). Also, the effect of **CD** was significant for Time Taken (F (2, 91) = 6.58, p = 0.002). No interactions were significant.

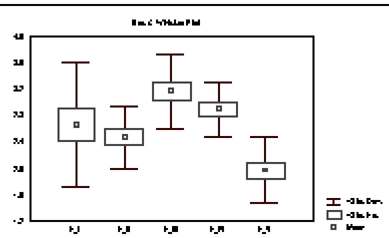

Figure 8.1. Age Distribution of AMT Sample

For Number Correct, two covariates gave significant effects, **AMT** age (t = -3.08, p = 0.003) and AMT experience (t = -2.13, p = 0.036). When either covariate was included in the analysis, Version became significant (Age: F = 3.76, p = 0.056, Experience: F = 4.29, p = 0.041). In both cases, the number correct decreased with the covariate, showing that older and more experienced AMTs had less correct answers. The regression equations were:

Number correct = 11.15 - 0.045 X age

Number correct = 9.82 - 0.03 X Experience

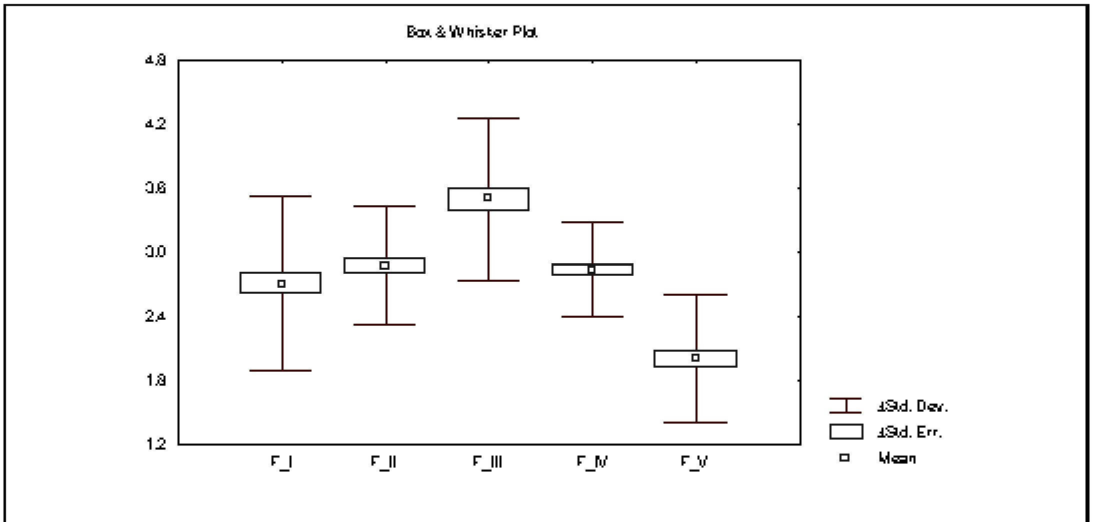

Figure 8.2. Experience of Distribution of AMT

The effects of version on the two performance measures are shown in **Figure 8.3** and **8.4**. Note that for consistency with previous studies Percent Errors is used in place of Number Correct where:

$$Percent Errors = \frac{Number Correct}{10} X \quad 100\%$$

Compared to the original **CD**s, the **DDA** version reduced the error rate by about 40% and increased the time taken by about a quarter. This is direct evidence that DDA -designed documents impact the major variable of interest to airlines, regulators and the public, i.e., error free performance. DDA-designed documents achieve this effectiveness at a modest cost in time to read, comprehend, and answer the ten questions, adding about two minutes to this total time.

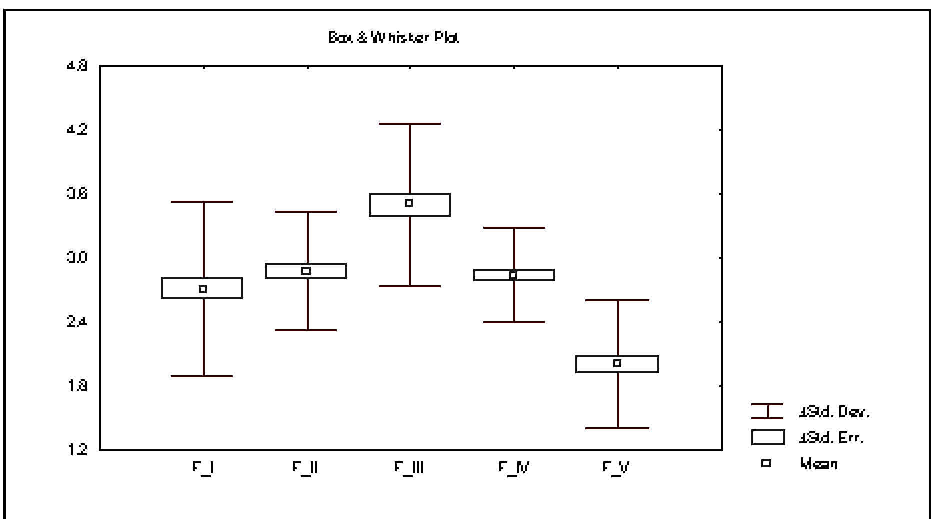

Figure 8.3. Number Correct for the Two CD Versions

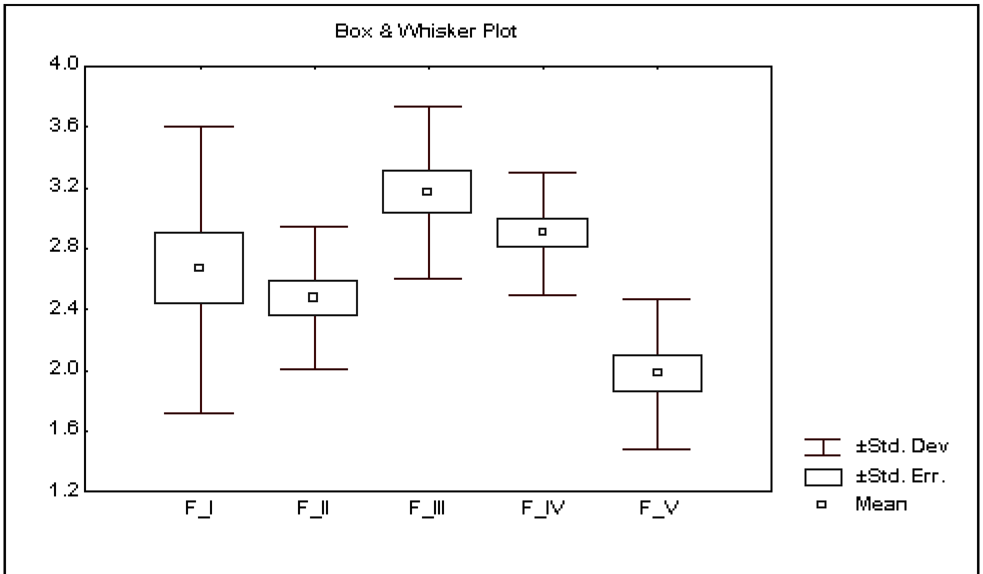

Figure 8.4. Time Taken for the Two CD Versions

It was expected that the time taken would be different for the three **CD**s used, and indeed it was. One CD was completed more rapidly than the other two. This was the one with the fewest steps and fewest words. Figure 8.5 shows the correlation between time taken and total number of steps in the CD. Note that the **DDA** format, by making all steps explicit, gives more steps and thus increases reading time. However, the accuracy, i.e. number correct, was not predicted by the number of steps or similar measures such as number of pages or words. Thus while the DDA version took longer to read, because of its greater length, its accuracy was greater as noted earlier.

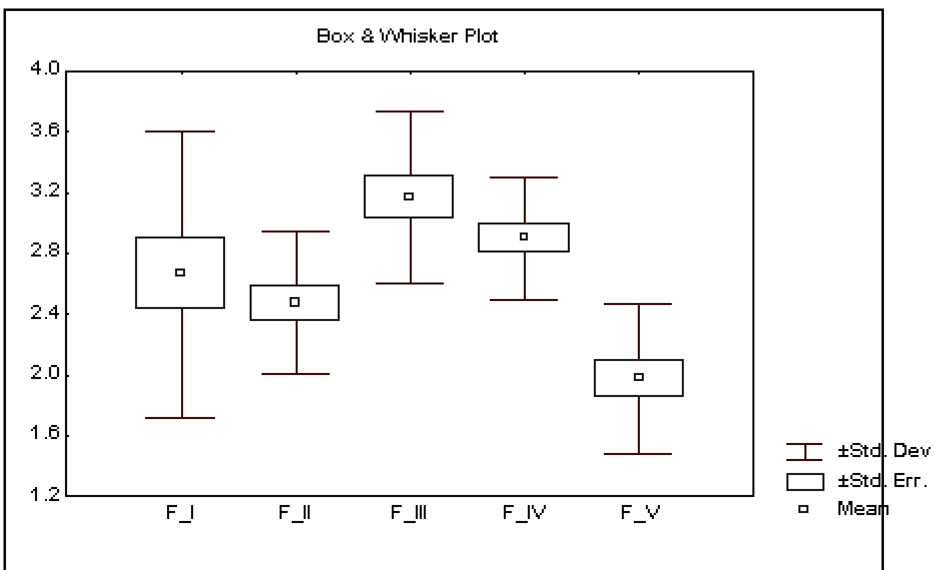

Figure 8.5. Effect of Number of Steps in the CD on Time Taken

A final finding concerning comprehension was that very few of the demographic measures affected either comprehension time or number correct. One-way ANOVA's were conducted for each of the fifteen variables measured, such as which station the **AMT**s were based at, which aircraft types they worked on, and their native language. Only two of these thirty statistical tests were significant at $p < 0.05$; by chance 1.5 would be expected to be significant at this level, so that little credence can be placed in these demographic results. For the record, number correct was related to whether or not the AMTs worked on Fokker products ($F(1, 99) = 4.20$, $p = 0.043$) and whether or not English was their first language ($F(1, 99) = 4.46$, $p = 0.038$). The latter finding reflects earlier work on Simplified English (Chervak, Drury and Oullette, 1996) which showed that native English speakers had higher comprehension performance. In the current study there were only four AMTs out of 101 who did not have English as their first language, again suggesting caution in interpreting these particular results.

Rating scale data to measure usability showed very few significant differences for either **CD** or for version. No effects of version were significant and only four ratings of CD:

Readability	$F(2, 69) = 3.64$, $p = 0.031$
Ease of relating figures	$F(2, 69) = 3.44$, $p = 0.038$
Ease of readability of attachments	$F(2, 69) = 3.20$, $p = 0.047$
Relating graphics to aircraft structure	$F(2, 69) = 3.14$, $p = 0.050$

Overall, ratings on single direction scales (0 = bad, 8 = good) were high, with averages ranging from 5.1 to 6.1. All median were significantly greater than the neutral value (4) and significantly below perfect (8) using the Wilcoxon test. On double-ended scales (0 = too little, 4 = just enough, 8 = too much), the ratings were all close to the center, ranging from 4.0 to 4.9. The conclusion is that **AMT**s found the DDA-designed **CD**s no different from the original versions, and rated both versions as highly usable.

Where possible, the actual errors made were tabulated in both studies. This allowed us to classify the errors and to determine where users were having difficulty with documents. For example, some errors were found to be system errors, such as stores supplying an incorrect part for fitting, rather than documentation errors.

In the comprehension study, the errors were tabulated for the five content questions and the five questions asking where in the **CD** the answer could be found. The total errors were as follows:

	Original	**DDA**
Content questions	19	6
Location questions	24	19

The difference between the original and the **DDA** versions is significant for content questions ($X^2(1) = 6.76$, $p < 0.01$) but not for location questions ($X^2(1) = 1.00$, $p > 0.50$). Thus the main effect of the DDA is to reduce content comprehension errors. In fact, the errors using the DDA version are reduced by two thirds from the original. Content errors are much more operationally important than errors in specifying where the relevant content can be found. This analysis of the types of errors made makes an even stronger case for the DDA versions of the **CD**s than did the earlier analysis based on overall error rates.

8.5DISCUSSION AND CONCLUSIONS

We now have a documentation design aid completed and ready for use. It was designed to incorporate the results of previous quantitative studies which define good human factors practice in documentation design. But no tool should be accepted until the design has been validated. The original **DDA** was tested for usability in 1996-97 and found to be effective even for first time users. Using DDA, document writers were able to find many improvements in an existing document, and all rate the usability as good.

This year we have re-written the **DDA** and tested it in a practical quantitative manner. The rewritten version is better human-engineered and now incorporates a Simplified English checker. Although the operational trials were few in number, they and the comprehension study fully vindicate the DDA. Documents designed using the DDA produced fewer errors than their original, and quite well-designed, counterparts.

In the operational study, only two errors were found, but both were for the original versions of the **CD**s. In addition, the **DDA** versions had less problems and confusions than the original versions. In the comprehension study, comprehension error rate was reduced by about 40%. Content comprehension errors, which have the greatest operational relevance, were reduced by about 70%. The time taken to read and comprehend the documents increased by about 25%, mainly due to the increased number of steps in the more explicit format of DDA-designed documents. Any system which reduces errors by 40% (or 70%) for a two-minute increase in task time represents an operationally- significant improvement. The DDA is also measurably easy to use (from the 1996-97 data) and produces documents which receive high ratings for usability (from the 1997-98 rating data).

This project has also been designed to provide a model for evaluation of human factors changes. The issues of sampling and testing have been explicit so that those with human factors responsibility in airlines and other repair organizations can perform their own quantitative evaluations of the changes they develop. As human factors functions in airlines become established, rapid quantitative evaluations will become an increasingly important aspect of their work.

8.6 REFERENCES

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8.7 APPENDICES

8.7.1 Appendix A – Original Campaign Directive

SUNY Airways

CAMPAIGN DIRECTIVE

CD No. ABCD1234

ATA

DATE:

AIRCRAFT/ENGINE TYPE	TITLE:	
SUNY 96 Weight Change Est. Manhours Est. Downtime	Reason for Request: Reliability Engineering has requested tracking of xx96 to analyze continuing problems with water dripping from the air condition system onto the passengers.	A **ETOPS** PROJE Referen

SPECIAL INSTRUCTIONS

1. *XX Dept.*:
   a. This CD is to be accomplished no later than 120 days from release to XX.
   b. If feedback sheet is not returned with completed paperwork, this CD must be rescheduled.
2. *SUNY Research*:
   a. Begin tracking the tail number, position, manufacturer's part number and serial number of xx92 on the SUNY 96 fleet.
   b. If feedback sheet is not returned with completed paperwork, this CD must be rescheduled.

Preparec
Checkec
Approve

Material Req'd to Accomplish:

Quantity	CCN	Description
N/A	N/A	N/A

Parts Removed:

Quantity	CCN	Description	Di
N/A	N/A	N/A	

PRIORITY	SUNY Requirement X FAA Mandatory _	NO LATER THAN : ** See Note to Planning	________CHECK ________DAYS ________FLIGHT HOURS ________MONTHS

WORK INSTRUCTIONS	Accomplished By
1. Locate water separators in rear of aircraft. The manufacturer's part number is found on the data plate on the side of the water separator. The serial number may be found on the data plate or within close proximity to the data plate on the side of the water separator. See Figure 1 for location of data plate.	
2. On the Feedback Sheet attached, record manufacturer's part number and serial number from the right and left side water separator. Be sure to return the Feedback Sheet to SUNY FAA Research Group. NOTE: Removal of the water separator may be necessary. Refer to XX 11-00-22 for procedure.	
3. If removal of water separator was necessary, reinstall water separator per XX 11-00-22. NOTE: N/A this step if removal of water separator was not necessary.	

All Campaign Directive Work Instructions accomplished, all sign-offs legible and information c

AIRCRAFT__________________ STATION______________ DATE_____________________

Logbook Page Number____

LEAD MECHANIC OR SUPERVISOR ________________________ EMP. #______________

SUNY Airways | CAMPAIGN DIRECTIVE | **CD No. ABCD**

TITLE: AIR CONDITIONING - Record Serial Number of Left and Right Water Separator Tracking

WORK INSTRUCTIONS (continued) **| Accomplished By |**

FEEDBACK SHEET

Please complete the following information:

Station: _________________________

Date : __________________________

A/C Tail Number: ________________________

Left Hand Side

Manufacturer's Part Number: ________________

Serial Number: ___________________________

Right Hand Side

Manufacturer's Part Number: _____________________

Serial Number: ____________________________

Upon completion of this Feedback Sheet, please return all paperwork to SUNY FAA Research Group.

SUNY Airways	CAMPAIGN DIRECTIVE	CD No. ABCD

AIRCRAFT EFFECTIVITY SHEET

TITLE: AIR CONDITIONING - Record Serial Number of Left and Right Water Separ Begin Tracking

DATE	EFFECTIVITY	No. of AIRCRA
11/21		
11/21		

8.7.2 Appendix B – DDA Version

SUNY Airways **Campaign Directive-ABCD1234**

Title: AIR CONDITIONING – Record Serial Numbers of Water Separators to begin Tracking Reliability	**Date :** 11/21/97 **ATA:**

Reason for Request: Reliability Engineering has requested tracking of form 92 to analyze continuing problems with water dripping from the air conditioning system onto the passengers.

AD/FAR No: N/A

ETOPS Requirement: NO

Project No: 7711x3

Aircraft/Engine Type: SUNY 96

Material Required to Accomplish: N/A

Effectivity:

Date	**Effectivity**
11/21/97 **(Original)**	

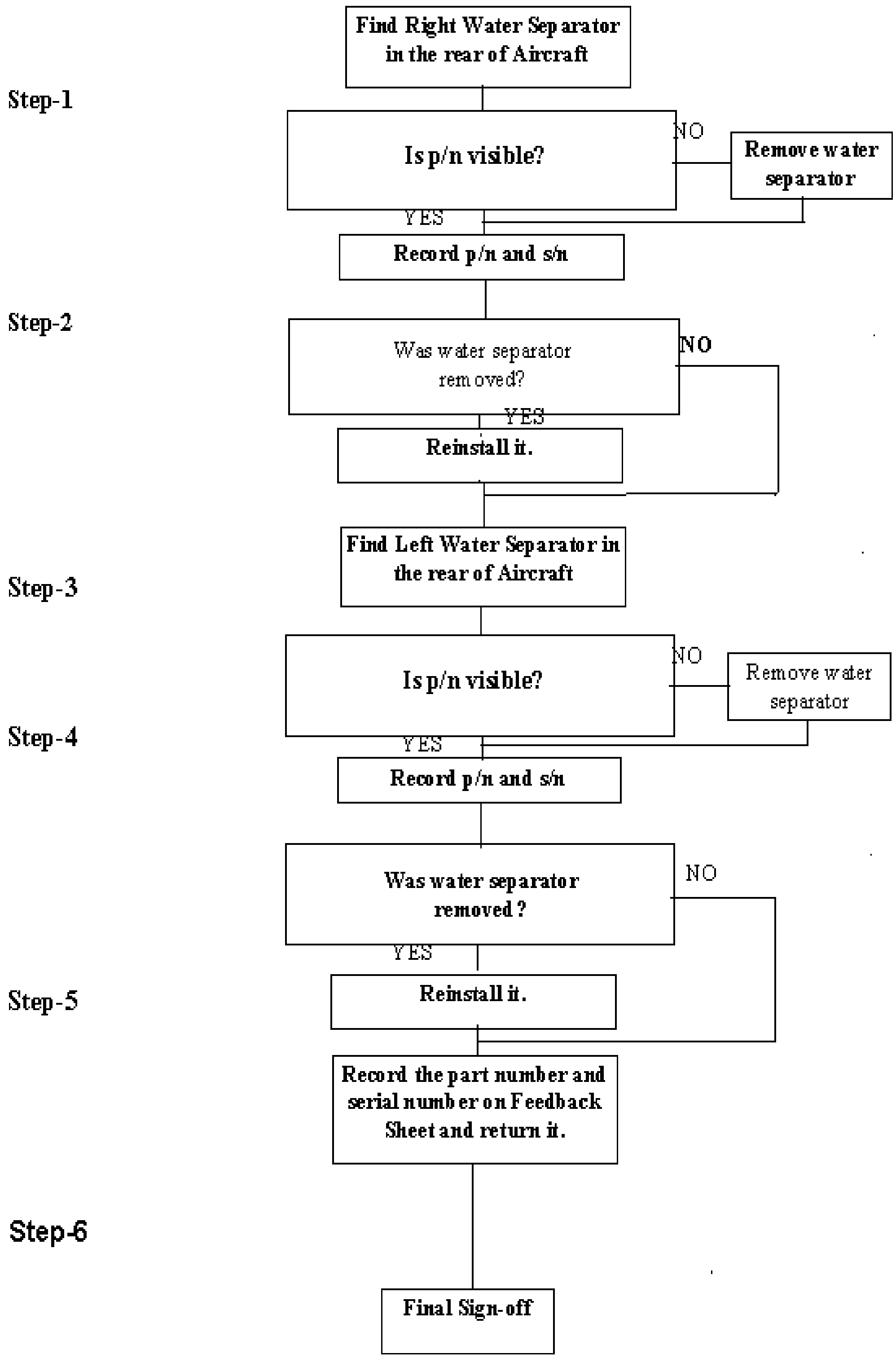
SUNY Airways

Campaign Directive-ABCD1234

Title: AIR CONDITIONING – Record Serial Numbers of Water Separators to begin Tracking Reliability	**Date :** 11/21/97 **ATA:**

FLOW CHART

WARNING: This flow chart is only for information purposes. Please do not use this flow chart to perform the steps in this Campaign Directive.



Find Right Water Separator in the rear of Aircraft
Step-1
Is p/n visible?
NO
Remove water separator
YES
Record p/n and s/n
Step-2
Was water separator removed?
NO
YES
Reinstall it.
Find Left Water Separator in the rear of Aircraft
Step-3
Is p/n visible?
NO
Remove water separator
Step-4
YES
Record p/n and s/n
Was water separator removed ?
NO
YES
Step-5
Reinstall it.
Record the part number and serial number on Feedback Sheet and return it.
Step-6
Final Sign-off

SUNY Airways Campaign Directive-ABCD1234

Title: AIR CONDITIONING – Record Serial Numbers of Water Separators to begin Tracking Reliability	**Date :** 11/21/97 **ATA:**

Work Instructions: **Accomplished by**
Checked by

1. Find right side water separator in rear of aircraft. Then, find manufacturer's part number on the data plate on the side of right water separator and record it. Then, find serial number on the data plate or within close proximity to the data plate on the side of the right water seperator and record it. See Figure 1 for location of data plate.

Note: If part number and serial number are not accessible, removal of the water separator may be necessary. Refer to XX 11-00-22 for procedure.

Right Water Separator Part Number_________________________

Right Water Separator Serial Number________________________

2. If removal of right water separator was necessary, reinstall water separator per XX 11-00-22.

Note: N/A this step if removal of water separator was not necessary.

3. Find left side water separator in rear of aircraft. Then, find manufacturer's part number on the data plate on the side of left water separator and record it. Then, find serial number on the data plate or within close proximity to the data plate on the side of the left water seperator and record it. See Figure 1 for location of data plate.

Note: If part number and serial number are not accessible, removal of the water separator may be necessary. Refer to XX 11-00-22 for procedure.

Left Water Separator Part Number_________________________

Left Water Separator Serial Number________________________

4. If removal of left water separator was necessary, reinstall water separator per XX 11-00-22.

Note: N/A this step if removal of water separator was not necessary.

5. On the Feedback Sheet attached, record manufacturer's part number and serial number from the right and left side water separator. Be sure to return the Feedback Sheet to SUNY FAA Research Group.

6. All Campaign Directive Work Instructions accomplished, all sign-offs legible and information completed.

Aircraft_________________Station__________________Date____/____/_____

Logbook Page Number_____________________________

Lead Mechanic Or Supervisor ______________________ Emp. #___________

SUNY Airways **Campaign Directive-ABCD1234**

Title: AIR CONDITIONING – Record Serial Numbers of Water Separators to begin Tracking Reliability	Date : 11/21/97 ATA:

FEEDBACK SHEET

Please complete the following information:

Station:____

Date:____

A/C Tail Number:______________________________

Right Hand Side

Part Number:________________________________

Serial Number:_______________________________

Left Hand Side

Part Number:________________________________

Serial Number:______________________________

Upon completion of this Feedback Sheet, please return all paperwork to SUNY FAA Research Group, Buffalo

SUNY Airways **Campaign Directive-ABCD1234**

Title: AIR CONDITIONING – Record Serial Numbers of Water Separators to begin Tracking Reliability	**Date** : 11/21/97 **ATA:**

(Example only. No actual figure included.)

Figure-1: Water Separator

SUNY Airways   Campaign Directive-ABCD1234

Title: AIR CONDITIONING – Record Serial Numbers of Water Separators to begin Tracking Reliability	**Date :** 11/21/97 **ATA:**

Management Data Section:

Prepared by S. Felix/P. King__________________

Checked by J. Oberdick __________________

Approved by M. Rudo_____________________

References:

Allied Signal CMM 21-70-3

MD-80 MM 21-20-02

DC-9 MM 21-20-02

Weight Change: N/A

Estimated Manhours: 1.0

Estimated Downtime: 1.0

Special Instructions:

1. **Planning:**
   a. This CD is to be accomplished no later than 120 days from release to planning.
   b. If feedback sheet is not returned with completed paperwork, this CD must be rescheduled.

1. **Technical Records**:
   a. Begin tracking the tail number, position, manufacturer's part number and serial number of rcn 92131 on the MD-80/DC-9 fleets.
   b. If feedback sheet is not returned with completed paperwork, this CD must be rescheduled.

Priority

US Airways Requirement: YES

FAA Mandatory: NO

No Later Than: ________ **Check** _________ **Flight Hours** ________ **Cycles**

(**See Note to Planning**)________ **Days** _________ **Months** ________ **Years**

CHAPTER 9
THE NTSB MAINTENANCE ACCIDENT REPORT ONLINE ARCHIVE AND CD

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9.1INTRODUCTION

Aviation in general—and commercial aviation in particular—has a stellar safety record. Accidents rarely occur, and the traveling public has come to expect safe, uneventful flights. Unfortunately, accidents *do* occur, however, and maintenance problems are often major contributing factors.

In the hopes of further reducing the number of commercial aviation accidents due to maintenance-related issues, the **FAA**'s Office of Aviation Medicine funded a project to make a large portion of the **NTSB**'s accident report archive more readily accessible by converting it from a paper-based format to an online one. Furthermore, once this online repository was created, the project was to freely distribute it throughout the aviation community.

This report summarizes what the project was to achieve and the products it ultimately delivered.

9.2PROJECT GOALS

This project had (and achieved) the following three key objectives:

1. *Inventory and analyze existing maintenance-related accident reports.*
   We were to gather together whatever hardcopy reports the **NTSB** could supply to us and do a thorough analysis of both the content and the structure of each.

2. *Convert the existing hardcopy accident reports to an* ***SGML****-conforming archive.*
   Using the information we gathered achieving the first objective, we were to convert the hardcopy reports into an online archive that conforms to the standards of SGML. This task included the following sub-tasks:

   a. The development of a *document type definition*, or *DTD*, for the data that was going to be captured and displayed online as well as a set of *conversion specifications* that would govern how the printed documents were going to be interpreted as they were keyed and/or scanned into the online format.

   b. The actual conversion of the **NTSB** accident reports from a paper-based to an **SGML**-based format.

c. Validation and normalization of the **SGML** data after it was created in the conversion process.

3. *Produce and distribute an accident report **CD-ROM**; Produce and deploy a comparable product for the Internet*.
   Once the **SGML** archive had been created and tested, we were to produce a "consumer" version of the data. This meant building a user interface, coupling the report data to a search engine and publishing the resulting product to both **CD-ROM** as well as the Internet.

9.3FACTORS AFFECTING THE COURSE OF THE PROJECT; PROBLEMS THAT HAD TO BE SOLVED

9.3.1 Poor Incoming Data Quality

All of the reports we received from the **NTSB** were in hardcopy; none were available in digital form. Some of the reports were so illegible they were essentially unusable. Also, virtually all of the reports were photocopies, which caused many of the photographs and forms they contained to be unusable as well.

All told, we took in 39 reports in a wide variety of formats and levels of legibility. Once we culled the unusable reports, there were 24 left that ended up in the distributed application.

9.3.2 Incoming Data Complexity and Inconsistency

Another factor that weighed heavily on this project was the overall complexity of the hardcopy data it was to convert to an online format. Nearly all of the reports contained elaborate collections of free-form text, tables, images and forms, and there was a great deal of organizational variability from one report to the next (some were much more consistently put together than others, however).

9.3.3 Online Archive Requirements

Compounding the problems of incoming data complexity and inconsistency was the rigorous structural requirements of the target **SGML**-conforming archive. There were primarily two issues here:

- *Reducing several disparate document structures down to one*.
  How does one get a wildly varying collection of documents to conform to a single, unified organizational scheme?

- *Enabling the special technical features that make electronic documents so much more valuable than paper ones*.
  How does one prepare a document for online use—where users expect features such as hypertext, fielded searches and collapsible outline views—when it was originally created for paper with no

thought whatsoever as to its reuse on a computer?

9.3.4 Scanned Image Size and Resolution Issues

There were over 250 scanned images included in the finished product. When put into graphic files several of these images turned out to be enormous—some were several megabytes each. Such huge file sizes made it impossible to distribute the archive efficiently; there wasn't enough room on a single **CD** for all of them, and in the Internet application it took much too long to download most of them through a typical modem-based connection.

9.4 A WALK-THROUGH THE ONLINE NTSB ACCIDENT REPORT ARCHIVE

9.4.1 Components and Organization of the SGML Archive

The **SGML** archive consists of three major components:

1. *The **NTSB** Accident Report **DTD***
   This is the blueprint for the organizational scheme any conforming SGML document must adhere to. Without going too much into the technical details (which are somewhat arcane), the DTD defines the categories of information these documents must contain and formally describes how these elements can be put together. For example, the DTD contains explicit instructions about how the internal hierarchy of each accident report is to be constructed. It is these specific instructions that made the collapsible outline view within the distribution application possible.

2. *The actual **SGML** document instances of the **NTSB** Accident Reports*
   These are fully structured ("tagged") SGML documents that conform to the NTSB Accident Report **DTD**. There is one SGML file for each of the accident reports that was converted.

3. *A library of systematically named graphic images stored as bitmap files.*
   The recoverable images were scanned into systematically named bitmap files and stored together in a common directory. Whenever an image is to be "placed" into an **SGML** document instance, it is one of these files that is referred to.

9.4.2 The Distribution Application

Even though the lion's share of the work for this project went into producing the **SGML** archive, this is not the product ultimately distributed to its consumers. What was actually distributed—either on the **CD-ROM** or on the Internet—was a specially compiled version of the archive, one that has been augmented with all of the modern conveniences of computer-based documentation.

To do this, the **SGML** data was converted to another format and bundled with a special computer program generically called a *search engine* or a *text base manager*. This other format is called an *infobase*, and the search engine Folio *Views*.

9.4.2.1 Folio Views 4.11; Folio siteDirector 4.12

Folio infobase technology was a compelling choice for this application. Out of the box, the software supports all of the online documentation features expected by most users: hypertext linking, full-text and fielded searching and embedded graphics and tables, as well as a few developer friendly ones. Using the same infobase file that contained all of the **NTSB** accident reports (including all of the images and an integrated full-text index), we were able to put the archive on both a **CD-ROM** (using the Folio browser, *Views*) and on the Internet, where it is accessible through most modern browsers using Folio's Web server product, *siteDirector*.

When the user opens the archive on the **CD**, you are doing so through the interface of Folio *Views*; to most users it seems just like a word processor with some powerful navigation and searching features thrown in (see **Figure 9.1**). When the user opens the archive on the Web, nearly all of this interface is rendered into whatever Web browser the user is using (see **Figures 9.2** and **9.3**).

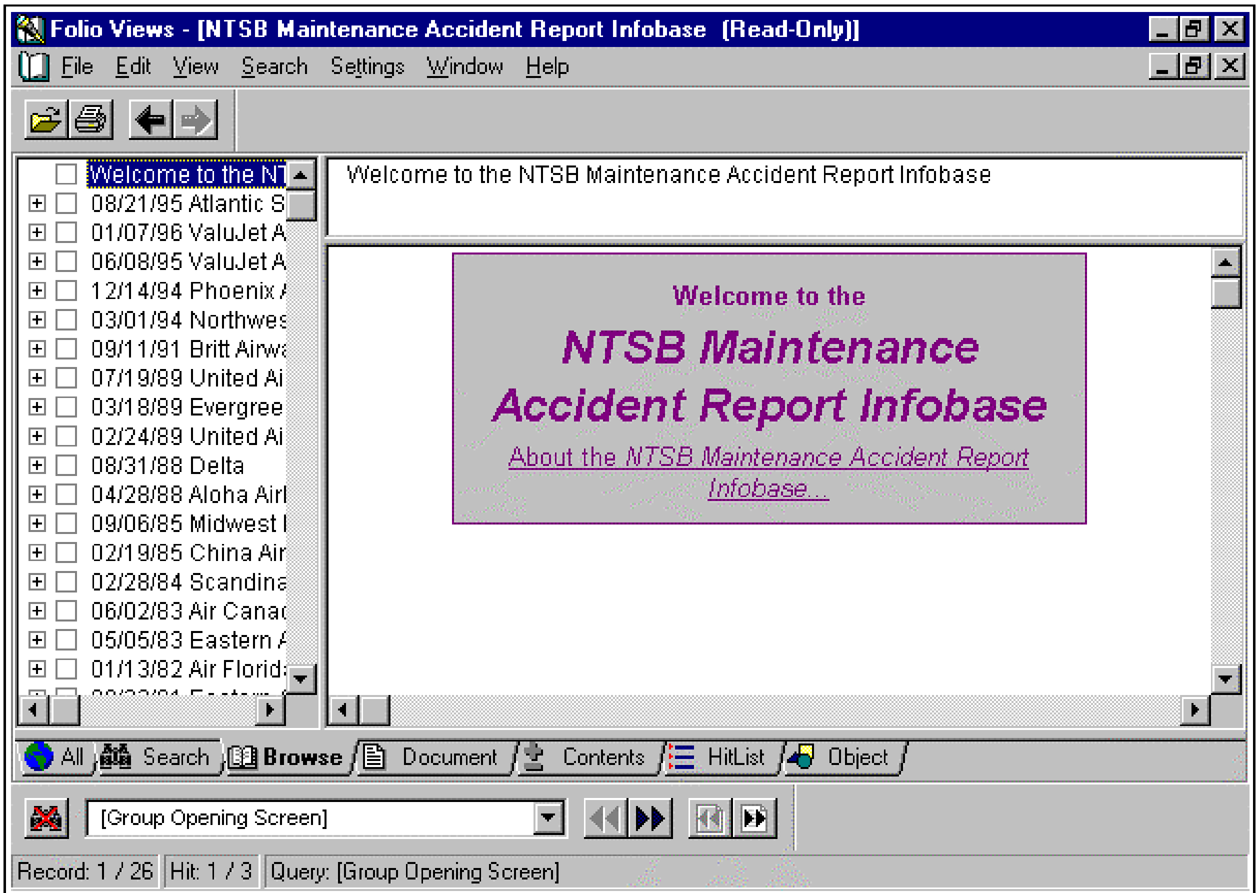

Figure 9.1. NTSB Accident Report CD-ROM Opening Screen

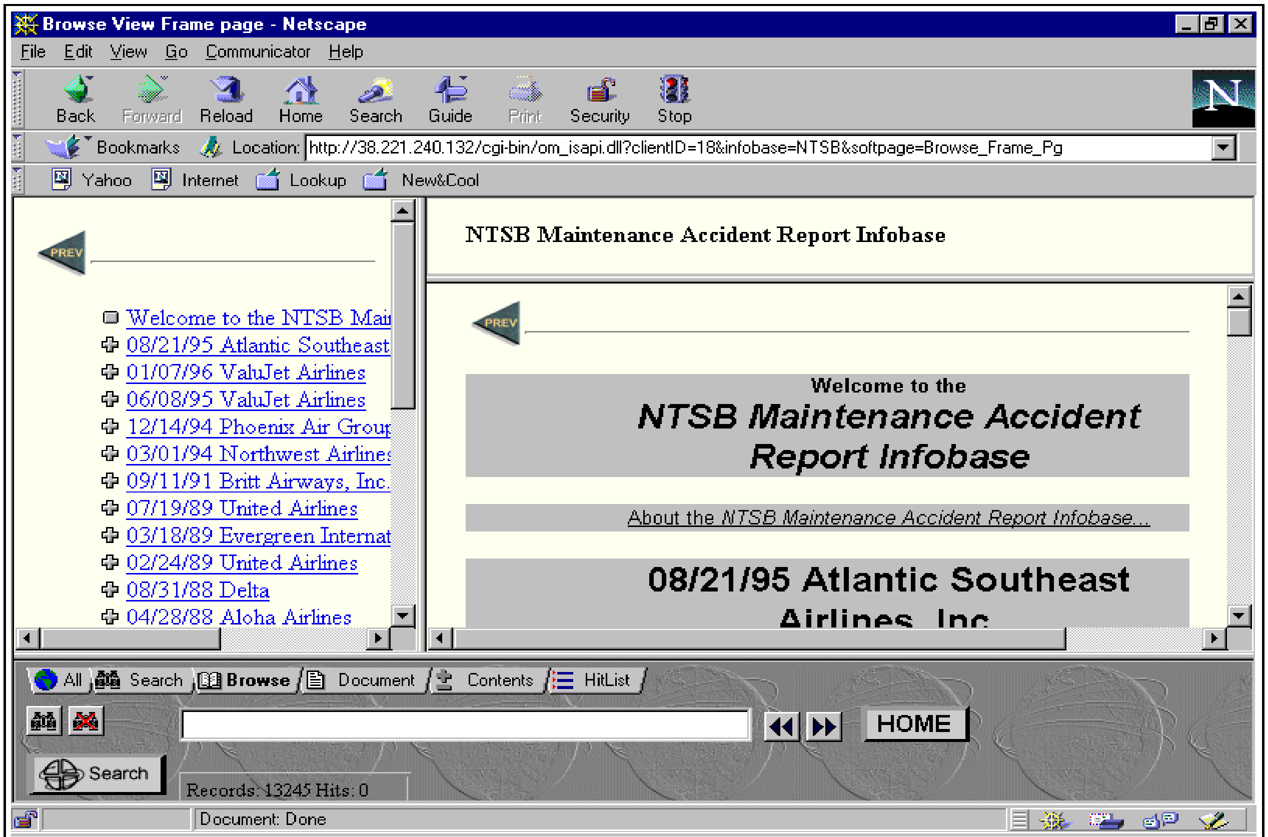

Figure 9.2. NTSB Accident Report Web Opening Screen/Netscape

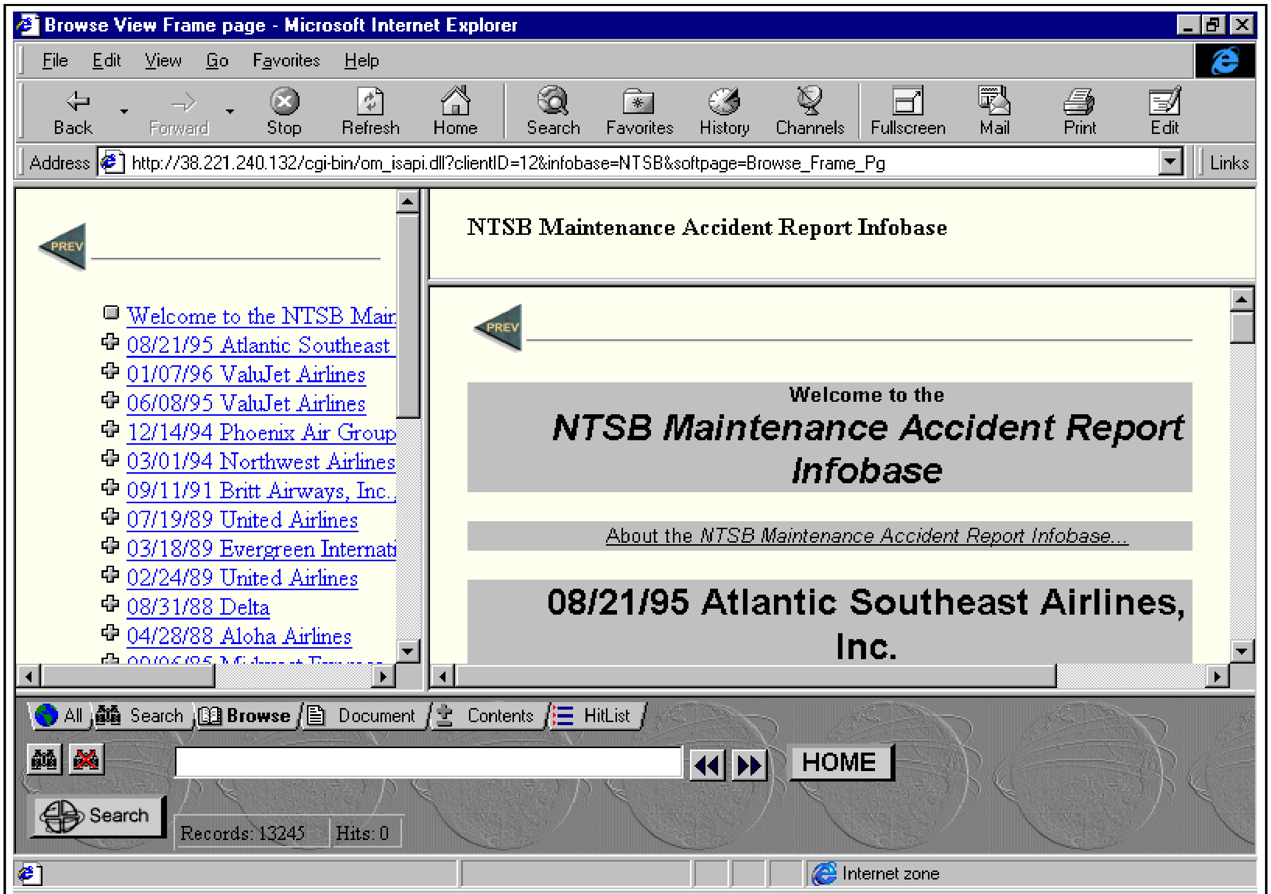

Figure 9.3. NTSB Accident Report Web Opening Screen/Internet Explorer

9.4.2.2 Seeing the Big Picture: Collapsible Outline View

One of the most useful navigational features of the **NTSB** infobase is the *integrated outline view*. On both the **CD** and Web applications this is displayed as a separate window, usually adjacent to the primary document pane (see **Figures 9.4** and **9.5**). Clicking on any of the entries in the outline causes the document to "jump" to that entry's actual location in the infobase.

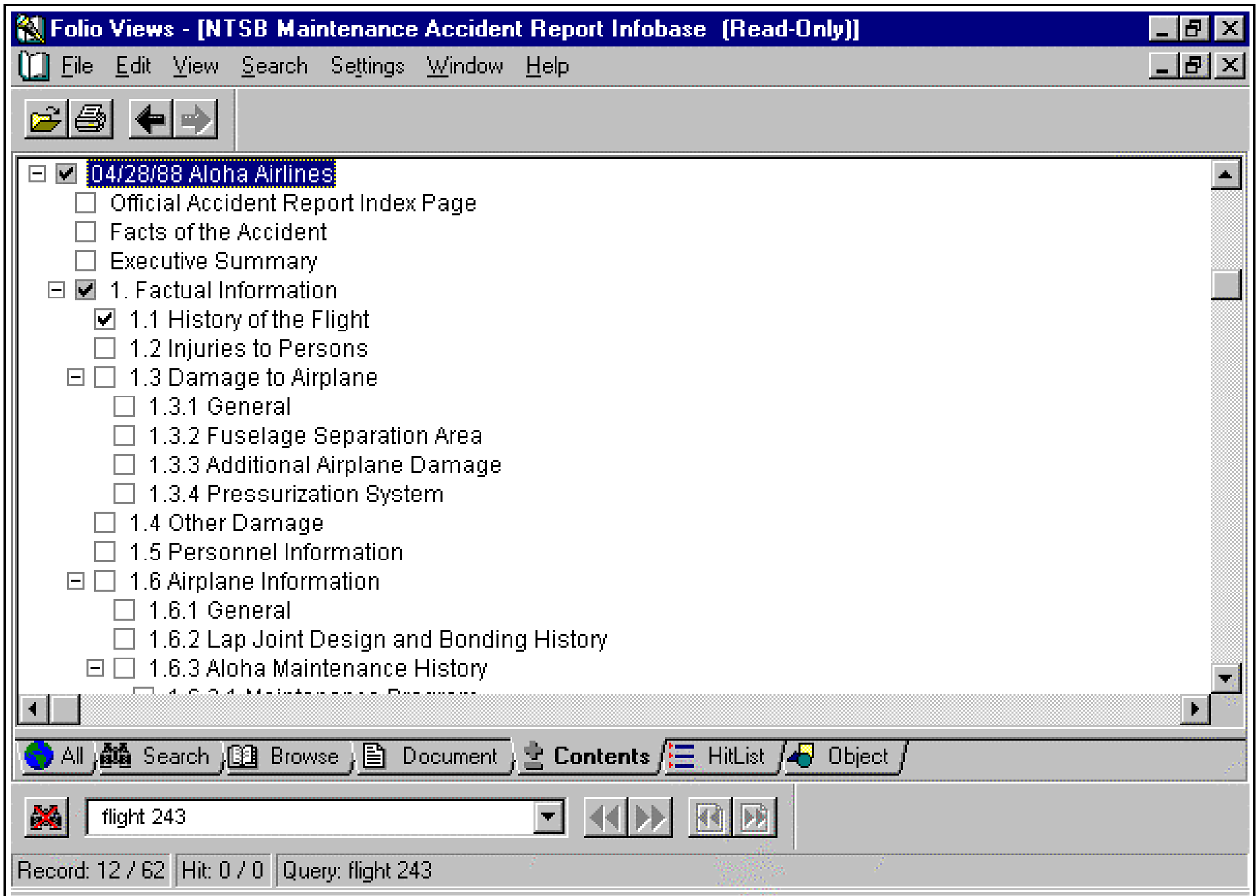

Figure 9.4. NTSB Accident Report CD-ROM Outline View

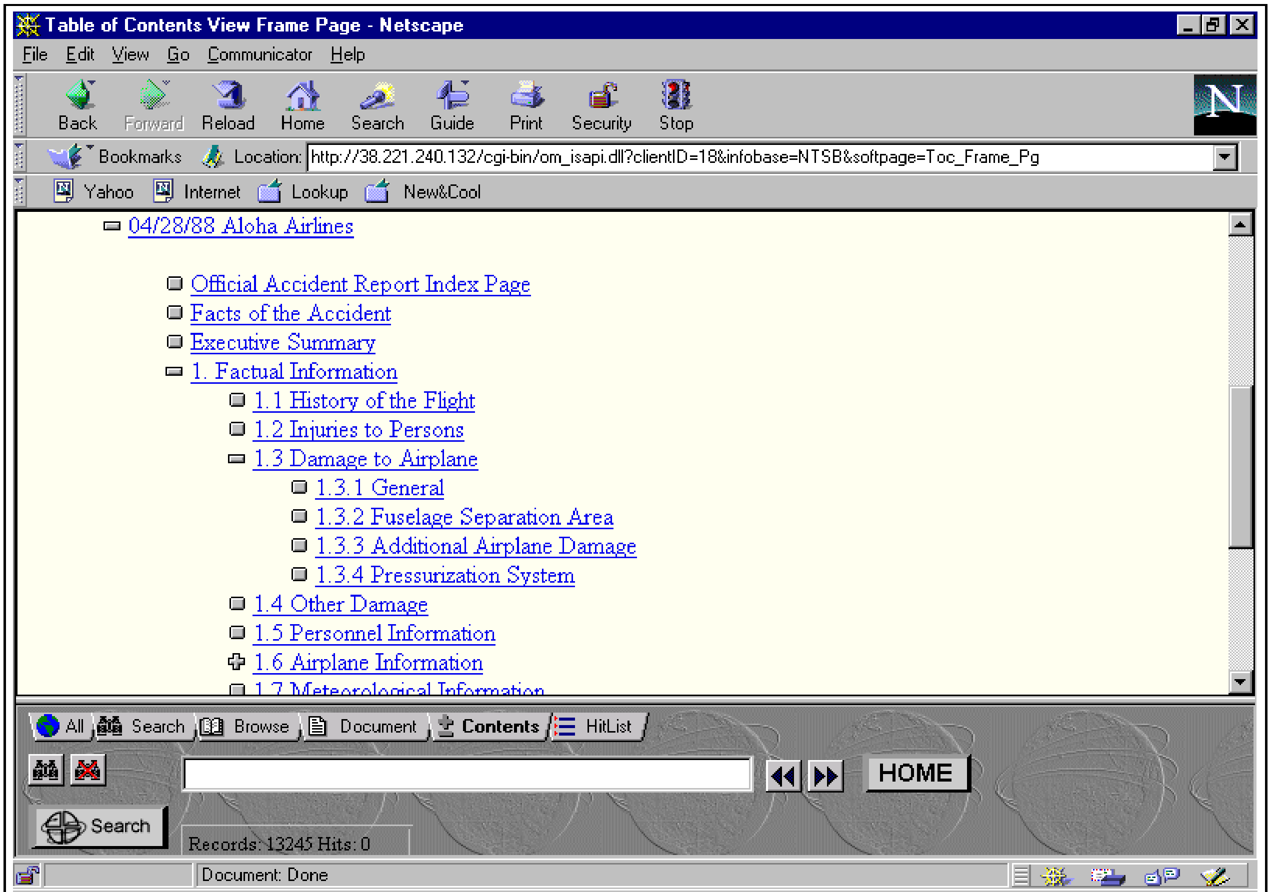

Figure 9.5. NTSB Accident Report Web Outline View/Netscape

9.4.2.3 Hypertext Linking

Scattered throughout the **NTSB** infobase are *hypertext links*, "jumping off" places that connect one point in the system to another. Clicking on one of these causes the focus of the document window to change to whatever point in the infobase the link is connected to. Also, it is just as simple to return to the original location: both applications have prominent *Go Back* functions (see **Figures 9.6a** & **b** and **9.7a** & **b**).

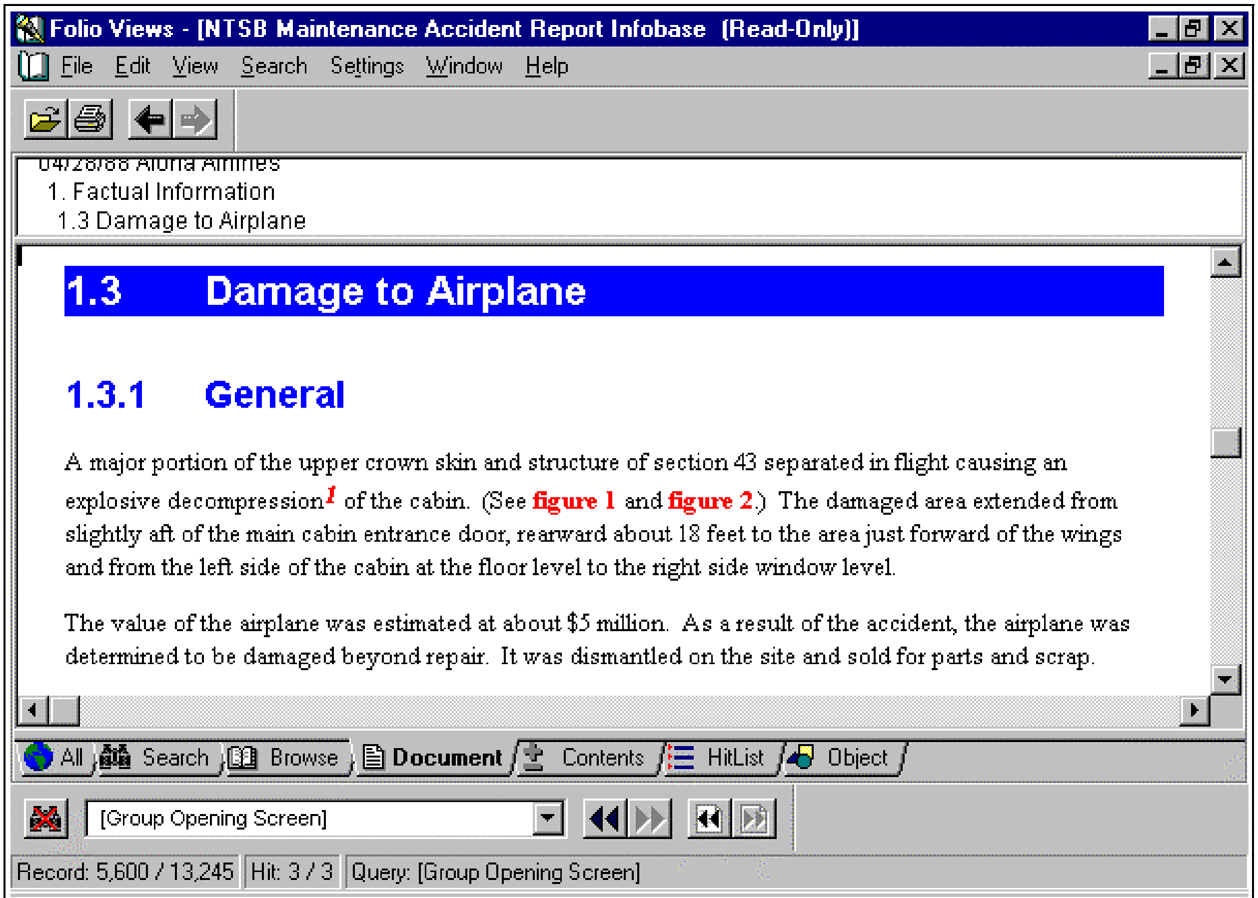

Figure 9.6a. NTSB Accident Report CD-ROM Hypertext Links: Clicking on any text item in red executes a jump link to whatever location the link refers to; for example clicking on "figure 1" cause the system to jump to…

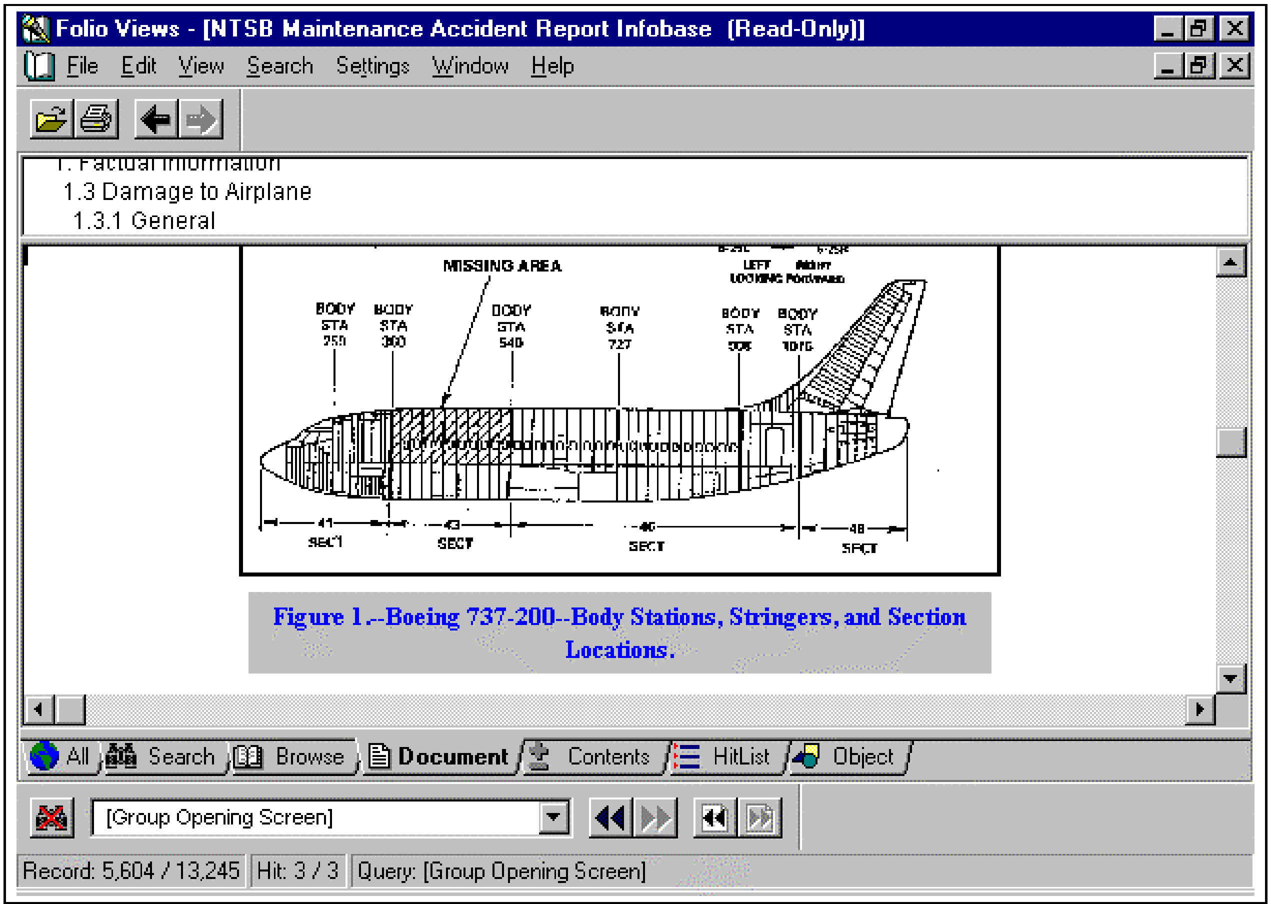

Figure 9.6b. NTSB Accident Report CD-ROM Destination of Hypertext Jump

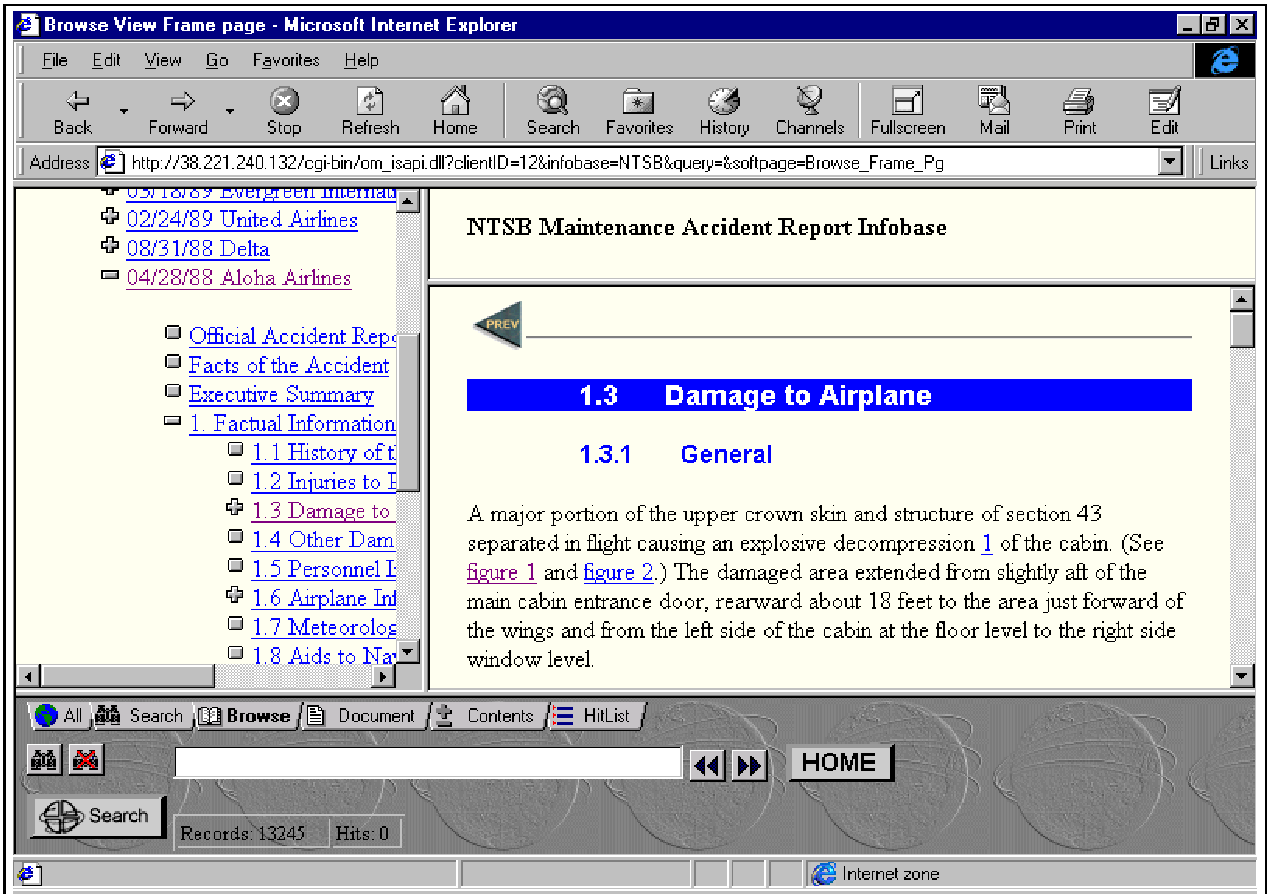

Figure 9.7a. NTSB Accident Report Web Internet Explorer Hypertext Links: Clicking on any text item in blue executes a jump link to whatever location the link refers to; for example clicking on "figure 1" cause the system to jump to…

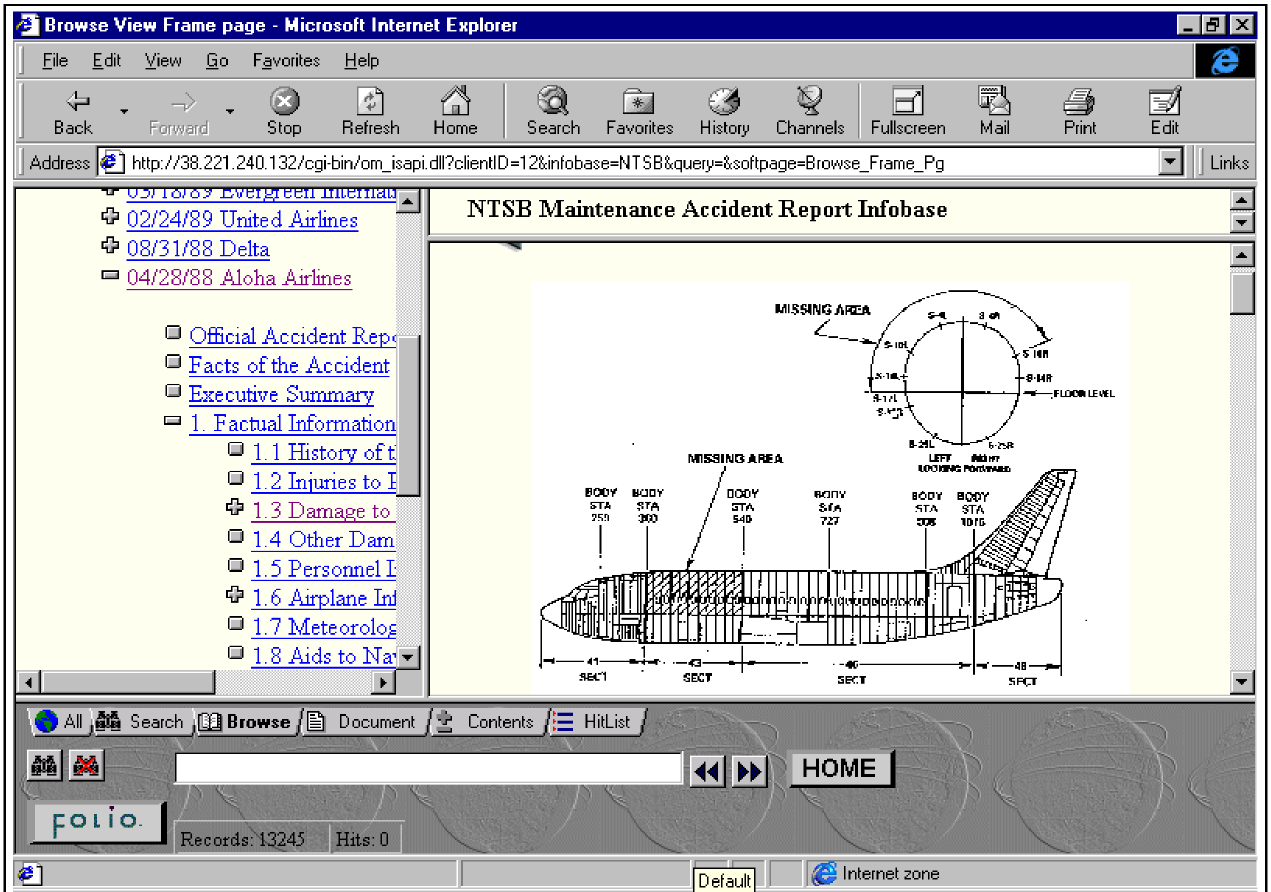

Figure 9.7b. NTSB Accident Report Web Internet Explorer Destination of Hypertext Jump

9.4.2.4 Instantaneous Searching

Searching in an infobase is both fast and straight forward. To conduct a search, the user opens an interactive dialog box and types in the words or phrases she is looking for; the system lets her know as she is typing whether or not there is anything in the file that matches (see **Figure 9.8**). Once she is satisfied her search results are sufficient, she can execute the search, which then takes her instantly to the first occurrence in the file (see **Figure 9.9**).

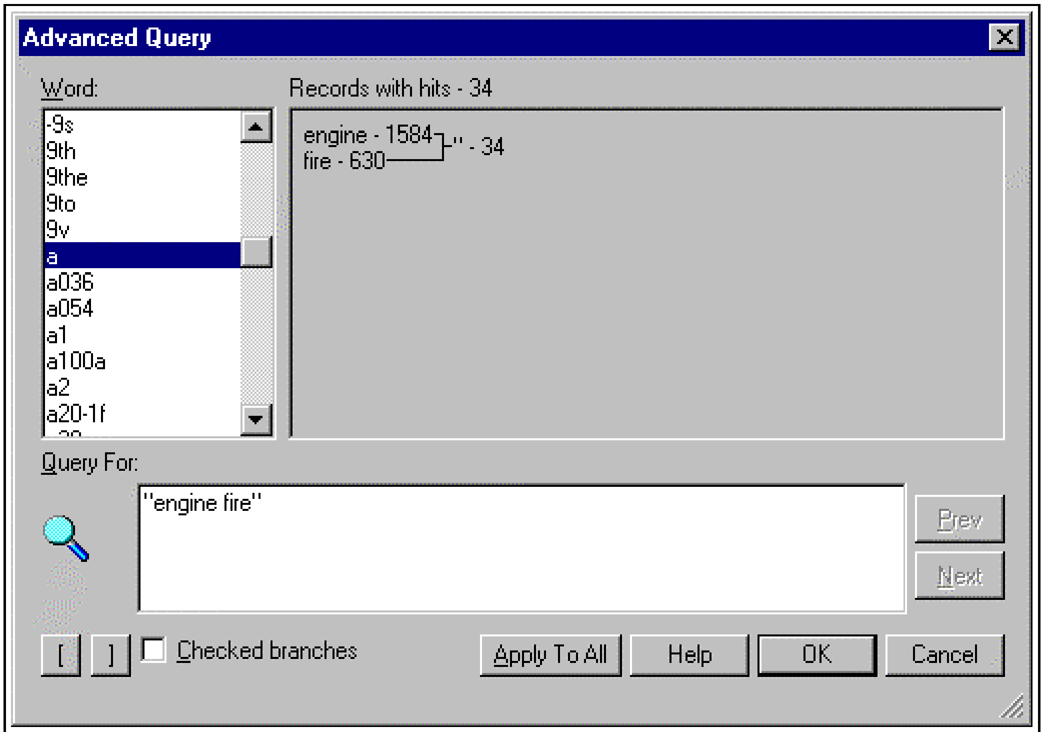

Figure 9.8. NTSB Accident Report CD Query Box

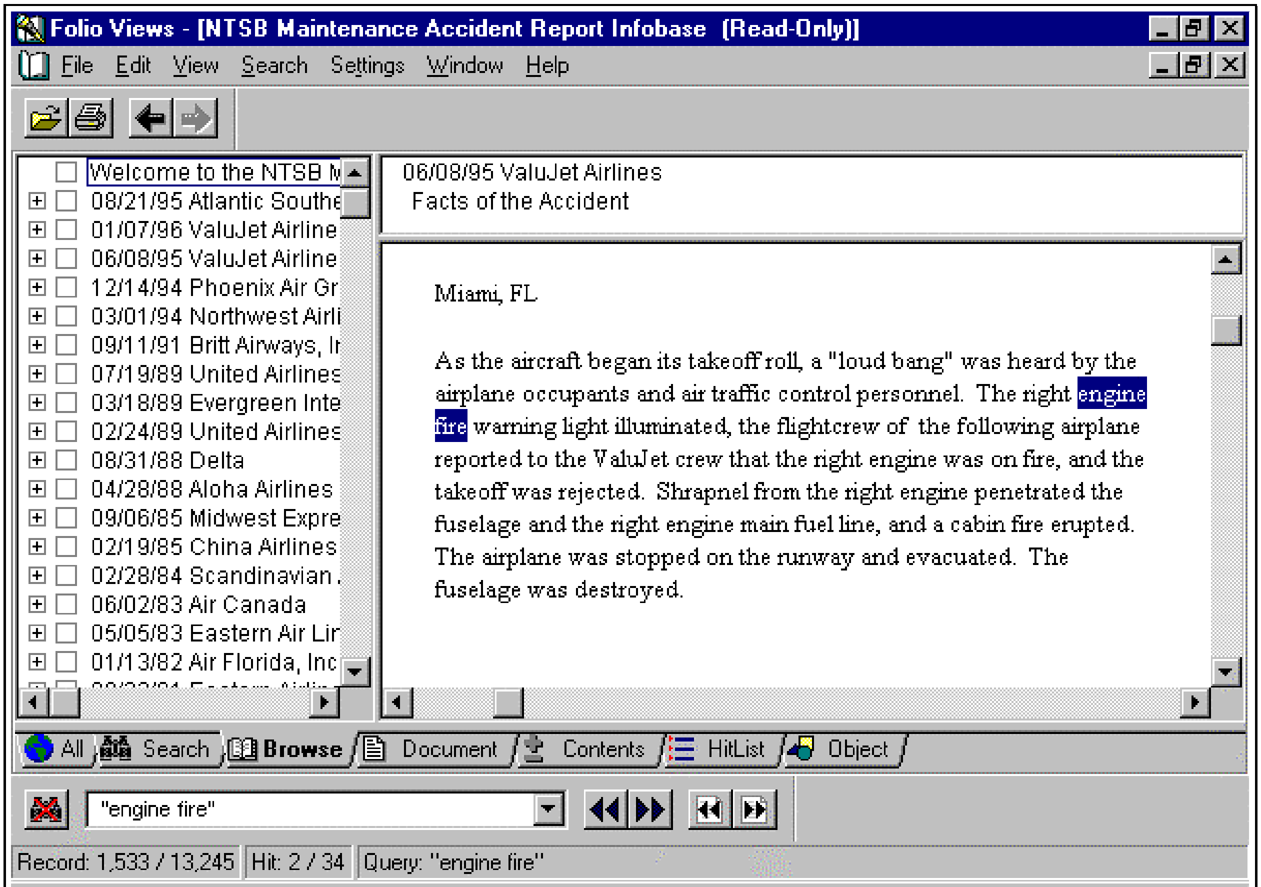

Figure 9.9. NTSB Accident Report CD Result of Search

9.4.2.5 Output: Print, Copy/Paste

Finally, it is possible to *Print* and *Copy* (to the clipboard) any portion of the infobase (see **Figure 9.10**).

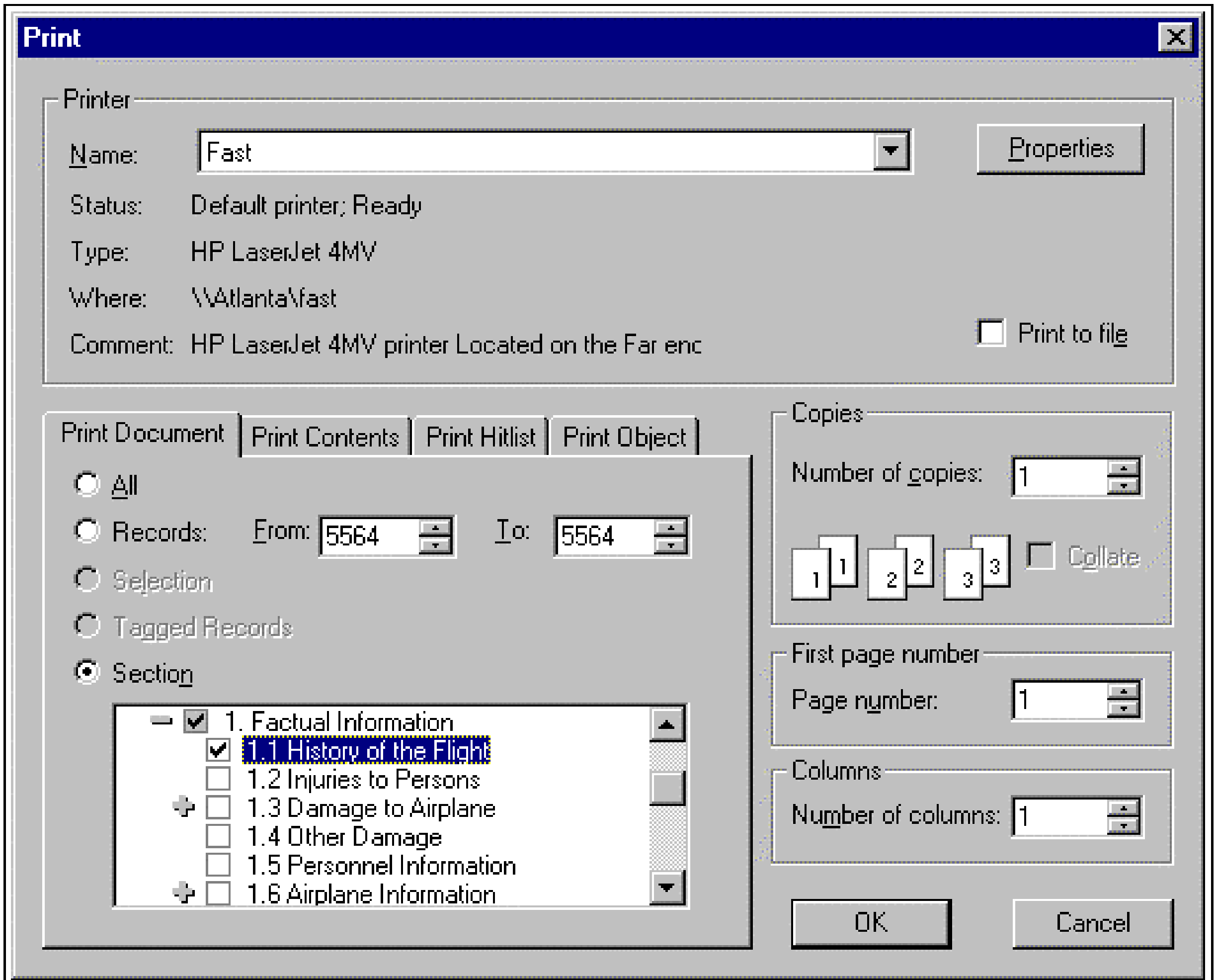

Figure 9.10. NTSB Accident Report CD-ROM Print Dialog Box

9.5 FUTURE CONSIDERATIONS

Our development team suggests improving the **NTSB** Archive in the following areas:

1. *Location, cleanup, and import of some of the "lost" accident reports*
   We can go through each of the reports that didn't make it into the distribution application and salvage whatever data we can from them. At the very least, we can to create "header pages" describing the particulars of each report.

2. *More robust searching dialogs in the distribution application*
   The current archive (even the compiled one within the distribution application) supports a wide variety of fielded data types that can be searched and/or used to narrow a search. For example, it is possible to limit a search to only those reports that involved fatalities in Boeing aircraft powered by

Pratt and Whitney engines.

What is currently not supported is a user friendly instrument to take advantage of the segmentation within the archive. In order for a user to access the fielded search mechanism, she must first understand the internal organization of the compiled archive and be able to navigate the somewhat arcane syntax of the Folio query dialog box.

We can circumvent all of this complexity by building a custom user interface to the underlying structure of the archive that will take the place of the standard (and overly general) Folio Advanced Query dialog box.

3. *Template application for development of future* ***NTSB*** *reports*
   Far and away the single biggest contributor to the cost of this project was the inconsistent quality of the data the archive was built from. One outcome we would like to see in the future is a comprehensive application that governs the creation and maintenance of NTSB accident reports. If built and used correctly, such a program would greatly reduce the time, trouble and expense it takes to publish the reports online.

CHAPTER 10
WIRELESS TECHNOLOGY: DELIVERING TECHNICAL INFORMATION TO LINE MAINTENANCE MECHANICS

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Electronic Data Systems

10.1 INTRODUCTION

As part of a joint effort between the Federal Aviation Administration and Continental Airlines, a study was conducted at George Bush Intercontinental Airport in Houston for the purpose of determining the feasibility of using Portable Data Terminals (PDT) to display aircraft maintenance documents. The PDT devices were connected to a network via spread spectrum (no **FCC** license required) Radio Frequency (RF) transmission.

The study was arranged to use the **PDT**'s in much the same way as they would be used in a production environment. A script was created using actual aircraft maintenance documents such as the General Maintenance Manual (GMM), Illustrated Parts Catalog (IPC), Minimum Equipment List (MEL) and others.

The purpose of the study was two-fold: to evaluate the human factors using specific vendor equipment and to sample response times for additional vendors as a continuation of testing performed in the Summer of 1996. A total of three vendors completed the requirements to participate in the study.

For the human factors evaluation, aircraft line maintenance mechanics performed simulated maintenance tasks while using the **PDT** devices. At the conclusion of the simulated maintenance the aircraft mechanics were surveyed to gather data necessary for the evaluation. This report concludes that based on the human factors issues, it would be feasible to use both **RF** and PDT in a production aircraft maintenance environment.

The objective of the *technical test* was to obtain a sampling of response times that can be expected when these devices are implemented in a line maintenance environment. Based on the results of the technical testing, it was determined that although some vendors response times were better than others, there were no clear cut winners that out-performed the others conclusively. Furthermore with exceptions for certain dead zones, response times were for the most part acceptable for use in a production environment.

10.2 BACKGROUND

Aviation Maintenance Technicians (AMT's) typically access maintenance documents using microfilm or microfiche, and print copies of these documents for use during work tasks. Increasing demand for fast and accurate maintenance information prompted research into alternative methods of passing technical documents to AMT's. Continental Airlines, **EDS**, and Galaxy Scientific Corporation (under **FAA** Contract No. DTFA01-94-C-01013) worked in partnership to explore the feasibility of spread spectrum wireless technology in line maintenance. The study focused on the delivery of technical publications to line maintenance technicians using portable pen-based computers that displayed technical publications. Types of information tested during the study included Maintenance Manuals (MM's), Illustrated Parts Catalogs (IPC's), General Maintenance Manuals (GMM's), Minimum Equipment Lists (MEL's) and Structural Repair Manuals (SRM's). The format of these documents was Adobe™ Portable Document Format (PDF).

The research team defined line maintenance tasks and compiled the relevant technical publications required for each task. The team developed a structured script that enabled mechanics to simulate five troubleshooting scenarios. The team also wrote a technical testing script that enabled the team to record response times for each vendor and network architecture.

10.2.1 Test Environment and Method

Tests were conducted during the night shift at Bush International Airport in Houston, TX. A total of three vendors participated in the testing which started July 29, 1997and ended August 12, 1997. Weather conditions were favorable during every test. Testing began with the outside setup of the hardware at Gate 40 around 9:00pm. A Boeing 737-500 arrived for overnight servicing around 10:00pm, when the simulation took place. The average length of time for a given test was approximately five hours.

The study consisted of two types of testing. The first type, called the *technical test*, evaluated response times and network load for each of the vendors. The technical test included a simultaneous use test, in which multiple computers downloaded technical documents at the same time. The second type, called the *human factors test*, involved a script of five troubleshooting tasks that were designed to require the testing mechanics to utilize all types of technical manuals. The mechanics simulated completion of five open logbook items while using the handheld computers to lookup necessary information in the technical manuals. After completing the script, mechanics rated the usability of the pen computer and digital manuals.

10.2.2 Participants

Participants in the study included the vendors who supplied the wireless **LAN** test equipment, the technical testers who measured performance aspects of the equipment, and the testing mechanics who gave subjective evaluations of the equipment.

Vendors

A total of three vendors participated in the wireless testing. A requirements list was provided to each vendor to standardize the testing environment; however, this list was not strictly followed by any vendor. Requirements included pen computers with Windows 95 or Citrix Winframe™ Client, two wireless access points to an Ethernet-based **LAN**, extra batteries, carrying cases and straps, external keyboards if needed, and technical support during the testing.

All of the vendors provided portable pen computers capable of operating on a wireless spread spectrum **LAN** (frequency-hopping 2.4 GHz band). The server for the LAN was either provided by the vendor or by Continental Airlines, depending on vendor preference. The following paragraphs describe in detail each of the vendors' hardware and network architecture.

- Vendor #1: July 29th, 1997
  - Server: Dell Pentium 133Mhz with 64MB **RAM**, Windows NT 3.51 running sessions of Citrix Winframe.
  - Clients: Wyse Winterm 2930, running Citrix Winframe client from the server. There is no hard drive in these units, only firmware ROM and 4MB RAM which contains the Winframe software and startup operating system. The display was dual-scan color **LCD**.
  - Wireless Architecture: Two Proxim access points with standard gain antennae. Access points were mounted on adjacent jetways (approximately 150 ft from the server) and connected to the hub with twisted pair Ethernet cable.
- Vendor #2: August 5th, 1997
  - Server: Dell Pentium 133Mhz with 32 MB **RAM**, Windows NT 4.0.
  - Clients: Fujitsu Stylistic 1000RF with 24MB **RAM**, Windows 95, transflective **LCD** displays. Used **NetBEUI** protocol with direct drive mapping to server.
  - Wireless Architecture: Two Proxim access points, one with high gain omnidirectional antenna mounted above adjacent jetway, and one with medium gain directional figure-eight antenna mounted on the server platform in front of the aircraft. Connected to hub with twisted pair Ethernet cable.
- Vendor #3: August 12th, 1997
  - Server: Dell Pentium 120Mhz XPi with 32 MB RAM, Windows NT 3.51 running sessions of Citrix Winframe.
  - Clients: Fujitsu-ICL TeamPad 7600 with 16MB RAM, each running Citrix Winframe™ client sessions. Active color LCD display.
  - Wireless Architecture: Two **RDC** access points mounted on adjacent jetways with standard gain antennae, connected to hub with twisted pair Ethernet cable.

Technical Testers

Participating technical testers were members of the research team that helped to facilitate the human factors scripting and then measured performance of the computers. The testing team was made up of representatives of Continental Technical Publications, **EDS** Network Architects, EDS Maintenance Automation Consultants, and the Galaxy Scientific Corporation.

Mechanics

The research team requested that three mechanics be present for each test, preferably the same mechanics each week to minimize variation of individual preference and initial training. However, only two mechanics were present for each test due to unforeseen sickness and scheduling difficulties. All participating mechanics had at least ten years experience as an **AMT** and understood the line maintenance tasks well. One mechanic was present for all three trials. One mechanic was present for the last two trials, and one mechanic was present for only the first trial. Mechanics had a wide variation of skill level with computers. The most proficient mechanic owned an Apple Macintosh computer and was familiar with the Adobe Acrobat Reader and the use of **PDF** files. The least proficient mechanic had never used a computer.

10.3 TECHNICAL TESTING

The Radio Frequency - Portable Data Terminal technical test was conducted to measure response times for hand-held portable computing devices at an airport aircraft maintenance environment. Multiple vendors participated in these tests with each operating under similar circumstances and with comparable equipment.

The testing was conducted over a period of three weeks. Five different vendors were originally scheduled to participate. The three previously mentioned vendors completed their participation. One, however, could not meet the time window for participation, the other had inadvertently routed their equipment to the wrong location.

10.3.1 Test Methodology

This test consisted of loading and navigating the same documents described in the Overview of Study section of this document. In each case the documents were loaded on the server and displayed on the portable data terminals.

A stopwatch was used to determine response times in loading and navigating through the various types of documents. The same tests were repeated in different sections of the aircraft. This was done to produce a test environment consistent with that which would be encountered in real life aircraft maintenance situations.

With the exception of the first test, the tests were performed simultaneously on two Portable Data Terminals loading the same data at the same time in the same section of the aircraft. The first test was performed on a single device while another device was being used to do similar tasks on other sections of the same aircraft. This situation would have likely produced better results in the response time testing.

Results

For vendor #1 and #2, certain areas of the aircraft were out of the range of coverage, causing the portable data terminal lose communications with the access point. The most troublesome area was the aft lavatory. However, vendor #3 had no difficulty with signal loss in any part of the aircraft.

In general, response times were adequate for use during line maintenance tasks. The average response time for a document load was only 1.9 seconds for the fastest vendor, #3. The most significant impact on response time appeared to be **RAM** and not the wireless link. This is an encouraging finding, suggesting that the only barrier to good response time is screen painting speed rather than lack of bandwidth. This means that feasibility of wireless connectivity is very positive. With augmented video RAM capability, response time should average in the sub-second range.

10.4 HUMAN FACTORS EVALUATION

Human factors refers to a set of engineering principles that takes into account the perceptual, physical, and mental constraints of humans as they complete work tasks. A central goal of human factors is to create and evaluate work tools and environments to achieve an optimum "human" fit. With the introduction of new technology, an assessment of the human impact should be undertaken to understand the benefits and costs associated with the technology. Prototype analysis and pilot group user feedback are valuable sources of information about how changes in work design affect productivity and job satisfaction.

The current study attempts to evaluate the usability of a proposed method of delivering technical manuals to **AMT**'s. The human factors evaluation targets a number of subjective aspects of the system, including screen legibility, computer responsiveness, timesaving potential, usefulness for the job, and other characteristics.

10.4.1 Methodology

The objective of the human factors test was to ask mechanics to use the proposed system for an extended period of time and make an assessment about it's usefulness and usability. In order to make certain that each mechanic tested all aspects of the system in a standard way, a structured script was developed. Members of Continental's Maintenance Operations and Technical Publications met to create a set of five troubleshooting tasks that would require technical manual lookups. A stipulation of the scenarios was that the mechanics would need to visit major zones of the aircraft to complete the lookups. Additionally, the mechanics would have to solve simple troubleshooting tasks and record their answers on the scripts so that the researchers could be sure that the mechanics were completing the entire script.

The scriptwriting was assisted by an outside consultant from Galaxy Scientific Corporation to ensure that clear and concise language was used. Hints were also added to the right hand side of the script so that mechanics could refer to them if needed. The script underwent minor revisions after the first trial due to typographical errors. These changes resulted in the deletion of one subtask lookup, and the correction of a reference pointer to reflect the proper digital document. The changes were assumed have no influence on the subjective ratings of the system. The time it took to complete the scenarios remained roughly equal. The final script is located in **Appendix A**.

A brief training program oriented the mechanics to all of the features of the software used to view the technical documents. **PDF** files were viewed using the Adobe Acrobat Reader™ 3.0. The training session was scripted for standardization purposes, and may be found in **Appendix B**. At the conclusion of the training, a walkthrough of the first seven steps of a troubleshooting task was used to gain proficiency with the program. A reference card that details the major functions of the Acrobat Reader was provided to the mechanics during the testing. This card may also be found in **Appendix B**.

The human factors evaluation consisted of two parts, the troubleshooting scenarios and the survey questions. Mechanics were given a script that described four open logbook items, and one routine servicing item. The five tasks involved a **VHF** communications transceiver, a lavatory pump motor assembly, foreign object damage (FOD) in the #1 engine, a leading edge bird strike on the right horizontal stabilizer, and an oxygen cylinder replacement. These five tasks enabled the mechanics to visit all major zones of the aircraft to test the wireless coverage for each area. The mechanics simulated each task according to the script, but did not actually replace or repair any components of the aircraft.

The troubleshooting scenarios were followed by the completion of a two-page survey measuring the following aspects of the pen computers:

- Potential Timesaving: a three-item scale measuring the potential for saving time using digital documents on a mobile computer compared to the current method of accessing technical documents.
- Usefulness to the Job: a four-item scale measuring the degree to which mobile computerized technical manuals would be useful to a line maintenance technician.
- Pen Computers vs. Microfilm: a five-item scale measuring the degree to which the pen computers are preferred to the microfilm readers.
- Legibility: a six-item scale measuring the legibility of both words and graphics, combined with items about the size of the screen and glare from the screen.
- Navigation: a four-item scale measuring the ease with which mechanics were able to access, view, and manipulate technical documents on the pen computers.
- Input: a two-item scale measuring the ease of using the pen as a pointing device.
- Responsiveness: a four-item scale measuring the speed of loading and displaying the technical documents.
- Handling: a three-item scale measuring the ease of carrying and handling the pen computer on the job.
- Durability: a three-item scale measuring the subjective durability of the pen computer.

Survey Scales:

The survey may be found in **Appendix C**. Scales were content validated for consistency and relation to target domain by the research team. All items were answered using a 1-5 Likert scale indicating agreement with statements about the computers. Scales were constructed by averaging items within each of the nine domains. Scales ranged from 1 to 5, with 5 being a positive evaluation. Some items were reverse coded as a check against rater repetition (e.g. when raters simply answer each question with the same value). Inspection of the data revealed no such repetitive trends. Due to the small sample size, accurate reliability estimates of the scales cannot be provided. Descriptive scale characteristics are presented in **Figure 1** below, in Box and Whisker plot format. As can be seen below, mean ratings across vendors for every scale are above the midpoint (3.0) of the scales, suggesting a possible halo effect or leniency bias. However interviews with mechanics after completion of the surveys confirmed this generally positive attitude toward the wireless units. **Figure 10-1** illustrates overall averages across vendors on each scale. The next section presents more detailed graphs that breaks each scale into it's own Box and Whisker plot for a comparative assessment of vendor equipment.

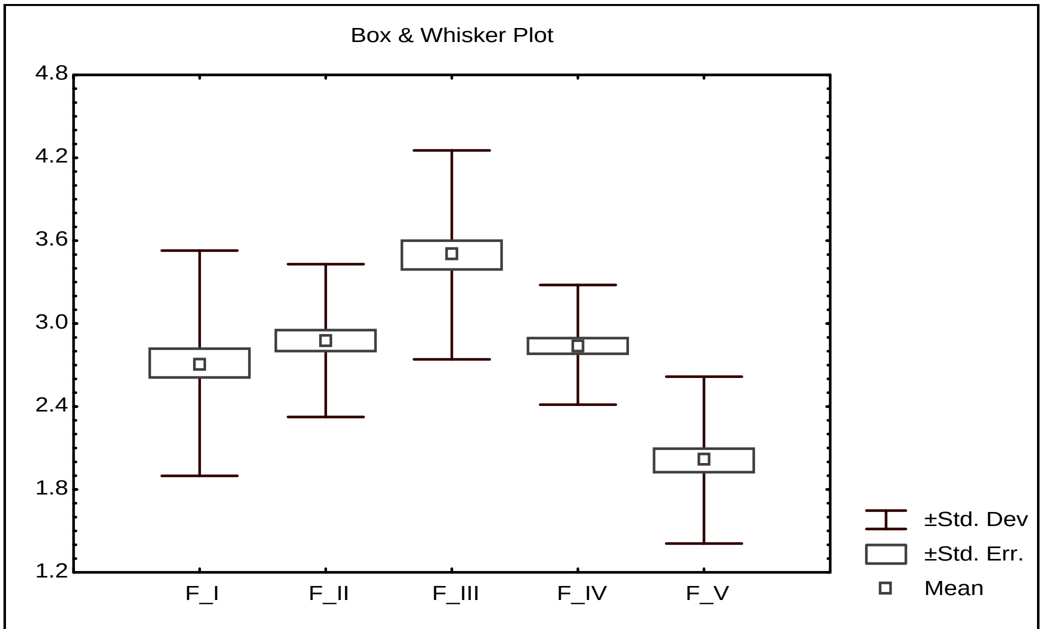

Figure 10-1: Descriptive Statistics for Survey Scales

10.4.2 Results

Box and whisker plots are displayed in **Figures 10-2 through 10-10** below. Results of the surveys are presented as box and whisker plots, which display the mean, standard error of the mean, and standard deviation by each computer vendor. It should be kept in mind when interpreting the results that each box plot contains ratings by two mechanics.

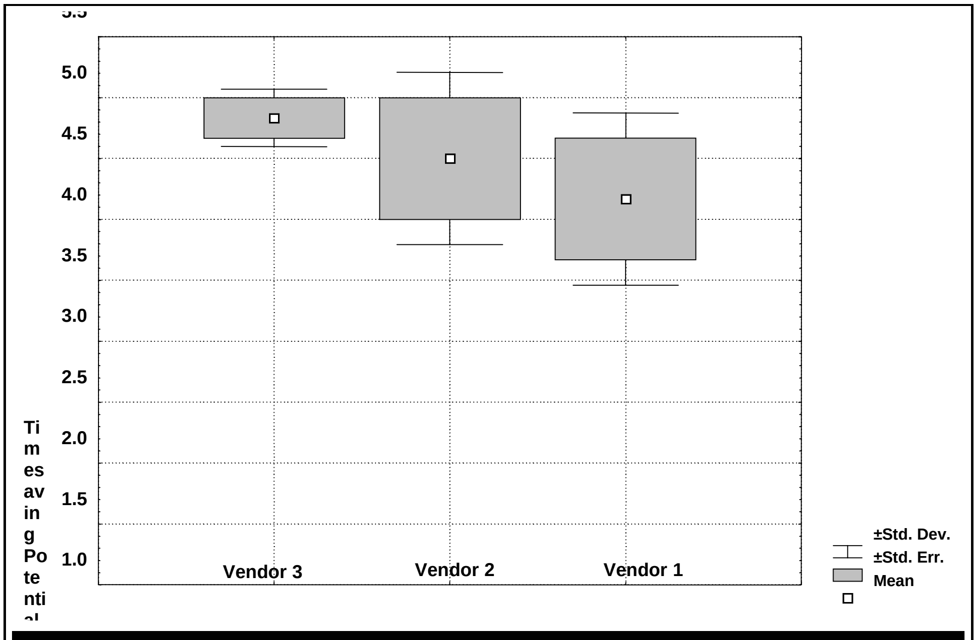

Figure 10-2: Timesaving Potential by Vendor

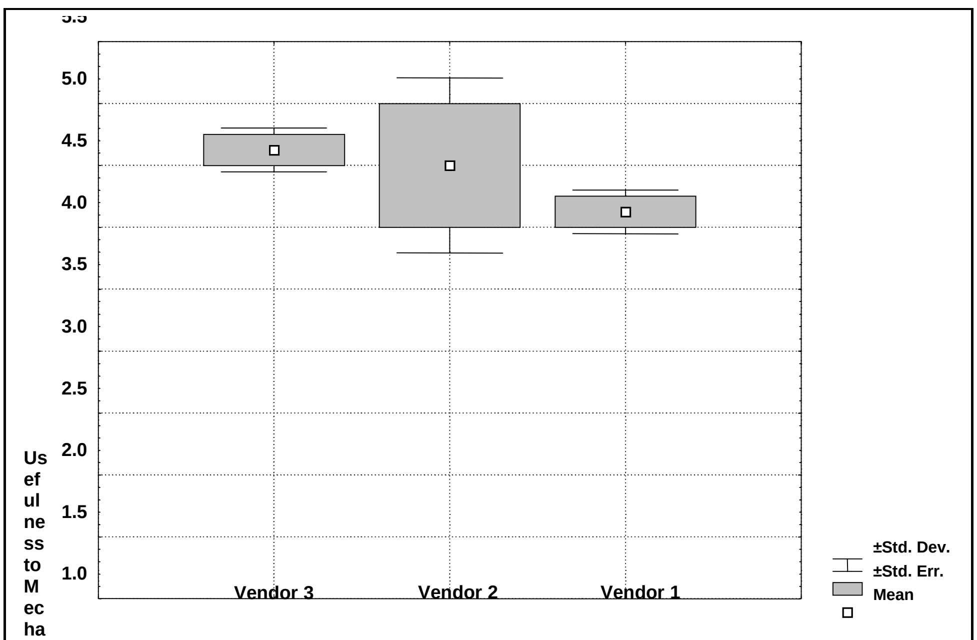

Figure 10-3: Usefulness to Mechanic's Work Tasks by Vendor

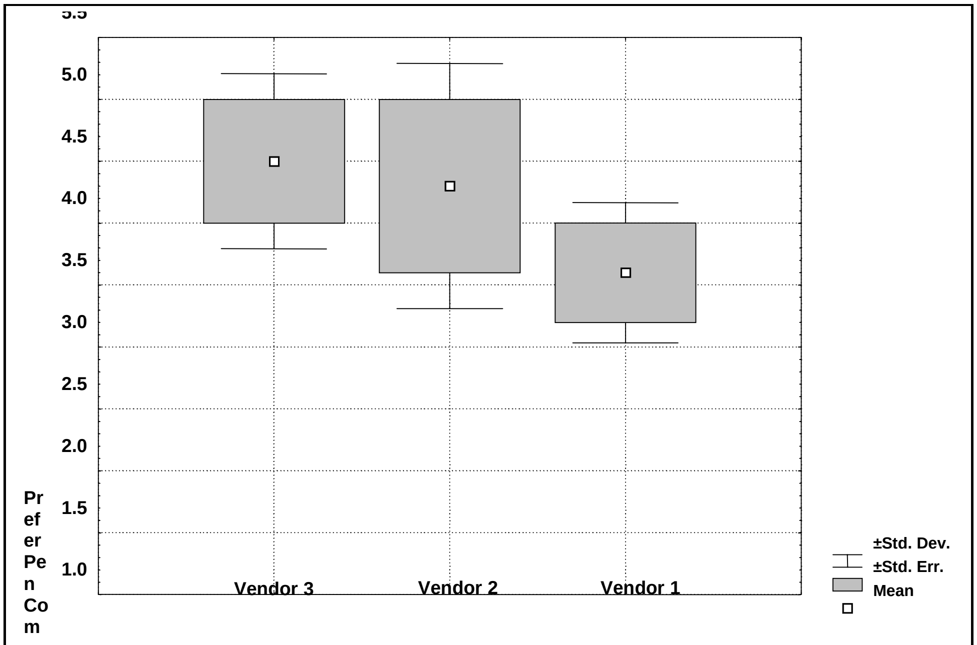

Figure 10-4: Preference of Pen Computers to Microfilm by Vendor

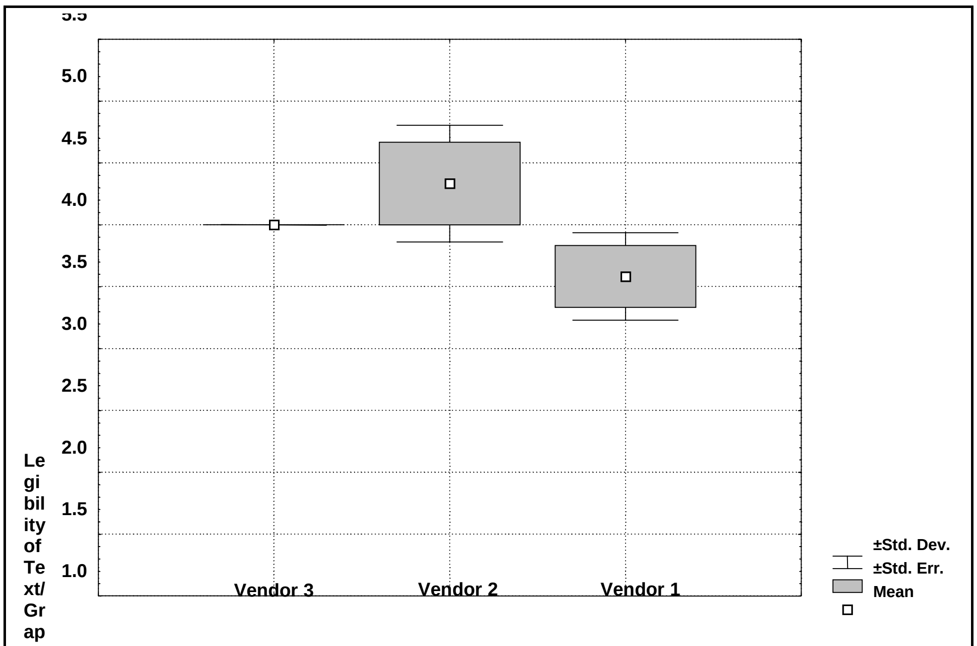

Figure 10-5: Legibility of Text and Graphics by Vendor

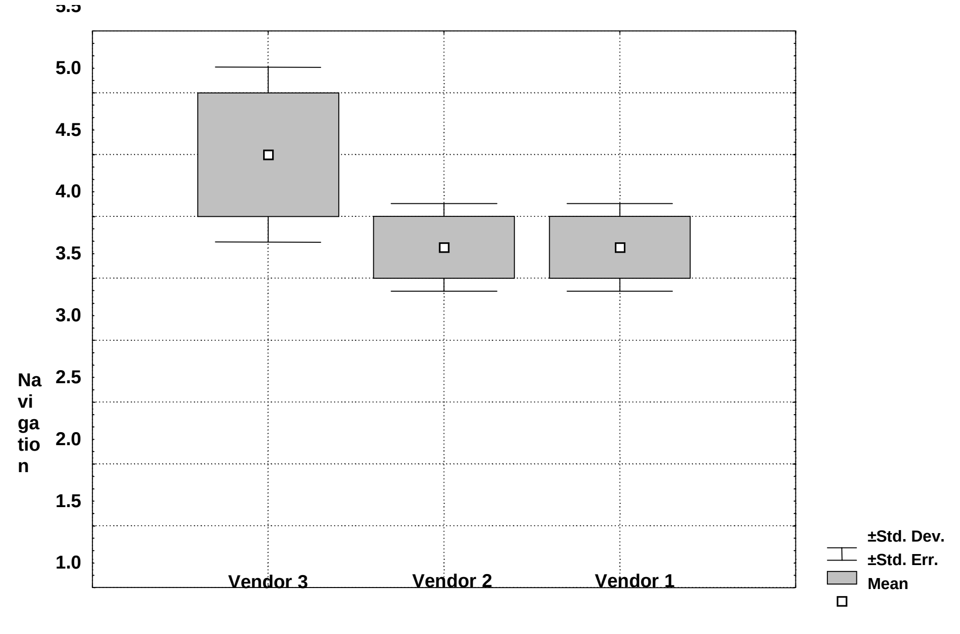

Figure 10-6: Navigational Ease by Vendor

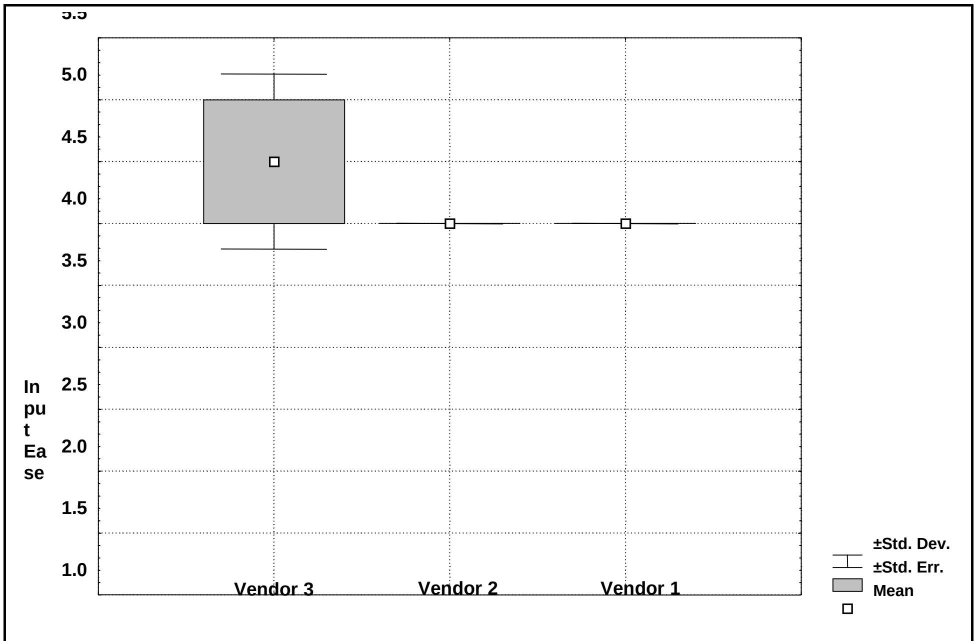

Figure 10-7: Input Ease by Vendor

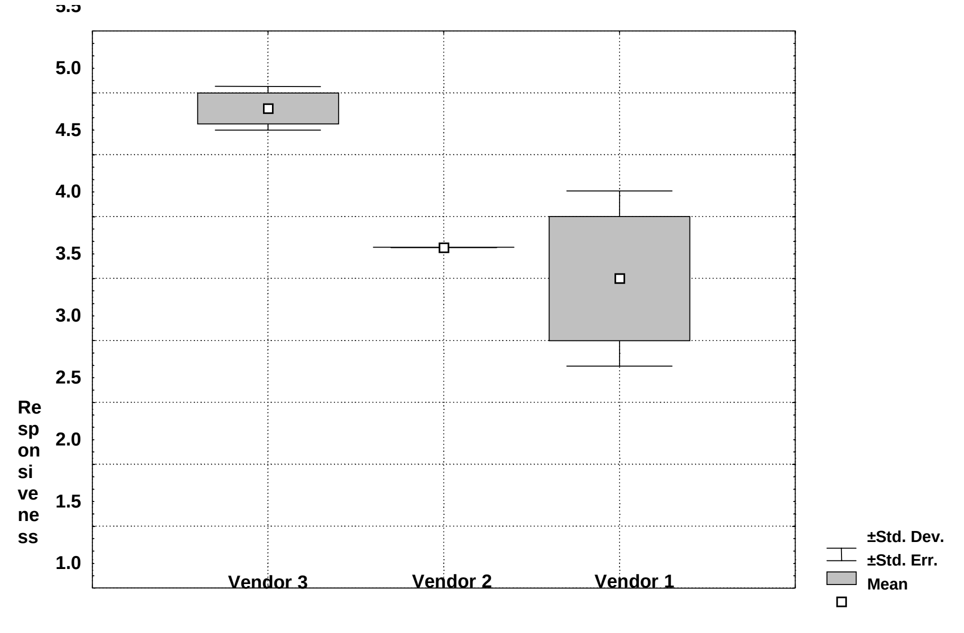

Figure 10-8: Responsiveness of Computers by Vendor

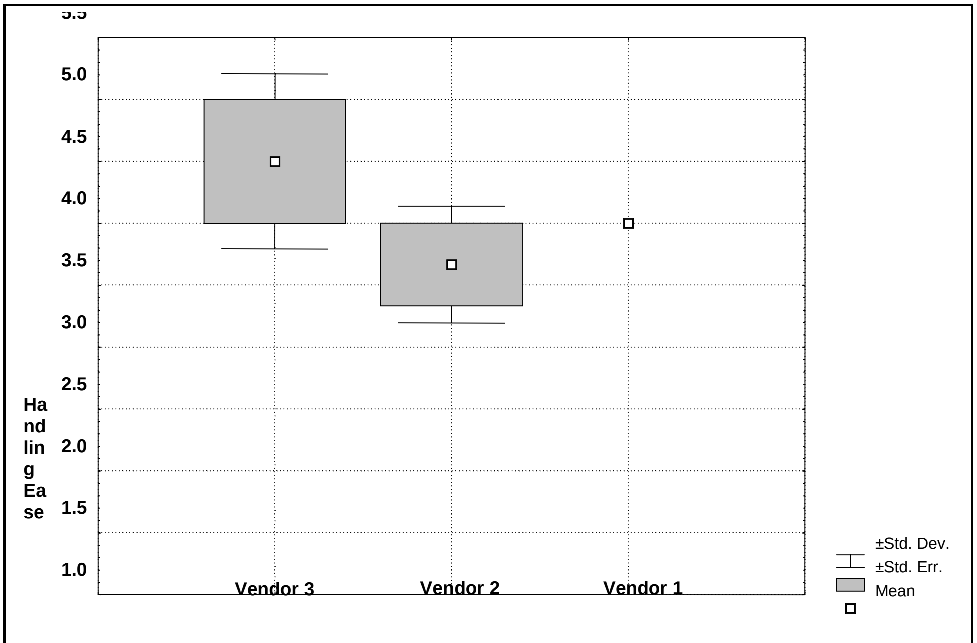

Figure 10-9: Handling Ease by Vendor

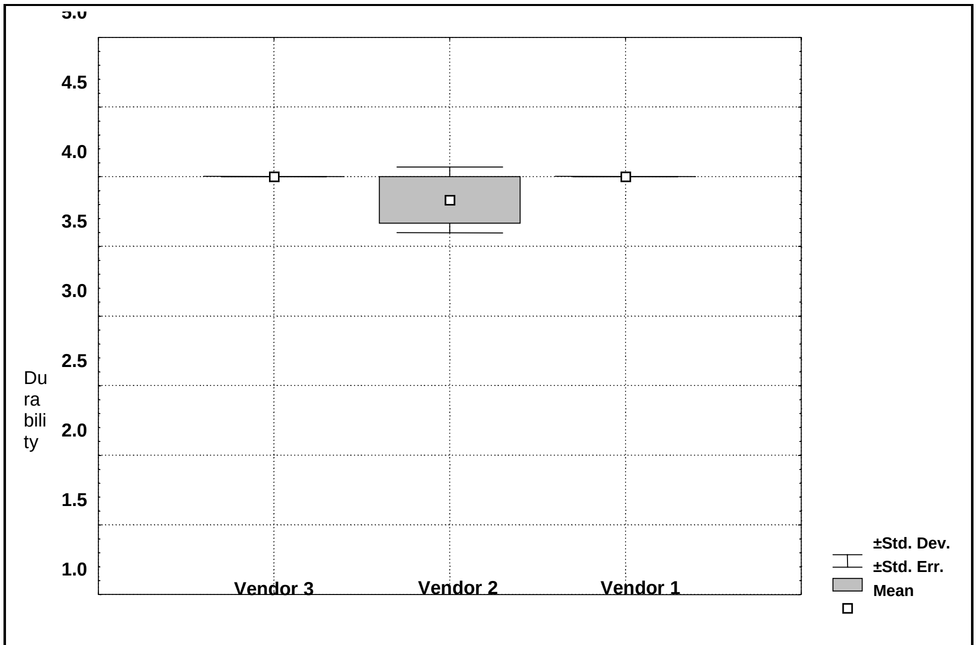

Figure 10-10: Durability by Vendor

10.5 DISCUSSION

Following is a discussion of the specific features and performance of the vendor products. The discussion is based on observations, survey results, and comments from the research team and the mechanics during the tests.

Vendor #1

The WyseTerm 2930 is a thinly designed pen computer with an integrated wireless antenna. The thin profile and lack of a hard drive contribute to its fairly light weight at 3.4 lbs. The unit is surrounded on its edges by a rubber bumper to reduce the shock of impact, although the bumper does not cover all edges. The grip of the unit is comfortable due to a thin and wide lip surrounding the unit.

A benefit of this unit is that it does not maintain any data on the client side; all transactions except for the graphical display commands occur on the server. This means that if a unit is damaged during data entry or data lookup, the session can be completely recovered on any other working unit. Additionally, the WyseTerm is a fairly simple implementation of an **LCD** touch screen display and integrated firmware, meaning that the unit is relatively inexpensive and requires less configuration maintenance than more complex designs. The pointing device is not active, so that any pen or tool (including a finger) can be used as the pointer. The display controls are located as icons on the right side of the unit and are fairly intuitive to use. The display was disappointing in bright fluorescent lighting, where there was a noticeable screen glare. It is assumed that daylight conditions would further decrease screen legibility due to glare. The vendor advised that there are monochrome screen options that are less vulnerable to glare. Battery life for the unit was superior to all other units tested. After 3.5 hours of testing, approximately 75% of battery life was left.

No carrying case or shoulder strap was provided for assessment. According to the representatives cases and straps are available as options.

Response times for these units were adequate but the slowest of all units tested. There was an occasional problem with continued scrolling of documents after the pointer was removed from the screen. Wireless coverage was problematic in the aft lavatories and in the aft cargo area. Slower response times were also encountered at the tail of the aircraft.

Vendor #2

The Fujitsu Stylistic 1000RF was the heaviest of the units evaluated at just under five pounds, but also contained the most components. Carrying cases and straps were provided for the Stylistic units, along with screen covers which protected the units and decreased glare. The handles on the carrying case were comfortable, and the unit was believed to be durable within its casing. This was the only unit containing a hard drive. The pointing device was active electromagnetic field and required a small battery. The mechanics believed that the pen would be easy to lose if it were not tethered to the machine. There was a tethering loop on the pen.

The unit had a transflective **LCD** black and white display with the largest screen size. The display was the most bright and legible of all units tested. It was the favorite display of the mechanics. Battery life was not as great after 3.5 hours of testing as the WyseTerm and was about the same as the TeamPad 7600, at about 42%.

The response time for this unit was much faster than the WyseTerm 2930, and almost as fast as the TeamPad 7600.

There were temporary coverage problems in the aft lavatories, but overall coverage was better than the WyseTerm 2930. It should be noted that Fujitsu-Personal Systems used higher gain antennae, which probably increased the coverage.

Vendor #3

The Fujitsu-ICL TeamPad 7600 was the lightest unit evaluated, at 2.7 pounds. A rubber bumper surrounded it on the edges, and all openings to the unit were sealed with rubber plugs. There were no external switches or controls except for the on/off buttons. The most prominent feature was the passive color touch screen display that covered most of the area of the computer. As with the WyseTerm 2930, any pointing tool could be used with the touch screen. The brightness of the screen was adequate, although it seemed that the screen was smaller than the Stylistic 1000RF and therefore words from technical documents were slightly less readable.

A wide stretchable hand-strap went across the back of the machine so that one could slide an open palm into the back of the unit rather than hold the computer on the sides. No carrying case or shoulder straps were provided. Representatives claimed that the cases and straps would be available soon. Other options demonstrated were an attachable numeric keypad, a docking station, and a barcode reader.

As with the WyseTerm 2930, there was no hard drive in the machine. All of the disk storage was located on a 20MB FlashRAM card, which contained the operating system and the WinFrame Client software for connection to the server. Thus there are similar benefits of data recovery discussed previously. However, the machine is not designed to be a graphics terminal machine, but follows the Intel™ specifications for a 80486 processor and circuit board. This contributes to more complex internal design and more expensive components.

Responsiveness for this unit was the best of all units tested, although probably not significantly better than the Stylistic 1000RF. Loading documents was very fast and scrolling through documents was also good. Though a standard gain **RDC** antenna was used for the testing, coverage was easily the best of any vendor. Connection to the server was reliable even within the aft lavatories, unlike the other trials.

10.6 CONCLUSIONS

The research team explored three major issues concerning the use of wireless technology to deliver accurate technical information to line maintenance technicians. First, we examined the feasibility of a wireless LAN in the line maintenance environment using technical measures. Second, we surveyed mechanics who used the system in order to evaluate its usability. Third, we interviewed mechanics to discover in what cases a similar system would be useful in relation to their work tasks.

The question of feasibility is fairly easy to answer in the affirmative. Network speed for wireless **LAN**s is fast enough to handle fairly large technical graphics, especially when using a graphics terminal architecture. Coverage was adequate even for the worst performing system tested, and could be considered excellent with the best system. Even when dead zones were encountered due to interference or distance, mechanics would simply walk toward an access point until the connection was restored. It is obvious when one encounters these dead zones; the machine is not able to respond to screen commands or load documents. However, in our tests the worst dead zone was inside of the aft lavatory. Mechanics handled this quickly by walking back into the main aisle without prompting. The radio technicians believed this was due to the large amount of steel contained in the lavatory.

The question of usability is more complex because so many factors enter into a rating of usability. Responsiveness, software interface, bulkiness, and screen size all interact to produce this overall concept of usability. However, certain aspects of the system can be improved to greatly increase user acceptance. These ideas originated from comments made by mechanics during the testing and are presented below.

- Responsiveness of the units is a top priority for user acceptance. Mechanics will not be satisfied with a system that requires noticeable “wait time” during screen updates and scrolling procedures. Even if the total amount of time to retrieve a technical document is far less than finding and using a microfilm machine, the user’s perception of time is what matters.

- Accessories, such as carrying cases and straps that are designed to fit well, are important to mechanics. Especially useful is the ability to grip the computer in multiple places to ease hand strain.

- Larger screen sizes with bright screens are preferred. Eyestrain was noticeable during testing with the smaller screens. Color screens were not important for the type of manuals tested, and mechanics could not think of a situation where color would be required. At this time, color screens tend to fade out in sunlight more than black and white screens.

- Although the Acrobat Reader™ was easy to learn and use, **PDF** file formats are not suited well to small screens on mobile computers. Mechanics were forced to zoom in to a document to read the words, rather than being able to read the document at the default screen size. Once a document was zoomed, it was difficult to navigate through the document because the page numbering system on the scroll bar did not reflect the page numbers at the bottom of each page. Also, PDF files are simply images of the paper manuals, so there is no word wrapping. On smaller screens, this is a serious problem because when the words are big enough to read, one cannot view the entire line at once and must resort to horizontal scrolling. Horizontal scrolling has been identified as a frustrating user action in a number of interface design texts. At the current time, the **FAA** has not approved any other digital format. However, it is expected that the **ATA** Spec 2100 will eventually become an aviation standard for **SGML** documents. This format allows word wrapping and word searching, as well as object handlers specific to many types of graphical data. Smaller screens should not be an issue when users are able to view words at a readable size without zooming out to see the words that are "off the screen". This research provides strong evidence for the use of data formats such as SGML that enable the use of various screen sizes.

The question of usefulness in the line maintenance job is particularly important when implementing broad changes in work design. Mechanics were generally positive about most aspects of the mobile computers, and viewed them as a significant improvement to the current method of looking up technical information. Mechanics envisioned themselves carrying the computers when necessary rather than wearing them in a holster or backpack. They believed that a workbench computer that could be undocked easily would the most effective method of use. Mechanics stated that the portable computers would be used most frequently in the following situations:

a) When values change frequently during repair (such as pressure limits during trim runs)

b) During lookups in the Illustrated Parts Catalog (IPC)

c) When accessing wiring diagrams (for zoom capability)

d) To send documents to other work stations (e.g. printing technical manual pages to a remote printer to discuss repairs with another mechanic or supervisor)

e) When there is limited or time-consuming access to paper or microfilm documents (such as the B-check pad)

f) During non-routine repairs and write-ups

g) When manuals could be accessed via modem while on road calls at remote repair stations

h) For use in accessing maintenance workcard and non-routine write-up systems.

Two of the mechanics emphasized that training for the system would need to be a high priority when it is actually implemented. Overall, the mechanics viewed the mobile pen computers as a useful and usable addition to their set of work tools, and looked forward to the implementation of a similar system in the future. Other mechanics not involved with testing who saw the units being used by their coworkers voiced similar positive attitudes toward the technology. The test of wireless technology in the line maintenance environment appears to have been successful. A broad implementation of a similar system would probably be accepted by many mechanics as long as concerns about legibility, training, handling, and data access are addressed.

APPENDIX A

Pen Computer Testing Script

Overview

The purpose of this test is to determine the effectiveness of using a wireless pen to look-up aircraft manuals in an airport environment. Information gathered from this study will be evaluated and applied to future development of the Document Management System.

The pen computer is similar to a normal computer, except that the pointing device is a pen rather than a mouse. Moving the pen across the screen will allow you to move the cursor. Tapping the pen on a button or a link on the screen will allow you to "select" that button.

The pen computer contains sample manual information for the B737-300 type aircraft. On the left side of the screen you will find buttons for the following manuals:

- AMM - Aircraft Maintenance Manual
- IPC - Illustrated Parts Catalog
- SRM - Structural Repair Manual
- MEL - Minimum Equipment List
- GMM - General Maintenance Manual
- Bulletin - M&E Bulletins

To open any manual, tap the button with the tip of the pen.

Practice

Tap/Select
Home
Toolbars
Scroll
Grab
Expand/Collapse
Hiding bookmarks
Full screen view
Zoom

Background
Aircraft 306 just arrived from **EWR**. The pilot called in stating that his **VHF** Com #1 is inop. He also

mentioned three other log book entries that maintenance needs to look into.
You meet the aircraft at the gate. The flight crew has already left, so you review the open log book entries in the cockpit. You find these items:

- VHF Com #1 inop.
- Left Aft lav flush motor inop.
- #1 Engine **FOD**
- Right horizontal stabilizer leading edge bird strike

Planning has also requested that you change the Oxygen Cylinder during the holdover. After looking up deferrable items in the **MEL**, you decide to proceed with repairs.

Log Book Item 1: VHF Com #1 inop	***Hints***
Walk into the cockpit with the pen computer turned on. Using the computer to reference the appropriate manuals, troubleshoot the system with these steps:	
1. Tap the **AMM** button on the computer (with the tip of the pen).	*This will "**select**" and open the AMM.*
a. Select ▷**23 TOC** (Chapter 23 Table of Contents).	*Tap the tip of the pen once to the computer screen for selecting buttons and references.*
b. Locate the reference pages for VHF Com #1 Description and Operation.	*The reference location should be 23-21-00 pg. 1.*
c. Expand ▷**23 TOC** in the bookmark section and select **21-00 Pg. 1**.	*The bookmark section is the left-hand portion of the screen. You "**expand**" a chapter to see what the chapter contains by tapping on the small triangle [▷]. You "**collapse**" a chapter the same way. When a chapter is expanded, the triangle will point downward [▽].*
d. Locate and read paragraph 5, Operation.	*You must "scroll" downward to see this paragraph. Tap the pen on the right side of the screen to move the document. This is the "scroll bar".*
e. Go to Figure 2, Wiring Diagram.	*You must scroll down again to see this figure.*
f. "Zoom" into the lower left corner of the drawing until you can read the words.	*Tap the button that looks like a plus sign inside a magnifying glass [🔍]. Now use the pen and drag it over the section of the picture you want to see. That section will become magnified, or "**zoomed**".*
g. Restore the page to normal size by selecting the "Page Width" [🗎] button.	*The Page Width [🗎]button may be found at the top of the screen. Selecting this will always restore the document to normal size.*
h. Select **21-00 Pg. 101** in the bookmark section.	*The bookmark section is the left-hand portion of the screen.*
i. Go to paragraph 2, Troubleshooting Chart, and view the chart.	
j. Assume that the TRANSCEIVER ASSY-VHF COMM was found faulty, so you must replace the unit.	

2. Select the **Home** [ ] button in the upper part of the computer screen.	*This will always return you to the main reference page.*
3. Select the **IPC** button to lookup the part number:	*You have now opened the IPC.*
a. Select ▷**23 TOC**.	*Chapter 23 Table of Contents.*
b. Locate reference page for TRANSCEIVER ASSY-VHF COMM.	*You should see reference 23-21-21-02 Pgs. 0-4.*
c. Expand ▷**23 TOC** in the bookmark section and select **21-21-02 Pg. 0**.	*Expand by tapping the triangle* [▷] *in the bookmark section. When a chapter is expanded, the triangle will point downward* [▽]**.**
d. Lookup the TRANSCEIVER ASSY-VHF COMM part number (effectivity 301379).	
e. Record part number here: ____________________	*Put the correct part number in the space provided.*
4. Assume that you have replaced the TRANSCEIVER ASSY-VHF COMM. The operational check you perform is OK.	**Congratulations!**
5. Select the **Home** [ ] button in the upper part of the computer screen to prepare for the next task.	*This will always return you to the main reference page.*

Log Book Item 2: Left Aft Lav won't flush	***Hints***
Walk to the aft of cabin to inspect the trouble. Enter the lavatory with the pen computer.	
1. Select the **AMM** button.	*This will open the AMM.*
a. Select ▷**38 TOC** in the bookmark section.	*The bookmark section is the left side of the screen containing chapter numbers.*
b. Locate the Toilet System Trouble Shooting procedures.	*You should see reference 38-32-00 pg. 101.*
c. Expand ▷**38 TOC** in the bookmark section and select **32-00 Pg. 101**.	*Expand by tapping the triangle [▷] in the bookmark section. When a chapter is expanded, the triangle will point downward [▽].*
d. Scroll downward to page 102 and begin reading "*Toilet does not flush. . .*"	*Use the scroll bar on the right hand side of the screen, or Page Down using the [▾] button on the scroll bar.*
e. After reading the chart assume that the lav motor must be replaced.	
2. Select the **Home** [ ] button on the tool bar of the Browser.	*This will always return you to the main reference page.*
3. Select the **IPC** button to lookup the replacement part number.	*This will open the IPC.*
a. Select ▷**38 TOC**.	*This will open the Table of Contents for Chapter 38.*
b. Locate the page reference for MOTOR ASSY-FILTER AND PUMP in the TOC.	*You should see 38-32-21-01 Pg. 0.*
c. Expand ▷**38 TOC** in the bookmark section and select **32-21-01 Pg. 0**.	*Expand by tapping the triangle [▷] in the bookmark section. When a chapter is expanded, the triangle will point downward [▽].*
d. Page down to Figure 1., Page 2.	*Use the scroll bar on the right hand side of the screen, or Page Down using the [▾] button on the scroll bar.*
e. Lookup MOTOR ASSY-FILTER AND PUMP part number (effectivity 301379).	
f. Record the applicable Part No. _________________.	

g. Assume that you attempted to order the part from stores, but the part number is not in stock. You must now review **MEL** requirements for a Lav Motor Inop placard.	
4. Select the **Home** [ ] icon button to get MEL information.	
5. Select **MEL** button.	
a. Expand ▷**38 TOC** in the bookmark section and locate Lavatory Flush Motor Inop MEL Number.	*Expand by tapping the triangle* [▷] *in the bookmark section. When a chapter is expanded, the triangle will point downward* [▽].
b. Select the appropriate **MEL** Number in the bookmark section.	
c. Record MEL No. _________ Page No. ________.	
d. Review MEL requirements for Lav Motors Inop placards. Assume you have read the requirements and placed the placard properly.	*View this section briefly.*
e. Select the **Home** [ ] button to prepare for the next task.	

Log Book Item 3: Foreign Object Damage (FOD) No. 1 Engine	***Hints***
Exit the aircraft and proceed to the front of the No. 1 engine.	
1. Select the **AMM** button.	
a. Select ▷**72 TOC** in the Bookmark section	
b. Page down to the reference for COMPRESSOR SECTION, BLADES - FAN ROTOR, Inspection/Check.	*You should see 72-31-02 Pg. 601.*
c. Expand ▷**72 TOC** in the Bookmark section and select **31-02 Pg. 601.**	*Expand by tapping the triangle [▷] in the bookmark section. When a chapter is expanded, the triangle will point downward [▽].*
d. Follow the inspection procedure in paragraph 2. D. 4). Page down to figure 601 to identify the damage.	*Use the scroll bar on the right hand side of the screen, or Page Down using the [▾] button on the scroll bar.*
e. Assume you found a nicked area of approx. 0.025 depth on the leading edge, Area B.	
f. Follow the inspection task to paragraph 2. D. 4) (d) 1) to review the damage limits.	*Use the scroll bar on the right hand side of the screen, or Page Down using the [▾] button on the scroll bar.*
g. Record the max allowable limit for leading edge Area B: ____________	
2. Select the **Home** [🏠] icon button on the tool bar of the Browser to prepare for the next task.	

Log Book Item 4: Right Horizontal Stabilizer Leading Edge Bird Strike	***Hints***
On a ladder with access to the computer, assume you have just measured the depth and diameter of the dent at station 86.66. The depth was 0.045 inch and was 1.5 inches from adjacent hole material. Complete the following while remaining on the ladder:	
1. Select the **SRM** button.	*This will open the SRM.*
a. Select ▷**55 TOC** in the bookmark section.	
b. Locate <u>Horizontal Stabilizer Skin Allowable Damage</u> in the TOC.	
c. Expand ▷**55 TOC** in the Bookmark section and select **10-01 Pg. 101.**	*Expand by tapping the triangle [▷] in the bookmark section. When a chapter is expanded, the triangle will point downward [▽].*
d. Scroll Down to Page 103 and review illustration.	*Use the scroll bar on the right hand side of the screen, or Page Down using the [▾] button on the scroll bar.*
e. Review Pages 104 and 105 to determine limits.	
f. Is damage allowable? (Circle One) YES NO	
g. What is that max allowable depth without repair? Depth _________	
2. Tap on the **Home** [ ] icon button to prepare for the next task.	

Planned Service Item 5: Oxygen Cylinder Servicing	***Hints***
Planning has informed you that the oxygen cylinder must be changed during the aircraft downtime. With the computer in hand, gain access to the forward cargo compartment.	
1. Select the **GMM** button to review procedures for servicing the oxygen cylinder:	
a. Expand ▷**LEP Chapter 09** in the Bookmark section and select **09-74-72 Oxygen Cylinder Servicing Procedures.**	*Expand by tapping the triangle [▷] in the bookmark section. When a chapter is expanded, the triangle will point downward [▽].*
b. Read paragraph 4, Replace Supply Cylinder.	*Located on pg. 4.*
c. Assuming you have now replaced the Supply Cylinder, Page Down to the Oxygen Temperature/Pressure Table.	*Located on pg. 6.*
d. Assume the Bottle temperature is 95 degrees. Locate the proper pressure for an 1850 PSI type bottle.	*You must read the table to get this value.*
e. Record the proper pressure here: _____________ .	
f. Tap on the **Home** [ ] icon.	*Congratulations. You have completed the simulation.*

Please return the computer and this script to the facilitator. You will be finished after completing a brief questionnaire.

APPENDIX B

OVERVIEW: PEN COMPUTER STUDY

Thank you for participating in the study of wireless computer technology at Continental Airlines. Our objective with these tests is to evaluate:

1. The delivery of timely information to line mechanics over wireless networks
2. The usefulness of the pen computers
3. The durability of the pen computers
4. The ease-of-use of the pen computers.

There are no right/wrong answers to the tests. You will not be graded on your performance. We would simply like to get your honest feedback about using the computers. The more feedback we receive, the better judgments we can make concerning the equipment.

We hope that you will find this experience as trouble-free as possible. In order to facilitate your use of the computers, we have designed a set of practice exercises to get you familiar with the equipment and software.

PRACTICE

Tap/Select

This is the method of choosing objects on the computer screen. Simply tap the tip of the pen on the desired object. When you tap a button, the button will perform a certain action. If you tap a text link (such as the name of a section of a manual) the computer will display that document.

Home

The **Home** [] button (or **Home** bookmark) will always return you to the top-most level of the manuals.

Toolbars

Rows of buttons are called Toolbars. The document viewer has a number of buttons which perform actions such as zooming in and out, fitting a page into the size of the screen, and changing the position of the document.

Scroll / Page Down

In order to move about in a document, it is necessary to use some tools. One tool is the scroll bar, which is always located on the right side of the screen. The plain button shaped object slides up and down the scroll bar when you drag it with the pen. To drag the button, simply touch the pen to the button and move it up or down. You can also move through a document by tapping on the buttons with small black triangles [▼].

Grab

You will notice that sometimes the cursor turns into the shape of a hand. This allows you to grab things and drag them to new places. For example, when your cursor is over the document, it will become a small hand. Touch the pen to the screen and drag it downward. You will notice the page move as if you grabbed it with the hand.

Expand/Collapse

The bookmarks, or chapter/section titles, are outlined to the left of the screen. When you first view the bookmarks, only the major headings will show. Any chapter with sub-sections will have an open triangle next to it [▷]. You "**expand**" a chapter to see what the chapter contains by tapping on the small triangle [▷]. You "**collapse**" a chapter the same way. When a chapter is expanded, the triangle will point downward [▽].

Hiding bookmarks

You may hide the bookmarks section of the screen by selecting the ___ button. This will allow you to view a bigger portion of the document.

Zoom

Tap the button that looks like a plus sign inside a magnifying glass [🔍]. Now use the pen and drag it over the section of the picture you want to see. That section will become magnified, or "zoomed". You can zoom out by using the tool with the minus sign.

Normal view

You can always return to the normal view of the document. The Page Width [📄]button may be found near the top of the screen, third button to the right. Selecting this will always restore the document to normal size.

Multiple Tapping

Sometimes the computer is slow to respond because it needs time to perform an action. You will see an hourglass icon next to the cursor when this happens. This means to wait for the computer to finish what you have asked it to do. Tapping the pen more than once when it is performing an action can cause the computer to malfunction or "freeze up". Be patient and you will get the hang of it.

APPENDIX C

Mechanic's Feedback

Thank you for participating in the study of new maintenance technology. Feedback about your experiences will help determine future tools that might be used by you and your fellow mechanics. Please rate your agreement to the following questions using the rating scale below:

1 = Strongly Disagree	2 = Disagree	3 = Undecided	4 = Agree	5 = Strongly Agree

Time	1. Having all necessary references on the pen computer would save me time.	1 2 3 4 5
	2. The pen computer would take more time to use than the microfilm machine.	1 2 3 4 5
	3. With more practice, I would probably save time using the pen computer.	1 2 3 4 5
Usefulness	4. Using technical documents on the portable computer would help me in my work duties.	1 2 3 4 5
	5. The pen computer with digital documents would *not* assist me in completing my work.	1 2 3 4 5
	6. With some improvement, the pen computer would be a useful tool.	1 2 3 4 5
	7. The pen computer would *not* be of much use to me.	1 2 3 4 5
Pen Computer vs. Microfilm	8. I would rather use the pen computer than print out the documents at the microfilm machine.	1 2 3 4 5
	9. I prefer using paper documents printed from microfilm.	1 2 3 4 5
	10. Having reference information on the portable computer is better than using the microfilm machine.	1 2 3 4 5
	11. I would prefer to use the pen computer to my current method of getting technical information.	1 2 3 4 5
	12. Viewing documents on the pen computer is easier than viewing on the microfilm reader.	1 2 3 4 5
Legibility	13. The words were clear enough for my work tasks.	1 2 3 4 5

14. The graphics/diagrams were clear enough for my work tasks.	1 2 3 4 5
15. I found it easy to read words.	1 2 3 4 5
16. I found it easy to read graphics.	1 2 3 4 5
17. The screen size was large enough.	1 2 3 4 5
18. I did *not* have much trouble with screen glare.	1 2 3 4 5

1 = Strongly Disagree	2 = Disagree	3 = Undecided	4 = Agree	5 = Strongly Agree

Navigation	1. Locating documents on the computer is fairly easy.	1 2 3 4 5
	2. Zooming in and out of the document was *not* difficult.	1 2 3 4 5
	3. I found it difficult to position documents so I could use them.	1 2 3 4 5
	4. I thought it was easy to navigate through the documents.	1 2 3 4 5
Input	5. The pen was easy to use.	1 2 3 4 5
	6. Pointing and clicking was easy to get used to.	1 2 3 4 5
	7. Using the on-screen keyboard was fairly difficult.	1 2 3 4 5
	8. Logging into the system using the pen was simple.	1 2 3 4 5
Response Time	1. The pen computer was too slow to be of use.	1 2 3 4 5
	2. Loading documents took only a short time.	1 2 3 4 5
	3. I spent too much time waiting for the computer to load documents.	1 2 3 4 5
	4. The response time of the pen computer was good.	1 2 3 4 5
Handling	5. Wearing the computer would not hinder my ability to do my work.	1 2 3 4 5
	6. I don’t like carrying around the pen computer.	1 2 3 4 5
	7. The pen computer is too bulky for general use.	1 2 3 4 5
	8. The carrying straps are well designed.	1 2 3 4 5
	9. The carrying case is well designed.	1 2 3 4 5

Durability	10. I think the pen computer would be durable enough for use on the job.	1 2 3 4 5
	11. I would bring the pen computer with me for rough jobs.	1 2 3 4 5
	12. I could wear/carry the pen computer into most work areas without fear of damage.	1 2 3 4 5