Meeting 11: Human Error In Aviation Maintenance

INTRODUCTION

William T. Shepherd, Ph.D.
Federal Aviation Administration
Office of Aviation Medicine

WELCOME

Welcome to the eleventh meeting in our continuing series of *Human Factors in Aviation Maintenance and Inspection* workshops. This meeting shall focus on human error in maintenance. We shall look at ways to detect, report, classify, mitigate, control and reduce human error. We trust that you will find the workshop to be interesting and valuable.

Our **first *Human Factors in Maintenance and Inspection* workshop**, in October 1988, helped to define our research and development agenda, which has evolved now for over eight years. Participants at that first meeting, and at many meetings since, have emphasized the importance of applied research and communication of results to the aviation industry. To ensure that such research is completed and properly communicated, we have worked closely with the industry. The industry is our research partner. Our scientists, engineers, and graduate students have worked with you on day and night shifts, in shops, hangars, flight lines, training centers and board rooms. We have worked closely with the **IAM** and with a variety of airline management at all levels. We believe that our research program epitomizes the quality working relationship between industry and government.

So, what are the obvious results of nearly eight years of cooperative government-industry research and development?

The first result is that meeting attendance has increased by over 500%. There is definitely a growing aviation industry awareness of human factors in maintenance. A recent editorial in a popular aviation maintenance magazine was titled "Human Factors is Hot."

A second result is information dissemination. Our research team has produced over 200 reports, published over 4,000 pages in hard copy and on five CD-ROMs. We have distributed these publications widely. The new '97 CD-ROM #5 being distributed at this meeting.

A third important obvious result is **The *Human Factors Guide for Aviation Maintenance***. The *Guide* has set the standard for maintenance human factors information. The CD-ROM version of the *Guide* provides a variety of multimedia information. It is also on the Internet at http://www.hfskyway.com.

Fourth, and hardly last, we have conceptualized, created, and evaluated numerous advanced technology training and job-aiding systems. The Boeing 767 environmental control system tutor, the System for Training Aviation Regulation (STAR), the Ergonomics Audit software, and the Coordinating Agency for

Supplier Evaluation software are only a few of the other tangible results produced by our team. The Performance Enhancement System (PENS) evolved into the **FAA** On-line Aviation Safety Inspection System (OASIS). That system is being fielded to all FAA inspectors.

The list of airlines, suppliers, manufacturers, schools, and other government agencies that have cooperated with us, since 1988, is impressive. The pride we have in our applied results is shared by many of you. I commit to you that we shall continue to listen to your ideas, involve you in activities, and report to you on the results and lessons learned. This meeting should reinforce that commitment. Thank you for being here.

Sincerely,

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Manager
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DR. WILLIAM T. SHEPHERD

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Dr. Shepherd holds a B.S. and M.S. in Aeronautical Engineering and Ph.D. in Psychology. He is a current pilot with Commercial, Instrument, and Mulitengine ratings.

List Of Abbreviations

ADM	Aeronautical Decision Making

AME	Aircraft Maintenance Engineer
AMI-Task	Aircraft Maintenance Information Cards
AMMS	Aurora Mishap Management System
AMT	Aviation Maintenance Technician
AMTS	Aircraft Maintenance Technology Schools
AMTT	Aircraft Maintenance Team Training
AQP	Advanced Qualification Program (For Flightcrew)
ASI	Aviation Safety Inspectors
ASRS	Aviation Safety Reporting System
ATP	Air Transport Pilot (An FAA-Issued License)
ATSA	Aircraft Technical Support Association
CAS	Continuous Analysis And Surveillance
CFR	Code Of Federal Regulations
CRM	Crew Resource Mangement
DM	Decision Making

DRB	Disciplinary Review Board
E&M	Engineering And Maintenance
ERK	Error Reduction Kit
FAA/AAM	Federal Aviation Administration Office Of Aviation Medicine
FARS	Federal Aviation Regulations
FOD	Foreign Object Damage
GOM	Ground Operations Manual
H.E.A.R.T.	Human Error And Accident Reduction Trend
HF/E	Human Factors And Ergonomics
IAM	International Association Of Machinists And Aerospace Workers
IBT	Instructor Based Training
IFSD	In-Flight Shutdown Data
ISAMP	International Society Of Aviation Maintenance Professionals
LAME	Licensed Aircraft Maintenance Engineer
LOFT	Line-Oriented Flight Training
MEDA	Maintenance Error Decision Aid
MESH	Managing Engineering Safety Health
MRM	Maintenance Resource Management
OJI	On-The-Job Injuries
OJT	On The Job Resource Management Behaviors
PERS	Proactive Error Reduction System
PSFS	Performance Shaping Factors
SA	Situation Awareness, Formerly Situational Awareness

SHEL	Software, Hardware, Environment, Liveware
SHEM	Safety, Health, And Environmental Management
SME	Subject Matter Expert
SOC	Systems Operations Center
SOJT	Structured On-the-Job-Training
SOP	Standard Operating Procedure
STAR	System For Training Of Aviation Regulations
TATS	Task Analytic Training System
TOME	Task, Operator, Machine, Environment
TOQ	Technical Operations Questionnaire
TQM	Total Quality Management
USAF	United States Air Force

List of Figures

Figure 2.1 Comparing the risks to the system of component failure due to (a) neglected maintenance, and (b) errors committed during maintenance. The family of diagonal lines advancing to the lower left-hand corner reflect the increasing reliability of components over time.

Figure 5.1 Maintenance Resource Management (MRM) model.

Figure 8.1 Comparison of Team Skills Perception Pre- and Post Training for Groups 1 and 2

Figure 8.2 Comparison of Team Skills Knowledge Tests Pre- and Post Training for Groups 1 and 2

Figure 8.3 Comparison of Usability Scores for Groups 1 and 2 on Training Delivery Issues

Figure 10.1 A Model for Integrating Human Factors

Figure 11.1 Conceptual Structure of PERS

Figure 11.2 Modules of PERS

Figure 11.3 Example of Hazard Pattern Event Tree

Figure 11.4 GDI Event Description Screen

Figure 11.5 Example of a Causal Tree

Figure 11.6 Solution Search Screen

Figure 12.1 Overview

Figure 12.2 Scenario

Figure 12.3 Informational Media

Figure 12.4 Pre- and Post Test Results

Figure 12.5 Task Flow Charts

Figure 13.1 Varieties of Human Factors Interventions: Technical Operations compared to Flight Operations

Figure 13.2 From Operational Errors to Focused Interventions

Figure 14.1 Station A - An effective facility design

Figure 14.2 Station B - A less effective facility design

List of Tables

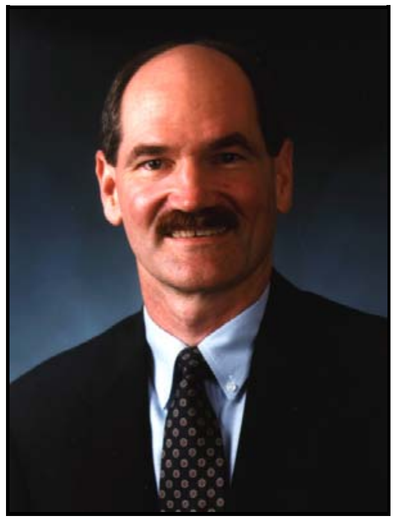
Table 10.1 Responses to Survey Questions from a Sample of Lead Mechanics

Table 10.2 Example of a Human Factors Skills Section from the Delta Ground Operations Manual (GOM)

Table 11.1 Ground Damage Incident Hazard Patterns

1.0 KEY NOTE SPEAKER

MR. GUY S. GARDNER



Mr. Gardner was appointed Associate Administrator for Regulation and Certification of the Federal Aviation Administration October 1996. Previously, he was the director of the **FAA**'s William J. Hughes Technical Center in Atlantic City, NJ. The agency's national test center comprised of experimental technical facilities and laboratories for all FAA research and development programs.

Selected as a pilot astronaut by the National Aeronautics and Space Administration (NASA) in 1980, Gardner served 11 years as an astronaut, working in may areas of Space Shuttle and Space Station development and support. In 1988, he flew his first mission aboard the Orbiter Atlantis. In 1990, Gardner piloted his second space flight aboard the Orbiter Columbia. After leaving NASA in 1991, Gardner served as commandant of the US Air Force test pilot school at Edwards Air Force Base, CA. He retired from the Air Force in 1992, returning to NASA as program director of the joint US and Russian Shuttle-Mir Program at Washington Headquarters. He attended the Defense Systems Management College in 1994, and then became the director of the Quality Assurance Division, Office of Safety and Mission Assurance, at NASA Headquarters.

Gardner earned a B.S. in Astronautics, mathematics, and engineering science from the US Air Force Academy in 1969 and a M.S. in Aeronautics and Astronautics from Purdue University in 1970. He completed US Air Force pilot training and F-4 upgrade training in 1971. In 1972, he flew 177 combat missions in Southeast Asia. From 1973 to 1974, Gardner was an F-4 instructor and operational pilot. He completed test pilot school at Edwards Air Force Base in 1975 and then served as a test pilot there in 1976.

2.0 APPROACHES TO CONTROLLING MAINTENANCE ERROR

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INTRODUCTION

The rapid technological advances in aviation have not only meant the replacement of human control by computers, they have also brought about very substantial improvements in the reliability of equipment and components. This has been achieved by the use of better manufacturing processes and materials, as well as through the widespread availability of sophisticated diagnostic techniques. But the maintenance schedule for a modern aircraft still demands the repeated disassembly, inspection and replacement of millions of removable parts over its long working life. Thirty or even twenty years ago, these inspections would have resulted in the frequent detection and replacement of failed components. Then, the risks of in-flight failure due to intrinsic engineering defects probably outweighed the dangers associated with allowing legions of fallible people access to the vulnerable entrails of the aircraft.

But now the balance has tipped the other way. The greatest hazard facing a modern aircraft-aside from gravity-comes from people, and most particularly from the well-intentioned but often unnecessary physical contact demanded by the current maintenance schedules. Before this claim is dismissed as mere provocation, consider the following data from Boeing.[1] Listed below are the top seven causes of 276 in-flight engine shutdowns.

- Incomplete installation (33%)
- Damaged on installation (14.5%)
- Improper installation (11%)
- Equipment not installed or missing (11%)
- Foreign object damage (6.5%)
- Improper fault isolation, inspection, test (6%)
- Equipment not activated or deactivated (4%)

These data show that various forms of faulty installation were the top four most frequent causal categories, together comprising over 70 per cent of all contributing factors. Comparable findings were obtained by Pratt and Whitney in their 1992 survey of 120 in-flight shutdowns occurring on Boeing 747s in 1991.[2] Here, the top three contributing factors were missing parts, incorrect parts and incorrect installation. In a UK Civil Aviation Authority survey of maintenance deficiencies of all kinds, the most frequent problem was the incorrect installation of components, followed by the fitting of wrong parts, electrical wiring discrepancies and loose objects (tools, etc.) left in the aircraft.[3]

This paper takes as its starting point, the following facts relating to maintenance:

- Of the two main elements of maintenance - the disassembly of components and their subsequent re-assembly-the latter attracts by far the largest number of errors. As discussed elsewhere, re-assembly and installation afford considerably greater opportunity for going wrong, irrespective of who does the task.[4] They are intrinsically error-prone activities.
- Of the various possible error types associated with the re-assembly, installation or restoration of components, omissions-the failure to carry out necessary steps in the task - comprise the largest single error type. In a recent survey, omissions counted for nearly 60 per cent of all recorded maintenance lapses in a major airline.[4] Similar observations have been made in the nuclear power industry.[5]

ERROR MANAGEMENT

Error management has two components: (a) *error reduction* - measures designed to limit the occurrence of errors, and (b) *error containment* - measures aimed at limiting the adverse consequences of those errors that still occur. There is no one best way. Error management tools must be targeted at different levels: the person, the team, the task, the workplace and the organization. In this paper, we will focus on two recently developed error management techniques: ERK (the Error Reduction Kit) aimed at error-prone tasks; and MESH (Managing Engineering Safety Health) designed to identify proactively those factors within both the workplace and the organization that are likely to promote errors and impede their recovery.

ERK (The Error Reduction Kit)

The rationale

From an analytical point of view, there are at least two approaches towards a better understanding of maintenance omissions, one seeking to identify the underlying cognitive mechanisms, the other trying to determine what aspects of a task cause it to be especially omission-prone. The former route is made difficult by the fact that an omission can arise within a number of cognitive processes concerned with planning and executing an action. Even when the omission is one's own, the underlying mechanisms are not easy to establish, but when the omission is made by another person at some time in the past, the underlying reasons may be impossible to discover. The task analysis route, on the other hand, is more promising.

An everyday illustration of omission-prone task steps is provided by the job of duplicating a loose leaf document on a simple photocopying machine. There is strong evidence to show that the most likely omission is to leave the last page of the original under the lid when departing with the copy and the remainder of the original pages.

There are at least four distinct features of the task of photocopying that combine to make leaving the last page of the original behind highly likely.

- The step is functionally isolated from the preceding actions. Before, the step of removing the previously-copied page had been cued by the need to replace it with the next page. In this instance, there is no next page.
- The need to remove the last page of the original occurs after the main goal of the activity has been achieved-obtaining a complete copy of the document-but before the task itself is complete.
- The step occurs near to the end of the task. Natural history studies of absent-minded slips have shown that such 'premature exits' are a common form of omission. These errors can be prompted by preoccupation with the next task. However, in maintenance work organized around an eight or twelve hour shift pattern, there is no guarantee that the individual who starts upon a job will be the one to complete it. And even when the same person performs the whole task, there is always the possibility that he or she may be called away or distracted before the task is finished.
- The last page of the original is concealed under the lid of the photocopier-the out-of-sight out-of-mind phenomenon.

To this list can be added several other features which, if present within a given task step, can combine to increase the probability that the step will be omitted. Other omission-provoking features include the following:

- Steps involving actions or items not required in other very similar tasks.
- Steps involving recently introduced changes to previous practice.
- Steps involving recursions of previous actions, depending upon local conditions.
- Steps involving the installation of multiple items (e.g., fastenings, bushes, washes, spacers, etc.)
- Steps that are conditional upon some former action, condition or state.
- Steps that are not always required in the performance of this particular task.

Maintenance activities are highly proceduralized. It is therefore possible, in principle, to identify in advance those steps most vulnerable to omissions by establishing the number of omission-provoking features that each discrete step possesses. Having identified error-prone steps, remedial actions can then be taken to reduce the likelihood of these steps being left out.

The characteristics of a good reminder

Although there are a variety of cognitive processes that could contribute to an omission, and their precise nature is often hidden from both the actor and the outside observer, the means of limiting their future occurrence can be relatively straightforward and easy to apply, once the error-prone steps have been identified. The simplest counter-measure is an appropriate reminder. What characteristics should a good reminder possess? Some suggestions are listed below.

- A good reminder should be able to attract the actor's attention at the critical time *(conspicuous).*
- A good reminder should be located as close as possible in both time and distance to the to-be-remembered (TBR) task step *(contiguous).*
- A good reminder should provide sufficient information about when and where the TBR step should be carried out *(context).*
- A good reminder should inform the actor about what has to be done *(content).*
- A good reminder should allow the actor to check off the number of discrete actions or items that need to be included in the correct performance of the task *(check).*

The previous five characteristics are universal criteria for a good reminder. They are applicable in virtually all situations. There are, however, a number of secondary criteria that could also apply in many situations

- A good reminder should work effectively for a wide range of **TBR** steps *(comprehensive).*
- A good reminder should (when warranted or possible) block further progress until a necessary prior step has been completed *(compel).*
- A good reminder should help the actor to establish that the necessary steps have been completed. In other words, it should continue to exist and be visible after the time for the performance of the step has passed *(confirm).*
- A good reminder should be readily removable once the time for the action and its checking have passed-one does not, for example, want to send more than one Christmas card to the same person *(conclude).*

It should be noted that the reminders described above are not a permanent solution to the omission problem. They are at best 'first aid' measures to cope with the difficulties experienced in the present generation of aircraft-whose working lives will run for many years into the future. A more lasting solution would be to design components so that they can only be installed in the correct way. Another would be to make the system disable itself automatically when it detect the presence of missing parts. A third and more fundamental solution would be to design a reduction in the need for 'hands on' human contact during maintenance inspections.

ERK elements

ERK allows a non-human factors analyst (e.g., a quality specialist) to identify in advance those steps in a proceduralised maintenance task that are most likely to be omitted. There are features that make certain task steps especially vulnerable to omission, regardless of who is doing the job. ERK guides the analyst in assessing these features for both individual task steps and the work situation. It then describes how to provide effective reminders to reduce the chances of these omission-prone steps being overlooked.

ERK has six components, available on a single plasticised sheet.

- Instructions for use.
- Task Step Check list identifying 20 omission-prone features together with their scores (reflecting their individual importance in predicting omissions). This stage yields a score for each task step.
- Explanations of each of the omission-prone features.
- An Organizational and Situational Factors Checklist. These identify workplace features likely to affect the reliability of the workforce carrying out this task. These features include:-
    - Changes in organization, gradings or tools
    - Environmental factors (humidity, noise, illumination, etc.)
    - Manning levels
    - Shift patterns
    - Availability of parts, etc.
- Criteria for a good reminder
- Score sheet

MESH (Managing Engineering Safety Health)

The rationale

MESH is a PC-based diagnostic tool, created for British Airways Engineering in 1992 by a team from the University of Manchester, for assessing the local and organizational factors that lie at the heart of quality and safety. It is designed to make visible those latent conditions most likely to impair human performance. In effect, MESH provides regular 'check ups' of the system's 'safety health' as it exists within individual workplaces and at the wider organizational level. Its purpose is to identify (for any one assessment period) those 2-3 latent conditions that are most in need of attention and which, if left untreated, will contribute to quality lapses and maintenance errors in the future. By this means, the maintenance system is able to conduct a long-term quality and safety 'fitness' program in a principled and targeted fashion. Any organization has only limited resources. The continued use of MESH shows where these resources should be most effectively deployed and charts the progress of the remedial measures.

Local factors

Exactly what local factors are assessed varies from workplace to workplace. Below are 12 factors that have been used in line maintenance and casualty hangars:

- Knowledge skills and experience
- Morale
- Tools, equipment and parts
- Quality of support
- Fatigue
- Pressure
- Time of day/night
- Environment
- Computers
- Paperwork, manuals and procedures
- Inconvenience
- Personnel safety features

Assessments are made through simple ordinal ratings of the extent to which each one of the local factors had been a problem in relations to a small number of recent jobs (how these are specified depends on the work location - in line maintenance, they could be aircraft; in base maintenance they could be shifts). Ideally, the assessments are made by 20-30 per cent of the 'hands on' workforce in any given location. The assessors are selected at random and continue to make assessments for a limited period on a weekly basis, after which a new set is selected, and so on. **MESH** is a sampling tool: it does not try to measure everyone's opinion about everything.

The computer program automatically updates the average of the assessments made in the past and provides a bar diagram profile of the relative degree to which each of these local factors has constituted a problem in that particular place. The **MESH** program also includes a free text 'comments' facility that allows users to described specific problems. This has proved useful in guiding subsequent remedial actions. All assessments are carried out anonymously. When logging on, a respondent merely indicates his/her location, grade and trade.

Organizational factors

MESH also assesses the impact of common organizational factors on each workplace. Such a list might include the following factors:

- Organizational structure

- People management
- The provision and quality of tools and equipment
- Training and selection
- Commercial and operational pressures
- Planning and scheduling
- Maintenance of buildings and equipment
- Communication

As with local factors, assessments are made on the PC using simple ratings in relation to specific tasks or jobs. Organizational factors are assessed by the local technical management. These are the people on the interface between the organization at large and the particular workplace. Since organizational factors are likely to change more slowly than local factors, the assessments are made more infrequently, say monthly or even quarterly. The organizational factor data are summarized in the form of bar chart profiles, computed automatically by the computer program. The purpose of the profile is to identify the 2-3 organizational factors that are most in need of reform. Subsequent profiles will map the progress of these remedial efforts, as well as identifying fresh candidates for improvement.

A MORE FUNDAMENTAL PROBLEM

The fundamental problem with aircraft maintenance is that it requires people to come into direct contact with aircraft components on frequent occasions. The orthodox engineering approach presumes that maintenance activities are both essential and benign. From an engineering perspective, the optimal level of preventive maintenance is established by summing the costs of both corrective and preventive maintenance, and then identifying the level associated with the lowest overall maintenance cost.[6]

But suppose preventive maintenance did not always prevent failure and that corrective maintenance did not always correct it. Suppose that both of these activities actually had the potential for doing serious harm, rendering previously reliable components inoperable, or simply removing them altogether.

Figure 2.1 looks at the maintenance issue from a broader perspective-one that includes human as well as technical factors. Here are plotted (in a very speculative fashion) the risks to the system posed by (a) neglected maintenance, and (b) by the likelihood of errors being committed during either preventive or corrective maintenance. The latter plot is based on the assumption that the likelihood of error will increase as a direct linear function of the amount of maintenance activity. Since only a relatively small proportion of human actions are erroneous, the human failure risk will never rise above a fairly low value. But, as we shall see below, it is not the absolute value that matters, but the relative proportions of the maintenance neglect and maintenance error risks. It is also assumed that these error risks will not change in any systematic fashion over time. Technology may advance, but human fallibility stays the same.

In sharp contrast, however, the risks due to maintenance neglect are likely to diminish steadily as manufacturing techniques and the intrinsic reliability of materials improve with technological developments. This is indicated in **Figure 2.1** by the family of diagonals advancing towards the lower left-hand corner of the graph. It is clear that if a given level of maintenance-determined by the economic and engineering considerations discussed above-remains relatively constant over time, then a point will soon be reached when the dangers to the system come to be dominated by even a relatively low error rate.

The data reported earlier on the causes of in-flight engine shutdowns show that all of the most common contributing factors are associated with human rather than 'unaided' technical failures. Of course, it could be argued that the advent of non-destructive testing and other advanced diagnostic techniques allow aircraft engineers to identify potential technical failures before they happen in flight, thus leaving human errors as the main residual category of failure. This may well be true, but it does not alter the fact that regular human contact with the 4-6 million removable parts on a modern aircraft poses an unacceptable level of risk.

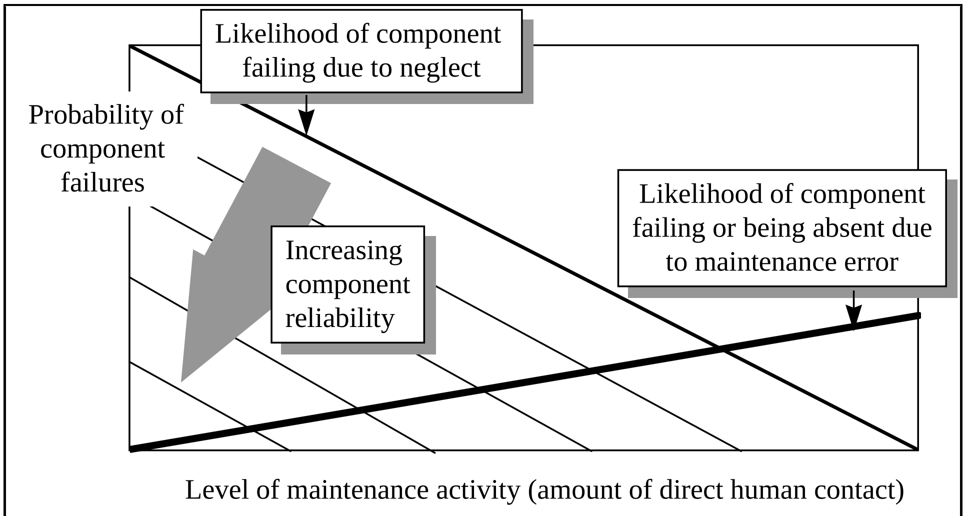

Figure 2.1 Comparing the risks to the system of component failure due to (a) neglected maintenance, and (b) errors committed during maintenance. The family of diagonal lines advancing to the lower left-hand corner reflect the increasing reliability of components over time.

Ironically, one of the pressures that sustains this high level of maintenance contact is the safety-criticality of the system. A catastrophic breakdown is unacceptable in commercial aviation. Everything must be done - and be seen to be done - to preserve the integrity and reliability of aircraft. But, as we have seen, the maintainer's touch can harm as well as heal. The point seems to be: the risks of the former may outweigh the benefits of the latter.

CONCLUSIONS

Aside from gravity itself, the greatest hazard facing modern aircraft comes from people, and most particularly from the well-intentioned but often unnecessary physical contact demanded by outdated maintenance schedules. We urgently need a greater awareness on the part of system designers and manufacturers of the varieties of human fallibility and the error-provoking nature of the maintenance task-especially during installation or re-assembly. Most of all, they must appreciate that maintenance can be a serious danger as well as a necessary defense. Until systems are designed and built with these issues in mind, good maintenance personnel will go on contributing to bad accidents and incidents, as well as to enormous financial losses.

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DR. JAMES REASON

James Reason has been Professor of Psychology at the University of Manchester since 1977, from where he graduated in 1962. He received his Ph.D. from the University of Leicester in 1967. After graduation, he worked at the **RAF** Institute of Aviation Medicine and at the US Naval Aerospace Medical Institute.

For the past 25 years, he has been researching human error and the ways in which people contribute to accidents in complex technological systems.

His books include: *Human Error* (1990), *Beyond Aviation Human Factors* (1995), and *Organizational Accidents,* to be published later this year.

In 1995, he received the Distinguished Foreign Colleague Award from the US Human Factors and Ergonomics Society. He has worked with British Airways Engineering and is currently implementing a Human Factors and Error Management program for Singapore Airlines Engineering Company.

3.0 MAINTENANCE ERROR DECISION AID: PROGRESS REPORT

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INTRODUCTION

Airplane maintenance errors have safety and economic costs. A study by Boeing and the U. S. Air Transport Association members[1] found that maintenance error was one factor, typically among a series of factors, that contributed to 39 of 264 (15 percent) major aircraft accidents from 1982 through 1991. More specifically, in those 39 accidents:

- 23 percent involved an incorrect removal/installation of components
- 28 percent involved a manufacturer or vendor maintenance/inspection error
- 49 percent involved an error due to an airline's maintenance/inspection policy
- 49 percent were design related

In addition, these 39 accidents resulted in 1,429 on-board fatalities.

Data from one engine manufacturer,[2] showed the percentage of specific engine events caused by error and economic costs of those events to the airlines:

- 20 percent to 30 percent of in-flight engine shutdowns are caused by maintenance error and can cost an estimated $500,000 per shutdown.
- 50 percent of flight delays due to engine problems are due to maintenance errors and can cost an estimated $10,000 per hour of delay.
- 50 percent of flight cancellations due to engine problems are caused by maintenance error and can cost an average of $50,000 per cancellation.

But can maintenance error be managed? An analysis at Boeing of in-flight (engine) shut down (**IFSD**) rates due to maintenance error for twenty different air carriers found that the rate differed by a factor of ten between the lowest and highest rates. Clearly, some airlines are able to manage these types of maintenance errors better than other airlines.

Also, error reduction programs are already used in some industries. For example, Lorenzo[3] discusses an error reduction program in the chemical industry based on modifying performance shaping factors (**PSF**s) as defined and discussed by Swain and Guttman.[4] McDonald and White[5,6,7] looked at the PSFs that lead to airport ramp accidents and incidents and developed a ramp safety program based on changes to these PSFs.

MEDA DEVELOPMENT

Based on the above ideas for error prevention and reduction, Boeing, working with three of its customer airlines--British Airways, Continental Airlines, and United Airlines--developed a process for following up maintenance-error-caused events[8,9] in order to determine what contributed to the error so that corrective actions can be taken to eliminate or reduce the probability of future, similar errors. The process is called the Maintenance Error Decision Aid (MEDA). The philosophy of the process is:

- Maintenance technicians do not make errors on purpose.
- Maintenance errors result from a series of contributing factors.
- Many of these contributing factors are part of airline processes and can be managed.
- Some individual errors will not have specific corrective actions.

The first part of the philosophy is tautological, i.e., if a maintenance technician carried out a piece of work incorrectly and on purpose, by definition this was not an error, but purposeful behavior. However, it has been a useful part of the philosophy, because it gets airline management to think about causes of error other than the technician himself/herself.

The second part of the philosophy--that maintenance errors result from a series of contributing factors--is the heart of the **MEDA** process. Called performance shaping factors in the human factors literature,[4] these contributing factors can negatively shape human performance. Also, there are usually several factors that, working together, finally shape the error.

The last parts of the philosophy suggest that while some errors (about 20 percent) will not have corrective actions because the contributing factors are unique and specific to an individual or a unique situation, most errors (about 80 percent) will have corrective actions because the contributing factors are under the control of airline management and therefore can be changed to eliminate or reduce the probability of future, similar errors.

The **MEDA** process was field tested at seven airline maintenance organizations.[9] Based on the field test results, the MEDA Results Form and implementation training were modified to improve the process. Beginning in November 1995, Boeing began to work with its customer airlines to help them implement MEDA.

PROGRESS REPORT

Since November 1995, the authors have trained over 40 airplane maintenance organizations on the **MEDA** philosophy, process, and investigation techniques. These airlines represent a range of size from several airplanes to several hundred airplanes. Most of the organizations are outside of the U. S. Several lessons have been learned during this training that are of importance to this discussion. First, the maintenance organizations that were visited differed greatly across several variables. These variables included:

- Whether a incident investigation process already existed in the maintenance organization.
- Local maintenance organization culture.
- Country aviation authority requirements.

Based on these variables, the authors are aware that not all of the implementation visits have been successful as measured by the changes the maintenance organizations made to their maintenance error investigation processes following the training/implementation visit. Below we will discuss implementation success and then discuss the variables that have influenced that success.

Implementation at Airplane Maintenance Organizations

The authors are collecting detailed information about implementation in the February 1997, time frame by using a survey sent to the Boeing Field Service Representatives at the visited airlines. Information from this survey will be presented at conference.

Existing Maintenance Error Investigation Processes

One variable that greatly affected the ease of **MEDA** implementation was the extent to which a formal maintenance incident investigation process already existed at the maintenance organization. Some organizations that we visited already had a formalized process in place for following up maintenance-error-caused incidents. That is,

1. An investigation would be carried out for pre-specified incidents.
2. A form was used to capture the information learned during the investigation and this form would be assigned a unique investigation number.
3. A person or team of people would be assigned to carry out the investigation.
4. Following the investigation and form completion, the form would be returned to the process owner.
5. Decisions were made about corrective actions based on the investigation results.
6. A process existed for making sure that the corrective actions were carried out.

Organizations that already had such a process in place found it easy to incorporate new ideas from the **MEDA** investigation. However, the continuum on this variable included organizations that had some sort of process that was used for investigations, but the process wasn't formalized. These organizations found it harder to implement a structured process, because they had to formalize what they were doing. However, some maintenance organizations had no process in place. They needed to develop a process for maintenance incident investigations from the ground up.

Organizational Culture

There were several organizational culture issues that affected **MEDA** implementation, but the one that had the greatest affect on ease of implementation was related to past history at the organization regarding punishment or discipline for maintenance errors. Some of the organizations that we visited had a history of disciplining the mechanics for errors. This discipline could take the form of days off without pay, reduced pay for some period of time, or termination of employment. Discipline had either been meted out uniformly (i.e., for most errors) or erratically (i.e., only for certain [costly] errors), and the mechanics often didn't see the relationship between the error and the discipline. Unfortunately, in these organizations, mechanics were reticent to talk about an error. In fact, they typically wouldn't admit to an error. Since the heart of the MEDA investigation process is an interview with the mechanic who made the error, the MEDA process couldn't be implemented at these organizations until a change occurred in their discipline policy.

Aviation Authority

The U. S. Federal Aviation Authority has an adversarial relationship with the airlines. That was an issue that had to be addressed during the Field Test with the U. S. carriers that participated. However, the additional issue that we faced during the **MEDA** training/implementation visits was with civil aviation authorities who had developed automatic fines for some specific errors. For example, in one country that we visited, the aviation authority fined anyone (typically a flight attendant or maintenance mechanic) who inadvertently deployed an emergency escape slide. The fine was sizable and had a very negative affect on the person who was fined (disciplined). This aviation authority discipline had the same type of affect as discussed above under organizational culture--i.e., mechanics who inadvertently deployed a slide would try to hide their error or would not admit their error for fear of the fine. The fine also had a negative affect on flight attendant safety behaviors--i.e., some of the flight attendants in this country were afraid to arm the emergency escape slides during flight for fear that they would forget to disarm the door at the airport and then deploy the slide when they opened the door for passenger off-loading.

Summary

When we first began to work with airplane maintenance organizations with **MEDA**, our visits were mainly aimed at training investigators. As we began to see the range of existing error investigation processes, we saw the need to work more and more with the management to help them understand their responsibilities for successful error investigation process implementation. When we first began MEDA implementation visits, we did not address the negative impacts that past discipline processes at the airlines greatly affected the ease with which MEDA could be implemented at an airline. Thus, we added a "discipline policy" portion to the management presentation and began to carefully determine the extent to which we needed to address the need for a change in the discipline practices before MEDA could be implemented. It is fair to say that we began our implementation visits as "investigator trainers" and had evolved to using our time equally between investigator training and management consulting.

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DR. WILLIAM L. RANKIN

Bill Rankin received his Ph.D. in Experimental Psychology in 1977 from Washington State University. His areas of specialization were human performance and cognitive psychology. Following his degree, he worked for the Battelle Seattle Research Centers for 10 years. The first five years there were spent in the area of opinion measurement as it related to nuclear power and other energy production technologies. His last five years at Battelle were spent carrying out human factors engineering work for the U. S. Nuclear Regulatory Commission, the U. S. Department of Energy, and the Gas Research Institute.

Since coming to Boeing in 1986, among other projects, he worked on the Cockpit Automation Technology program, which dealt with the development of a rapidly reconfigurable fighter cockpit for design testing purposes; managed the development and implementation of the Boeing Employee Opinion Survey; managed the development of the performance management process for hourly workers; developed a training evaluation process for Employee Training and Development; and helped develop a hiring assessment for tooling employees and an assessment for promotion into first-level management. He joined the Human Factors Engineering group at Boeing in 1994 and has worked on maintenance human factors projects including development, testing, and implementation of the Maintenance Error Decision Aid, and improving the Boeing fault isolation manuals used for maintenance troubleshooting.

4.0 QANTAS ENGINEERING & MAINTENANCE HUMAN FACTORS: THE H.E.A.R. PROGRAMME (HUMAN ERROR AND ACCIDENT REDUCTION)

John Fitzpatrick. JP.
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And
Matthew Wright
L.A.M.E. Line Maintenance, Chairman. H.E.A.R.. Program.
QANTAS AIRWAYS LTD.

BACKGROUND

The Qantas E&M Human Factors Program commenced in February 1995 as the result of several ongoing repeat incidents that had occurred over the previous twelve months. A pro-active result of this was the bringing together of seven Aircraft Maintenance Engineers from the aircraft 'frontline' sections to be formed as a Human Factors Steering Group. The 'frontline' areas were defined as: Brisbane (BNE) Domestic Terminal; Sydney (SYD) Domestic Terminal, International Terminal, Heavy Maintenance, Minor Maintenance; Melbourne (MEL) International Terminal, Heavy Maintenance. Group members were from Mechanical (Airframe/Engine) or Avionic (Electrical/Instrument/Radio) Trades and are classified as Aircraft Maintenance Engineer (AME), Licensed Aircraft Maintenance Engineer (LAME), Senior LAME (Senior Licensed Aircraft Maintenance Engineer), or Maintenance Supervisor with an experience level between eight and 30 years.

The group has the guidance and support of a 'Patron' (General Manager Line Maintenance Operations) together with the full backing of the Executive General Manager, Engineering & Maintenance.

The group was to be largely autonomous in nature in terms of direction or scope of projects with minimal Management direction other than to 'find ways and means to help our people do their work better' and to 'find out what prevents our people doing their work.'

To this end the Qantas Engineering and Maintenance Human Factors Group differs greatly from other airlines' Human Factors Groups in that the highest rank of anybody within the group is that of Maintenance Supervisor, and thus the Qantas Human Factors Group is governed by a philosophy of 'by the engineers for the engineers.'

Following various training sessions and an introduction to the principles of Human Factors, the group was left to 'get on with it.' This consisted mainly of reading voluminous amounts of material and various HF meetings proceedings, so that group members could become familiar with the subject.

Within a short time an acronym was chosen to help identify the programme. The acronym chosen was the H.E.A.R. Program, being **H**uman **E**rror and **A**ccident **R**eduction, which, after all is what the basic underlying principles of Human Factors are all about.

The group generally holds meetings of 1 or 2 days duration every 3 - 4 weeks to co-ordinate and plan their work and strategy.

As a foundation stone of Human Factors is to share knowledge, two members of the H.E.A.R. Group undertook a study tour of the British Airways Human Factors Program spending time both at Heathrow and BAMC (Cardiff). H.E.A.R. Group members have also attended various conferences such as the **IATA** 1995 Aircraft Maintenance Seminar and Exhibition held in Sydney, NSW, Australia; the 10th Annual FAA Human Factors Conference held in Alexandria, Va. USA in 1996 and the Australasian Airlines Ground Safety Conference in Sydney, NSW, Australia in 1996.

CURRENT PROJECTS

To continue the 'shop floor' based approach two members of the group developed and now present a Human Factors package to Qantas' apprentices whereby the apprentices are encouraged to express their concerns openly. The importance and the relevance of Human Factors as pertaining to them is explained. Apprentice numbers are approximately 300 in Sydney and 90 in Melbourne.

In November and December of 1995 several of the H.E.A.R. Group members conducted a tour of all Australian bases so that **E&M** frontline staff would receive the same information on Human Factors and the H.E.A.R. Program. By this method of being visible and as well as being peers, it seems that the H.E.A.R. Program is having some success. A similar tour for 1997 is currently being planned, however, the focus this time will be on the Managers and Senior **LAME**s to create a desire for the need of consideration and implementation of Human Factors within their work environment.

To date the H.E.A.R. Group has carried out several projects, not only to establish a 'feel' for Human Factors within Qantas **E&M**, but also to assist the staff. Projects include:

1. **NASA**/University of Texas Management Attitudes Survey (adapted for Qantas **E&M**) so that a 'base line' could be established
2. Representation at the 10th Annual **FAA** Human Factors conference
3. Apprentice Training Package
4. Investigation of Aircraft Cannibalization Methods and a proposed new format
5. Investigation of current **ETOPS** Maintenance Procedures and development and presentation of a reworked package
6. Investigation of current Accident/Incident Investigation procedures and development and presentation of a reworked package;
7. Development of a Heavy Maintenance Shift Handover package - written and oral
8. Identifying areas that prevent 'frontline people' from doing their job and informing those areas of their responsibilities under the auspices of the '**SHEL**' model
9. Development of Staff Induction Programmes (for existing staff when transferring to different areas e.g., MEL International Terminal to Domestic Terminal, etc.)

The members of the **H.E.A.R.** Program realized quite early on that Human Factors is not an exact science or an instant fix; and consequently it would be a big ask to expect an instant embracing of HF principles by all the staff. A long term approach would undoubtedly be the most successful one. Of course there are the doubting Thomases, but the H.E.A.R. Group has been able to 'get some runs on the board early' with several issues and the majority of people can see that we are not a threat; essentially we are asking the engineers to help themselves.

A PLACE FOR MANAGEMENT?

While this philosophy is no doubt most successful, so far as many of the issues the **H.E.A.R.** Group have addressed have in fact been raised by the work force in general. It was also seen that unless Management felt the desire or a need to look at Human Factors issues within their portfolios, the entire program could soon collapse. To this end the H.E.A.R. Group members presented a paper on a modified version of Gordon DuPont's 'Dirty Dozen' to Senior E&M Management. This modified version is known within Qantas E&M as 'The 12 E.R.C'**s** (**E**rror **R**educing **C**onditions)**(Appendix A)**. An accompaniment to this paper was an area self assessment form for each Manager known as 'The **H.E.A.R..T.** (**H**uman **E**rror and **A**ccident **R**eduction **T**rend) Survey' whereby Managers are asked to address the appropriate E.R.C. that scored low on a scale of 1 to 10 **(Appendix B)**. To date this has raised eyebrows amongst our E&M Managers and the response from them has been positive.

MEASURING SUCCESS

The Qantas **E&M** Human Factors Program, although in its early stages, is considered to be a successful initiative to date. By their very nature, engineers, and particularly Australian engineers, are a cynical lot and are quite unforgiving if the promised goods are not delivered. The **H.E.A.R.** Program was received as 'another' process team trying to change the climate of the place. However, in this instance the make-up and self autonomy of the group has been a masterstroke as far as Qantas engineers are concerned. As mentioned previously the H.E.A.R. Program has been able to get some 'runs on the board' viz: Cannibalization Procedures, **ETOPS** Procedures, involvement in accident/incident investigations. This has been successful in giving the group valuable credibility as these initiatives and involvements have been the ideas of the 'people.' The engineers are now also pleased to see that Management is becoming involved at the direction of the H.E.A.R. Program and not the other way around.

CONCLUSION

The concept of Human Factors within Qantas is not a new idea. In fact the Flight Operations Department has had Human Factors as part of the curriculum for Flight Crews in excess of 30 years and for Cabin Crew for approximately five years in the form of **C.R.M**.

Like most other organizations, the idea of Human Factors for **E&M** staff is quite a recent one and although the approach Qantas has taken differs from just about everybody else, we feel it is the best one for them and their people. Australians have a culture of questioning (probably from our convict past) and are always concerned that anything new represents worthwhile change and value. At this time it can be argued that given recent past successes and support the **H.E.A.R.** Program will be given at least equal time to the existing Flight Crew Human Factors Program.

Perhaps it is our motto which best describes our approach: 'If you're not part of the solution, then you're part of the problem' which not only emphasizes the importance of peoples actions, but also their inactions.

APPENDICIES

Appendix A

H.E.A.R. PROGRAMME.

IMPROVING SAFETY HEALTH IN E&M.

In 1995 Qantas formed H.E.A.R. (Human Error and Accident Reduction). Made up of a group of engineers coming from departments that represent the last barrier of defense against the 'human factor', their task was to eliminate the results of human failure - accidents and incidents.

E&Ms response to incidents and accidents is exemplary. Great effort goes into 'getting it right' so as the same mistake is never made again. Procedures are improved and responsible individuals who fall victim to human fallibility are treated fairly and become central to an energetic awareness program. Problem solved? Not really! The reality is that E&M is reacting to random events due to random causes. Given that the reactive process is handled well it is timely that a proactive process is introduced to complement it. The proactive process against human errors would be of:

- identification of the type of errors;
- the measurement of how bad the problems are; and
- the targeting of remedial action.

The proactive process will improve what James Reason calls 'Safety Health'. That is our organizational resistance to human failure. The immediate challenge is to establish how healthy we are. We need to do the equivalent of 'having a check-up' in the same way as we would go to a doctor.

If incidents and accidents are the result of active and organizational latent failures, then good safety health is the result of the elimination of those failures before the event.

It is argued that **E&M** would do well to focus on twelve (12) main error reducing conditions (ERCs).

1. EFFECTIVE COMMUNICATIONS.

Communication is more than telling someone something. It involves the transfer of information and understanding from one person to another. It is successful only when it is understood by the receiver in the way the sender intended.

2. CAREFULNESS.

That quality that makes up good 'airmanship' Taking pains, fussing over, attentiveness, diligence and cautiousness. These things eliminate complacency.

3. KNOWLEDGE AND EXPERIENCE.

There is the need to ensure that the correct person is assigned to a task. We need to ensure that those who don't know 'how' are learning.

4. VIGILANCE.

Where concentration is totally focused. Distraction is either eliminated or is effectively managed.

5. EFFECTIVE STRESS MANAGEMENT.

Stress is a reaction to physical or psychological tension. The reaction needs to be managed.

6. CONTINUOUS QUESTIONING OF HOW WE DO THINGS.

We have some good norms and some bad. Some have originated as a result of previous incidents. Their application may still be effective or may not. We need to eliminate the bad ones and look to make new good ones.

7. EFFECTIVE TEAMWORK.

Teams need to be coordinated with each team member knowing their role and trusting other team members. Effective teams are higher achievers than individuals and less likely to make errors than bad teams or individuals.

8. PHYSICAL & MENTAL ALERTNESS.

An exhausted person has the equivalent performance of a drunk.

9. NECESSARY RESOURCES.

Without the necessary resources, additional pressure is applied to a situation.

10. EFFECTIVE MANAGEMENT OF EXTERNALLY IMPOSED PRESSURE.

This is an issue for supervision. If allowed to break through the supervision defense barrier stress is allowed to develop in an individual.

11. ASSERTIVENESS.

Engineers are the last defense against organizational failure. If an organizational failure or error has penetrated all other defense barriers and is identified by an engineer he needs assertiveness skills to enunciate the problem. Particularly a problem with those who feel vulnerable: Apprentices; Junior Tradesmen and new employees. **CRM** for junior **QF** pilots has proved helpful when flying with cranky old pilots. **E&M** has a few cranky old engineers. Strategies need to be developed to take the bark out of cranky old engineers; and ones that don't encourage middle order engineers to become cranky old engineers.

12. SITUATIONAL AWARENESS.

In knowing what is going on in a given situation and being able to project what may happen if nothing is done about it. Historically a problem for **E&M** when things are about to move.

e.g.:

- an aircraft is about to be towed into a hangar and contacting docking; or amongst light poles.
- functionals where thrust reversers, landing gears and flight controls are moved whilst other maintenance is still being performed.

E&Ms performance is currently measured against the parameters of profit, costs (particularly equipment and aircraft damage) and schedule. E&M needs to include the 12 error reducing conditions (ERCs) in our measured parameters. It then needs to respond to the weak areas. The response will be more important than the act of measurement or the size of the problem.

HEAR proposes that a manager of a department and his 'key people' would regularly ask of themselves how their department rated with respect to the 12 **ERC**s. Say a score of 0 - 10. Recent past big and little incidents and near misses should be a reference.

THE PRO'S.

HEAR has successfully raised a profile and have had reasonable success in convincing engineers that they are vulnerable to human factors. This is an approach from beneath which is ingenious by design. Inviting active management participation complements this with an approach from above. Change is perceived as painful and is only ever implemented by active intervention. Measuring the problem generates the NEED.

When a given department analyses their results they:

- accept that THEY have a problem of defined magnitude;
- accept OWNERSHIP of their problem; and
- originate STRATEGIES that suit local needs.

Subsequent incidents when analyzed for human factors elements of the 12 **ERC**s can be compared with the ratings they gave their department. This highlights any subjectivity error. It also removes the reward for rating the department higher than the reality.

Whilst **H.E.A.R.** encourages engineers to accept their vulnerability to human factors and adopt recommended strategies to combat them, there is a reluctance to do this. Principally among them is that they feel they may be ignored or reprimanded for chasing a goal that may be in conflict with our current goals of cost, profit and schedule. Even if it is not, they would be operating in a manner perhaps different to their peers. In short, they need to be rewarded in knowing that despite these barriers that they face that their 1st level management will appreciate their efforts. For the same reasons the managers efforts will not be transparent and he will be more inclined to chase those goals.

THE CONS.

The ratings scores are highly subjective. For this reason the 'panel of key people' should be cycled frequently. This would also help to spread the ownership of the problem. Individual managers may feel threatened by comparison between departments.

In an effort to totally take out the subjectivity of the ratings, we could end up with a cumbersome document.

A poor score for a department may reflect unfairly on the manager. What should reflect on the manager is his management of the given identified weakness areas.

Matt Wright.
John Fitzpatrick.
HEAR Program.
November 1996.

Appendix B

HEAR PROGRAMME.

H.E.A.R.T. SURVEY.

(Human Error & Accident Reduction Trends.)

DEPARTMENTAL SELF - ASSESSMENT.

A departmental self-assessment of the 12 **E**rror **R**educing **C**onditions (ERCs).

Note: When rating: '1' is lowest, '10' is highest.

1. EFFECTIVE COMMUNICATIONS.

Communication is more than telling someone something. It involves the transfer of information and understanding from one person to another. It is successful only when it is understood by the receiver in the way the sender intended.

Rating: 1 2 3 4 5 6 7 8 9 10.

2. CAREFULNESS.

That quality that makes up good 'airmanship'. Taking pains, fussing over, attentiveness, diligence and cautiousness. These things eliminate complacency.

Rating: 1 2 3 4 5 6 7 8 9 10.

3. KNOWLEDGE AND EXPERIENCE.

There is the need to ensure that the correct person is assigned to a task. We need to ensure that those who don't know 'how' are learning.

Rating: 1 2 3 4 5 6 7 8 9 10.

4. VIGILANCE.

Where concentration is totally focussed. Defocused is eliminated or is effectively managed.

Rating: 1 2 3 4 5 6 7 8 9 10.

5. EFFECTIVE STRESS MANAGEMENT.

Stress is a reaction to physical or psychological tension. The reaction needs to be managed.

Rating: 1 2 3 4 5 6 7 8 9 10.

6. CONTINUOUS QUESTIONING OF HOW WE DO THINGS.

We have some good norms and some bad. Some have originated as a result of previous incidents. Their application may be still effective or may not. We need to eliminate the bad ones and look to make new good ones.

Rating: 1 2 3 4 5 6 7 8 9 10.

7. EFFECTIVE TEAMWORK.

Teams need to be coordinated with each team member knowing their role and trusting other team members. Effective teams are higher achievers than individuals and less likely to make errors than bad teams or individuals.

Rating: 1 2 3 4 5 6 7 8 9 10.

8. PHYSICAL AND MENTAL ALERTNESS.

An exhausted person has the equivalent performance of a drunk.

Rating: 1 2 3 4 5 6 7 8 9 10.

9. NECESSARY RESOURCES.

Without the necessary resources, additional pressure is applied to a situation.

Rating: 1 2 3 4 5 6 7 8 9 10.

10. EFFECTIVE TEAM MANAGEMENT OF EXTERNALLY IMPOSED PRESSURE.

This is an issue for supervision. If allowed to break through the supervision defense barrier, stress is allowed to develop in an individual.

Rating: 1 2 3 4 5 6 7 8 9 10.

11. ASSERTIVENESS.

Engineers are the last defense against organizational failure. If an organizational failure or error has penetrated all other defense barriers and is identified by an engineer, he needs assertiveness skills to enunciate the problem. Particularly a problem for those who feel vulnerable. Strategies need to be developed to take the 'bark' out of cranky old engineers and ones that don't encourage middle order engineers to become cranky old engineers.

Rating: 1 2 3 4 5 6 7 8 9 10.

12. SITUATIONAL AWARENESS.

The ability to be aware of what is happening around you and what will be the end result of any action you may take.

Rating: 1 2 3 4 5 6 7 8 9 10.

MR. JOHN FITZPATRICK

John is a Justice of the Peace (JP) and is currently employed in the Heavy Maintenance Department in Sydney as a Senior **LAME**. John commenced his career with Qantas as an apprentice in 1976 and after qualifying as an **AME** has successfully advanced to his current position. John holds mechanical licenses on the B747 Series, B747-400 and B767 Series as applicable to the Qantas fleet.

As well as being involved in the **H.E.A.R.** Program from its inception John is involved in various other projects such as: Occupational Health and Safety Representative; Member of Qantas Jet Base Occupational Health And Safety Committee; Member Qantas Aircraft Recovery Team (Airsmash); Member of Qantas Sydney Hazardous Materials Committee. John has also worked as a Technical Representative in Australian and Overseas Ports. John is continuing in his studies to obtain an MBA and in 1997 is commencing a Graduate Diploma in Aviation Human Factors.

MR. MATTHEW WRIGHT

Matthew is currently employed in the Line Maintenance Department at Melbourne (MEL) International Airport as an **LAME**. Matthew began his career with Qantas as an apprentice in 1984 and transferred to the Line Maintenance Department in Melbourne in 1987. Matthew holds mechanical licenses on the B747 Series, B747-400 and B767 Series as applicable to the Qantas fleet. Matthew also holds limited Avionic licenses on the aforementioned aircraft types.

Matthew has been a member of the **H.E.A.R.** Program since its inception.

5.0 ERROR CONTROL SYSTEMS AT NORTHWEST AIRLINES

David B. Graham
Director of Base Maintenance, Technical Operations, Northwest Airlines, Inc.
and
Joan Kleman Kuenzi
Senior Specialist, Human Factors, Technical Operations, Northwest Airlines, Inc.

INTRODUCTION

Almost three years ago, a 747-200 bound for JFK from Hong Kong was touching down in Narita, Japan for an overnight layover. Flight and landing roll-out were routine. From the report on the incident, "Engine thrust reversing was normal on all four engines until coming out of reverse at about 90 knots. The airplane was stopped on a taxiway and the (front of the) engine was seen touching the ground. A fire near the number 1 engine was extinguished by local firefighters. All passengers were deplaned through portable boarding stairs about 30 minutes after the airplane came to a stop on the taxiway."

What caused this incident? Initial indications were that the fuse pins that held the pylon diagonal brace sheared in the incident. The upper fuse pin was recovered intact, however, the two diagonal brace fuse pins and their retainers were not found. The aircraft involved in this incident had undergone a maintenance check at the Minneapolis heavy maintenance facility a month before, and had flown 18 flight cycles since that check. Following the Narita incident, the missing set of retainers was found on a maintenance stand at this facility.

While Northwest Airlines Technical Operations staff were interested in bringing human factors principles into their work organization, this event served to catapult the issue to a high priority. Subsequently, we began the development of a human factors program for error control within Technical Operations.

SYSTEMS APPROACH TO ERROR CONTROL AND MANAGEMENT

Northwest uses a "systems approach" to analyze human error in maintenance. We believe that by combining different methods of dealing with human error, we will be more successful at reducing the risk for future error in our maintenance facilities. A positive by-product of this approach is increased communication with other aspects of our company (e.g., Flight Operations, In Flight, And Ground Operations). Increased communication alone will serve to reduce the risk of human error in situations where these different operations must work as a team. The error control methods fall into three broad categories: (1) Error Data Collection Tools, (2) Education and Training, and (3) Workplace Human Factors and Ergonomics.

ERROR DATA COLLECTION TOOLS

In early 1995, Boeing representatives introduced Northwest Airlines to their paper-based system called **MEDA**. Northwest participated in the MEDA trial. In October of 1995, the Aurora Mishap Management System was introduced to the maintenance workforce for their use. It is still in use today.

Maintenance Error Decision Aid (MEDA)

The MEDA program is a paper-based system for analyzing errors. It was created by human factors personnel at Boeing and is used by many air carriers. More information can be found in **Chapter 3** of this report.

Aurora Mishap Management System (AMMS)

In October of 1995, Northwest began its association with Aurora Safety and Information Systems. Their system (AMMS) is a computer-based data collection tool similar in concept to **MEDA**. AMMS investigators come from both the **IAM** and the management within the heavy check hangars in Minneapolis, where the system is primarily in use.

People involved in a given error are interviewed by trained investigators who use the system to guide them through the event and possible causes for that event. These people are asked for ideas on preventing this kind of event from happening. Data is collected and analyzed to look for trends. Using these trends, Northwest assembles an Employee Involvement Group (from both contract and management) to study the problem. They take into account what the people involved had to say about preventive strategies within each report, and then decide on a course of action. This course of action is weighed against each error report to assess how well it would solve each scenario. Cost data for each event (if available) is also used to assess the return on investment for a preventive strategy.

The system was introduced to one cost center within the Minneapolis facility as a beta test. At the beginning of this test, Dave Graham, then Director, 747 Maintenance, and Eugene "Dutch" Drescher, then District **IAM-FAA** representative, informed the workforce that they would have immunity from punishment from the company if they participated in this system after reporting an error.

Shortly after this introduction, Dave Graham was given responsibility for all Minneapolis heavy check hangars. The system was put in place in the other hangars during the Autumn of 1996. Unfortunately, questions of immunity and discipline have compromised the system's use in all areas. Management is currently using the system. Contract personnel are waiting for clarification on how participation in this system will impact the current disciplinary policy, or if the policy will change.

There are two challenges that face us as users of this system: (1) how to motivate people to talk about the errors they have just committed without fear of being punished for something that was beyond their control; and (2) how do we as managers change our way of thinking from a more punitive to a more enlightened system of management in order to learn from mistakes and reduce the error in our hangars? Part of the **AMMS** is the Disciplinary Review Board (DRB). The purpose of this board is to objectively analyze the facts in a mishap and come to a decision as to the level of copability involved.

For more information on this subject, the reader is referred to **Chapter 6** of this report. The author, David Marx, has extensive expertise in **MEDA**, **AMMS** and the **DRB**, as he has been an integral part of all three efforts.

People are reluctant to change, even if given the promise of a better work culture, if that promise is not demonstrated in word and in deed. Northwest Airlines management is in the process of discovering how to mesh the **AMMS** with their existing mode of discipline, and demonstrate the way in which it will handle human error and learn from events that occur. The **IAM** is working with management to come to consensus on how this new culture will look and act.

EDUCATION AND TRAINING

Human Factors Awareness Seminar

A seminar in Maintenance Resource Management is being provided for the aircraft maintenance organization. It provides an awareness that what a person does out on the floor affects others, and is affected by factors such as stress, and suboptimal communication.

Seminar Development

There are many companies, some represented at this meeting, whose main product is courseware for this very purpose. Our own Flight Operations department has an extensive program for Crew Resource Management that they have used for many years. However, we as Technical Operations saw the opportunity to demonstrate the concepts that we wanted to teach, by involving the "end users" in the process of development. Our development team is lead by Phyllis Dozier, an instructional systems design expert. Her role is important in that the product that we are striving for is to be much more interactive than a traditional class. Joan Kuenzi, the Senior Human Factors Specialist for Technical Operations, was also involved in the development as a subject matter expert or (SME). The remainder of the team was made up of people from the International Association of Machinists and Aerospace Workers (IAM) and the Aircraft Technical Support Association (**ATSA**) who provide technical training for our workforce. The development team for the seminar determined that it would not be called a "class" because it was not like any of the other classes that were available to mechanics; it is an interactive session in which the participants discuss the content among themselves.

Seminar Content

The majority of the seminar is devoted to having the participants discuss and internalize the concepts presented in our Maintenance Resource Management model**(Figure 5.1)**. Other aspects of our seminar include video vignettes designed, scripted and acted by our workforce. These vignettes serve to illustrate some of the points covered under the model. The model is based on one used in Flight Operations, Systems Operations Center (SOC), and In Flight Services, however, we used **SME**s to tailor the content to maintenance.

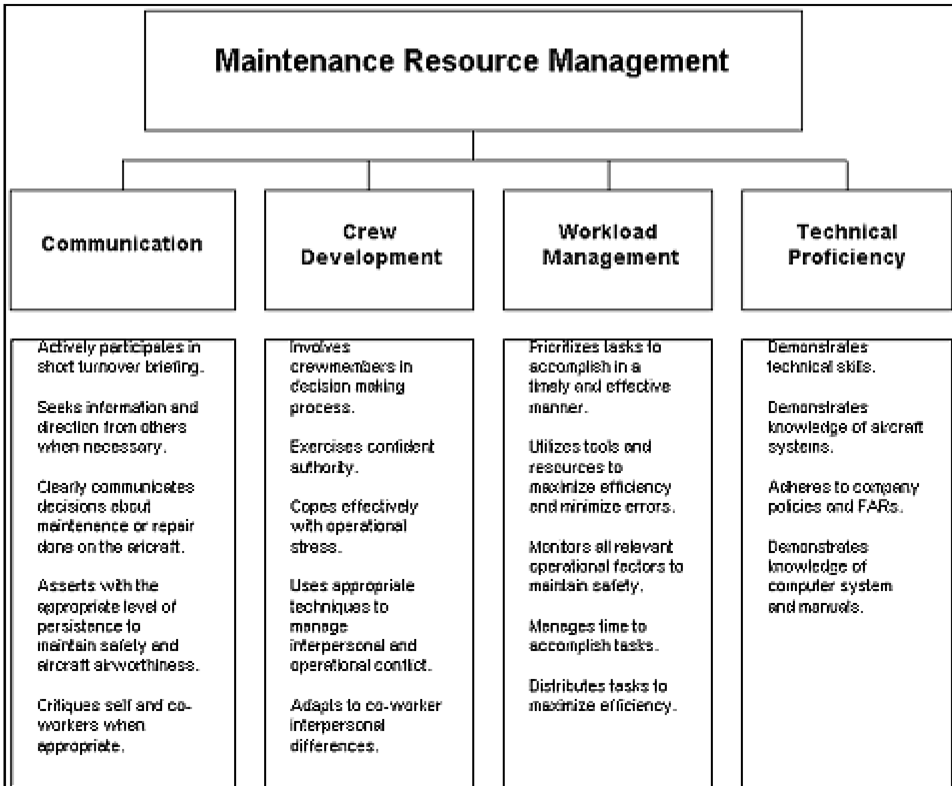

Figure 5.1 Maintenance Resource Management (MRM) model.

Status

The seminar was prototyped in Minneapolis on May 16, 1996. To date, over 1300 people have participated in the seminars. Participants range from mechanics to managers, and include people from Engineering, Quality, Inspection, Shop personnel, and Process Improvement. We are currently prototyping the seminar for introduction to the Line Maintenance Organization, both domestically and internationally and our other heavy check facilities in Atlanta and Duluth. Our goal is to provide this seminar both to the people who work on the aircraft, and to those who work with them.

AMMS Training

All people who use the **AMMS** to record events have had training from Aurora Safety and Information Systems that include:

1. The theory behind the system and how human error is defined
2. How to use the system
3. Interviewing techniques and who to interview
4. How to look at the data to construct preventive strategies

5. How to assess the impact of preventive strategies using errors in the data

The course was tailored by the company to fit our schedule, including off shift work, and used our own data to teach concepts within the course. Representatives from Northwest Airlines were allowed to evaluate a prototype of the course and our evaluation was taken into account in the final content and layout of the course.

WORKPLACE HUMAN FACTORS AND ERGONOMICS

This third piece completes the error control puzzle. The previous pieces served to collect data on the errors and make our workforce aware of their part in reducing human error. Human Factors and Ergonomics (HF/E) principles address the mismatches within the Human/Maintenance interface. Several projects currently address HF/E-related issues in our work environment: (1) Task Analytic Training System (TATS), (2) Structured On-the-Job-Training (SOJT), and (3) Aircraft Maintenance Information-Task (AMI-Task). The following sections will discuss each of these initiatives as well as future plans related to Human Factors and Ergonomics.

Task Analytic Training System (TATS)

Initially provided by Boeing, **TATS** uses job analysis methods to break a given task into component parts. The purpose of this program is to assess what information needs to be provided (in the form of on-the-job training) to someone new to the area in order for that person to be considered competent on that task. The technique uses people who already perform the task, has them break down the task as a group, and assess the steps and information needed to do the task, and design the task aid used for On-the-Job training.

Structured On-the-Job-Training (SOJT)

The need for a Structured On-the-Job-Training project was driven by the Federal Aviation Administration. There was a concern in 1995 that mechanics were being assigned to tasks for which they had received no formal training. At that time, Northwest had informal on-the-job-training, in that workers who had done the jobs taught those who had not. **SOJT** was developed to formalize the **OJT** by providing structure. The purpose of this program is to assess what information needs to be provided (in the form of on-the-job-training) to someone new to the area, in order for that person to be considered competent on that task. The technique uses people who already perform the task. With a facilitator to guide them, this group breaks down the task, assesses the steps and information needed, and then designs a task aid to be used in training. To date, all check hangars in Minneapolis and Duluth, Minnesota, and Atlanta, Georgia have completed the design phase of the project. The implementation process is currently underway.

Aircraft Maintenance Information (AMI-task)

AMI-Task (Aircraft Maintenance Information - Task cards) is a system developed to provide a combined text and graphics maintenance Workcard to the production floor. The Workcards created for use within Northwest Airlines have been implemented with several features to clearly delineate separate work steps, and the skills required to accomplish those work steps. Duplicate access has been virtually eliminated from the aircraft work package through the auto-generation of Access Workcards, using databased information from the routine Workcards scheduled during the aircraft visit. In addition, having the Aircraft Maintenance Manuals digitally available (in the same desktop-publishing system - currently under development) will allow for direct links between Aircraft Maintenance Manual and Aircraft Workcard information. This will both speed revision processing and allow for a closer audit of Workcard information without adding resources.

Other Human Factors/Ergonomics projects

Currently, there are joint efforts between our Human Factors Specialist and the Technical Operations Safety, Health, and Environmental Management (SHEM) department, as well as with the Process Improvement department. All of these efforts are aimed at modifying physical aspects of the work that have a negative impact on human performance.

SUMMARY

There is no single way to reduce maintenance related human error. At Northwest Airlines, we believe that the key lies in taking a systems approach to human factors. Only by looking at the problems we face from several angles can we truly begin to see a more realistic picture. Only then can our efforts to minimize the risks for human error be realistically focused. The projects and initiatives discussed within this paper serve to increase communication between and within workgroups, to lessen the probability for risk of injuries and errors, and to create a more positive culture in which to work.

MR. DAVID B. GRAHAM

David B. Graham is the Director of Base Maintenance Operations for the Minneapolis/St. Paul facility at Northwest Airlines, and is responsible for 727/MD80/757/DC10/747 heavy maintenance. Previously, his responsibilities included Director 747 Aircraft Refurbishment Modification And Renewal, Manager Aircraft Structures, Senior Foreman Aircraft Structures, and Mechanic. He is a member of **ATA MOC** subcommittee and was recently asked to be part of **IATA** Human Factors Working Group. David is also a member of NWA Technical Operations Human Factors Steering and Planning committees. He received his **A&P** license at Colorado Aerotech.

MS. JOAN KLEMAN KUENZI

Joan Kleman Kuenzi has been the Senior Human Factors Specialist with Technical Operations at Northwest Airlines for just over a year. She has a M.S.I.E from the University of Wisconsin-Madison specializing in Sociotechnical Systems, and a B.A. in Psychology from the University of Minnesota-Twin Cities. Her experience in Human Factors/Ergonomics has come from work design to reduce injury/error in maintenance, control room design for nuclear power stations, musculoskeletal disorders research, and job/task analysis. Joan is also a member of NWA Technical Operations Human Factors Steering and Planning committees, and serves on the **ATA** Maintenance Human Factors Subcommittee.

6.0 MOVING TOWARD 100% ERROR REPORTING IN MAINTENANCE

David A. Marx
Independent Consultant

INTRODUCTION

Before I begin my presentation, I'd like to ask the air carrier representatives in the audience to participate in a small field study. Will each air carrier representative please stand up?

I'd like you to answer these questions. If we were to go to your facility, could we, with the help of your business colleagues, track down data on each hydraulic pump failure that has occurred in your aircraft fleet during the month of January 1997? Could we find the hours or cycles of each pump when it failed, and could we find shop reports for each repaired pump? Could we go to your reliability group and find the historical trend on hydraulic pump failures and compare that trend to the failure rate in January? If the answers to these question are predominately yes, please remain standing. If the answers are predominately no, please sit down.

For those of you still standing, I have a second set of questions. If we were to return to your facility, could we, with the help of your business colleagues, track down data on each shift turnover error that has occurred in your operation during the month of January 1997? Could we find an investigation record for each turnover-related error? Could we also go to the reliability group and find historical trends on the shift turnover-related error rate and compare those to the shift turnover-related error rate in January? If the answers to these questions are predominately yes, please remain standing. If the answers are predominately no, please sit down.

Without the benefit of seeing the actual results to this survey, my experience tells me that nearly all air carrier representatives would remain standing after the questions about the hydraulic pump, yet nearly all would sit down after the questions regarding shift turnover. So what is it that makes this small field study at all interesting? It is that the hydraulic pump, in our lifetime, will likely never again be the cause of a jet transport accident. Yet, when the next maintenance-related accident occurs, there is a reasonable probability that a poor shift turnover will have been involved in the accident.

It is interesting to consider the disparate treatment that we afford mechanical versus human failure. On the mechanical side of the airline operation, nearly all failures are investigated, analyzed, and monitored for their effect upon reliability and safety. Mechanical reliability programs, engine condition monitoring programs, shop findings - all of these have contributed to making equipment failure a small piece of commercial aircraft accidents. So why is it we can track equipment failure with precision, yet human errors still go undetected or hidden within an air carrier's operation? Human error, after all, contributes to 80% of commercial jet accidents.

It has been a full decade since the Aloha Airlines disaster - a decade since we first came together for these maintenance human factors conferences. In that time we have learned that maintenance error contributes to 15% of air carrier accidents and that maintenance error costs the US industry more than 2 billion dollars per year. We've adapted flight-crew resource management programs for use in maintenance and thanks to the efforts of many of you, we've developed a number of analytic tools for the assessment and reduction of maintenance error. Yet what we have done to help facilitate internal airline reporting of error can be described in two words. Very little. In fact, there are many who say that we will never convince a technician to report his or her error inside the company.

I, for one, am simply unwilling to believe that actual event data is beyond reach. While we haven't made much advance in the last ten years, I'd like to believe that ten years from now most of the air carrier representatives would remain standing after the question regarding shift turnover.

So what I will address today is the concept of 100% error reporting, and its logical progression: the human reliability program. It is the concept that through 100% error reporting, we can track, analyze, and develop prevention strategies to effectively manage human error. As the hydraulic pump demonstrates, this is not a new idea. It is the simple idea that in any endeavor to improve a system's performance, the first step is data collection, event data in particular.

THE HISTORY OF MECHANICAL RELIABILITY PROGRAMS

First, a little history for those unfamiliar with what we have so successfully done on the equipment side of the industry.

The first generation of formal air carrier maintenance programs was based on the belief that each functional part of the aircraft needed periodic disassembly inspection. Time limits were established for service, checks, and inspections. Periodically, the entire aircraft was disassembled, overhauled, and reassembled to maintain the highest level of safety. This was referred to as "hard-time" maintenance.

As the industry grew and more complex aircraft entered service, literal application of the "hard-time" maintenance process became obsolete. Each component and part no longer required scheduled overhaul on a fixed-time basis. A second primary maintenance process known as "on-condition" evolved. The on-condition process was assigned to components on which continued airworthiness could be determined by visual inspection, measurements, tests or other means without disassembly, inspection, or overhaul. In the US, the FAA controlled these programs by approving hard-time or on-condition check periods individually for the aircraft, engines, and components. This new method of reliability control was oriented toward mechanical performance rather than the previous method of predicting failure points through mandatory teardown inspection.

In the 1960's, the **FAA** first began to approve reliability programs internal to air carrier maintenance organizations. These programs allowed air carriers to explore the relationship between component age and component reliability and to make changes necessary to optimally manage equipment performance. It is important to recognize that these programs involved a high degree of self-determination on the part of the airline. The rapid advance in aircraft and process technology simply forced the FAA to move toward performance measurement.

As a result of this new relationship between the **FAA** and its air carriers, what exists now at the typical large carrier is a sophisticated system of data collection, data analysis, and corrective action. It is an expansive system of people that includes everyone from the technician removing the failed components to the regulator conducting oversight. It is also a structured set of processes that distinguishes critical from benign failures, a system that allocates resources based upon the needs of the aircraft. It is a system that has provided us with unimaginable equipment reliability. Where in the early days of flying, a pilot might worry about multiple engine loss, the typical young commercial pilot today might wonder if she'll ever experience an in-flight shutdown during her entire career. So while we in the maintenance community have been looking toward the pilots with admiration of their flight deck human factors programs, the greatest insights for maintenance human factors, and the potential for the greatest benefit may be sitting right under our nose within our own mechanical reliability programs.

Yes, some attitudes would have to change and some new techniques developed, but the potential rewards are great. Imagine a human reliability program sitting right beside your mechanical reliability program, building a culture where technicians, pilots, ground crew, and cabin crew all feel a duty to report their errors, participate in error investigations, and actively participate in the development of prevention strategies. Imagine a system where sophisticated analysis tools spot trends and develop systemic solutions to less critical errors while structured engineering processes provide comprehensive fixes to errors endangering safety of personnel or safe operation of the aircraft. Imagine a system where engineering and quality assurance groups put human error on the agenda for every reliability control board meeting. Imagine a system where the regulatory agency spends less time tracking down violators and more time monitoring the effectiveness of the carrier's approved error management program. Put simply, imagine a program where human error is afforded the same status and same expenditure of resources as the lowly hydraulic pump.

MOVING TOWARD 100% ERROR REPORTING

There is a growing momentum to consider the human reliability program as a cornerstone of a full-fledged human error management system. Yet, there can be no human reliability program without consistent data collection. More specifically, there can be no human reliability program without near 100% reporting. So what I would like to discuss today are some issues that stand in the way of more extensive error reporting and investigation. These are issues we must address if we are to ever have an effective human reliability program.

Recognize that Errors can be Predicable Events

We have grown comfortable with equipment reliability data - every month the typical carrier will pour over charts and graphs of equipment failure data. It is upon this data that an air carrier will manage much of its maintenance resources. When faced with the data that 400 hydraulic pumps failed prematurely last year, nearly all of us would predict similar results this year if we did nothing different.

Yet faced with 400 shift turnover errors in 1996, many engineering and maintenance executives will argue that this data says little about shift turnover errors in 1997. After spending their careers faced with a comedy of employee errors, many senior managers settle into the belief that human errors are just random unpredictable events. To say that 400 shift turnover errors occurred last year is only to say that 400 people had a bad day.

The truth, however, is that human error, just like equipment failure, *is* predictable. Not in the sense that we could walk out on your hangar floor and predict where the next error will occur. Nor can we, as we discussed earlier, tear down a piece of equipment and predict when it will fail. But we can collect actuarial data on human error, just as we do with the hydraulic pump, that will be helpful in establishing the probability of future error. If human error data collection is to have any practical benefit, human error data must be considered to be as meaningful as hydraulic pump failure data.

Identify Error Reporting Thresholds

We cannot assess the true contribution of any error management strategy until we believe that all errors are reported. Yet, it is impossible to investigate every single error made by a pilot, technician, or ground agent. Rather, reporting thresholds for human error must be established, just as they are for equipment failure. A passenger service unit light bulb burns out - we don't track this failure in a reliability program because the criticality of the failure, from either a safety or economic perspective, does not justify the expense of tracking these items. We must do the same on the human side. We must understand that humans err at incredible frequency; many errors are caught before any undesirable consequences occur. What I am not suggesting is that each and every human error in your operation needs to be investigated in order to provide benefit. Rather, I am suggesting that consistent guidelines be created to assuring that historical data has meaning. For example, we would all agree that in-flight shutdown data is meaningful data. We do believe that nearly all **IFSD**s are reported, and we can assume that a statistically significant increase in the IFSD rate is likely the result of some identifiable intervening cause.

The same credibility can be given to human error data, as long as the thresholds are properly selected. Failures that endanger safety of flight, errors costing above $1,000 in damage - it is thresholds like these that can make a human reliability program both manageable and productive.

Develop Criticality Assessment Tools

There appears to be an unwritten rule that says: If you have had an adverse event, you must have a corresponding corrective action. If you don't take specific corrective action, you open yourself to liability from the regulatory authority, a potential injured plaintiff, the media, and/or your boss.

Yet let's consider your previous efforts to reduce the frequency of, for example, shift turnover-related errors. If you are like most managers, you've conducted a review and implemented prevention strategies after the occurrence of a particular high visibility event. Yet for your review team, the data is sparse. You have the investigation results from this one incident to guide your strategy for the elimination of all future turnover-related errors. The problem is that humans are creative, leading to a variety of error scenarios, each with a little twist not evident in your single high visibility event. Implementing a human error prevention strategy based upon data from the one event just about ensures that errors will continue to occur, until the next high visibility outcome causes your review team to get back together once again.

If instead, you recognize that to best modify the shift turnover process, it is important to understand the contours of the problem; you decide to investigate a larger population of shift turnover errors, each time finding a slightly different story. The pieces of the puzzle are coming together with an effective set of prevention strategies on the drawing boards. Now, however, you've had to violate the rule that no documented event can go without an immediate corrective action.

The exposure to liability is a concern we will face with 100% error reporting. Having knowledge of errors, without specific corrective action, arguably opens you up to liability. Therefore, just as we did for equipment failure, we must develop criticality assessment methods that will allow the less critical errors to be distinguished from those endangering safety. We do not implement a new prevention strategy every time a hydraulic pump fails, because failure of the pump is considered normal and acceptable. Yet we take immediate action if an engine disk fails, because the known criticality demands that efforts be made to prevent reoccurrence.

Human error can be viewed in the same light: each known error having some risk of being a precursor to a much more catastrophic event. If we are to significantly increase the investigation and documentation of errors, we must have methods to separate the critical errors from the masses of purely economic events.

Develop a Supportive Disciplinary System

The road to a reporting culture is riddled with potholes. And if we get past the potholes, we find that our typical approach to discipline is a gate, making movement nearly impossible. Quite simply, we cannot ask an employee to come forward to discuss his error without considerable disciplinary reform. Employees must be certain of how they will be treated after reporting an error. Systems that reserve the unilateral right of punitive action may provide flexibility for the manager, but they do not provide the necessary assurances needed to promote open and honest communication with an erring employee.

We must come to the realization that discipline will be counterproductive in the vast majority of errors, although essential for the small percentage of errors involving intentional violations that put passengers' lives at risk. As John Kern, Chair of the **ATA**'s Safety Council, would say, we must define the "box" inside which incidental human errors can be reported without punitive action being taken. We must draw a line in the sand, proscribed blameworthy intentional behavior, that every employee can see. Crossing the line mandates discipline, staying away from the line guarantees that no disciplinary action will be taken.

We must additionally consider discarding concepts like immunity and amnesty that only tell the world that someone at fault is getting away with culpable behavior simply because a safety expert wants the data. Just think about hearing on the news that a drug dealer was given immunity for his testimony. To most of us, words like immunity and amnesty serve only to undermine our faith in the justice system. Now consider announcing over the aircraft's public address system that the airplane was grounded for an hour while the error of a technician was fixed - but not to worry, he was given immunity so that he would talk about his error. The problem of reporting is not that immunity is needed, it is rather that the disciplinary system itself needs fixing.

Establish Affirmative Duties

I don't think anyone here will be shocked by the suggestion that the typical aviation professional does not feel a duty to report his or her error. Although it may be required by the air carrier's policies and procedures, that does not ensure that people report. Fear of punishment, shame, expediency, a feeling that no good will come if they do report mistakes - all of these contribute to the failure of aviation professionals to raise their hands and say "I've made a mistake."

Yet, it would be naïve to stand here and tell you that a simple disciplinary system modification will be all that is necessary to effect 100% reporting. We are battling years of labor/management distrust - not to mention the reality of a world in which a supervisor may subtly reprimand his erring employee while claiming no disciplinary action was taken.

What we must ultimately do is develop a culture where each aviation professional, whether labor or management, feels a duty to report his error and a duty to truthfully participate in an investigation of the error. Just as we feel a duty to give aid when we are first to the scene of an automobile accident, just as we give help to a child who has lost his parents, reporting our mistakes must become more than a cultural norm; it must become reflective of a core belief of what it means to be an aviation professional.

Adopt a Carrier/Regulatory Relationship Similar to that for Mechanical

Reliability Programs

The advent of high technology aircraft forced air carriers and the **FAA** to work together in new ways. Continuous airworthiness maintenance programs and mechanical reliability programs were recognition that the FAA was not in a position to investigate or monitor each failure occurring within an air carrier's fleet. It meant that some level of self determination was needed for the airline, with the regulatory authority monitoring system effectiveness. The technology of new aircraft such as the 777 make this point even more clear - not everyone can or should be an expert on the working of an ARINC 629 data bus. So each carrier, having resources considerably greater than the local Flight Standards Office, must develop internal systems designed to monitor and maximize the safety and performance of their aircraft fleet.

We must do the same for human error where, arguably, the variation and extent of human error far exceed equipment failure. The system would be one of data collection, data analysis, and corrective action approved by the **FAA**. Human reliability for less critical tasks would be monitored by the FAA through the carrier's human reliability program, thus allowing time to address, on an event-by-event basis, those human errors endangering safety of flight or involving highly culpable behavior.

CONCLUSION

Many of us at this conference have been working in the field of maintenance human factors since before the Aloha disaster in 1988. We have poured our hearts and souls into preventing accidents like the ValuJet accident in the Florida Everglades. For some of us, the road has been too riddled with political and scientific potholes - causing us to abandon the idea that human factors in maintenance will ever save a life. Yet many stay true to the course - fighting to bring human factors into the mainstream of maintenance process. Perhaps it is time to re-evaluate where we have gone. Yes, we have developed human error reduction methods and tools, but how much more do we really know about the precursors to the tragic accidents like Aloha ten years ago and ValuJet today?

There are many of us who believe that the human reliability program is a good idea, yet there are many who are likely saying, "I'll believe it when I see it." Unfortunately, this may be a program where seeing it will only come after believing in it first. So I encourage you to give human reliability a chance within one area of your operation, even if you investigate only one issue. Grab the **MEDA** form, pick a hangar and investigate every shift-turnover related error for a period of 90 days. Get a small team together at the end of the 90 days, and using your MEDA data, look for ways to improve the shift turnover process. Find a few other airlines who would agree to do the same, and get representatives from your teams together to share ideas. A beginning like this may snowball into a full fledged human reliability program.

MR. DAVID MARX

David has a BS in Mechanical Systems Engineering and is a former aircraft design engineer for the Boeing Company. David served as a consultant to airlines in the areas of maintenance program development, aging aircraft, and extended twin operations. David also served as a team member or team leader on a number of maintenance evaluations and maintenance error audits for US and foreign airlines. Five years ago, David organized the maintenance human factors and safety group at Boeing and led the development of the Maintenance Error Decision Aid (MEDA).

David has more recently served as VP of Commercial Aviation Systems at Aurora Safety and Information Systems, Inc. At Aurora, David led the development of the Aurora Mishap Management System, a turn-key approach to human error management. Currently finishing his last year of law school at Seattle University, David has committed his energies to the development of disciplinary systems that are supportive of human factors learning. In conjunction with Seattle University School of Law, the **FAA**, and a number of US carriers and labor unions, David is performing research on the inter-relationship between mishap culpability and aviation safety. Additionally, David teaches a two day course entitled, "Improving Aviation Safety through Disciplinary System Design."

7.0 THE DIRTY DOZEN ERRORS IN MAINTENANCE

Gordon Dupont
Special Programs Coordinator
Transport Canada, System Safety

PURPOSE

The dirty dozen maintenance errors posters were designed to be a follow up to the two-day "Human Performance in Maintenance" workshop offered by Transport Canada and numerous other companies which have adopted this workshop. The purpose was to maintain the level of awareness which maintenance personnel take from the workshop. By displaying one poster each month, complacency, where one no longer notices the posters, is avoided. The posters are designed to be used in all segments of aviation (i.e., major airline, general aviation and helicopter) and depict scenes most maintainers can relate to, no matter what branch he/she works in.

WHAT ARE THE DIRTY DOZEN?

The dirty dozen are the 12 most common causes of a maintenance person making an error in judgment which results in a maintenance error. The posters also offer safety nets which can be used to help avoid the error in judgment. Errors, when they occur, will likely be found to be caused by one, or even more common, a combination of the following causes. These dirty dozen causes of error are:

1. Lack of Communication

Lack of communication can be in the form of verbal or written or a combination of the two. The poster depicts leaving a panel undone and surmising that day shift can finish the job. The safety nets: a) Use logbooks, worksheets, etc. to communicate and remove doubt. b) Discuss work to be done or what has been completed. c) Never assume anything.

2. Complacency

Complacency is an insidious cause which with the constant repetition of many maintenance inspections can cause or contribute to an error in judgment. The poster depicts a maintenance person walking away from an aircraft which has a frayed cable behind a multi-screwed panel. He has signed the inspection sheet and is saying to himself "I've looked back there 1,000 times and never found anything wrong." The safety nets are: a) Train yourself to expect to find a fault. b) NEVER sign for anything you didn't do.

3. Lack of Knowledge

In this ever changing world, Lack of Knowledge is not that uncommon a cause of an error in judgment.

When coupled with the "Can-Do" attitude of most maintenance personnel, it becomes even more probable. The poster depicts a helicopter technician with a bent part in his hand saying, "This is the third one to bend! What's going on?" The safety nets offered are: a) Get training on type. b) Use up to date manuals. c) Ask a Tech. Rep. or someone who knows.

4. Distraction

This cause is thought to be responsible for about 15% of all maintenance errors. One leaves a task (both physically and/or mentally) for any reason and returns thinking that he/she is further along with the task then they are. The poster depicts a maintainer being called away from a job to answer a phone call from his wife. The safety nets listed are: a) Always finish the job or unfasten the connection. b) Mark the uncompleted work. c) Lockwire where possible or Torqueseal. d) When you return to the job always go back three steps. e) Use a detailed check sheet.

5. Lack of Teamwork

This cause is often tied in with lack of communication but can be responsible for major errors. With maintenance often involving a multitude of workers, good teamwork becomes essential. The poster depicts two persons guiding an aircraft in, in opposing directions. The caption says "I thought you wanted him to turn left right here!" The safety nets call for: a) Discuss what, who and how a job is to be done. b) Be sure that everyone understands and agrees.

6. Fatigue

Fatigue is a very insidious cause because, until it becomes extreme, the person is usually unaware that he/she is fatigued. They are even less aware of what the effects of fatigue are. The poster depicts a person walking off the end of a horizontal stabilizer commenting that he is glad the double shift is over. The fatigue safety nets call for: a) Be aware of the symptoms and look for them in yourself and others. b) Plan to avoid complex tasks at the bottom of your circadian rhythm. c) Sleep and exercise regularly. d) Ask others to check your work.

7. Lack of Resources

No matter who the maintainer works for, there are times when there is a lack of resources and a decision must be made between ground the aircraft or let it go. The average maintainer is a "Can-Do" type of person and takes great personal pride in repairing aircraft. Thus the decision to be made can be difficult. The poster depicts a maintainer standing in front of a helicopter with a skid on the right side and a float on the left. The caption says "We have nil stock of left skids so I guess this will have to do." The safety nets are: a) Check suspect areas at the beginning of the inspection and **AOG** the required parts. b) Order and stock anticipated parts before they are required. c) Know all available parts sources and arrange for pooling or loaning. d) Maintain a standard and if in doubt ground the aircraft.

8. Pressure

Few industries have more constant pressure to see a task completed. The secret is the ability to recognize when this pressure becomes excessive or unrealistic. The poster depicts a captain looking at his watch as a maintainer rushes to close up a panel, with a line sticking out of it. The caption says "Hurry up or we're going to be late again!" The safety nets to counteract this are: a) Be sure the pressure isn't self-induced. b) Communicate your concerns. c) Ask for extra help. d) Just say No.

9. Lack of Assertiveness

The average **AME**/**AMT** is not an assertive person and most of the time his job does not require him/her to be. However there may come a time when something is not right and he/she will have to be assertive in order to ensure the problem is not overlooked. The poster depicts a float plane leaking oil into the water and the aircraft owner telling the maintainer that he owns the aircraft and he says it's NOT a bad leak. The counteracting safety nets offer: a) If it's not critical, record it in the journey log book and only sign for what is serviceable. b) Refuse to compromise your standards.

10. Stress

Stress is a normal part of every day life until it becomes excessive. The secret is to be able to recognize when it is becoming excessive. The poster depicts a maintainer pulling his tool rollaway, toward the propeller of a running engine. The caption says: "We lost our best aircraft! How are they going to pay my wages? What if I'm sued?" Stress safety nets call for: a) Be aware of how stress can effect your work. b) Stop and look rationally at the problem. c) Determine a rational course of action and follow it. d) Take time off or at least have a short break. e) Discuss it with someone. f) Ask fellow workers to monitor your work. g) Exercise your body.

11. Lack of Awareness

This often occurs to very experienced maintenance personnel who fail to think fully about the possible consequences of work they are doing. Manuals do not cover the failure and after the fact one will often hear that common sense should have told you that. The poster depicts a passenger flying forward in his seat and striking a bulkhead mounted fire extinguisher with his head. The caption says: "All the regulation said was, 'Install Where it is Easily Accessible.'" The safety nets are: a) Think of what may occur in the event of an accident. b) Check to see if your work will conflict with an existing modification or repair. c) Ask others if they can see any problem with the work done.

12. Norms

This last cause is a powerful one. Most people want to be considered one of the crowd and norms develop within such a group which dictates how they behave. The poster depicts an jet engine being installed with its pylon to the underwing of an aircraft. This is being done using a forklift and the caption says: "Never mind the Maintenance Manual. Its quicker the way we do it here." The safety nets offered are: a) Always work as per the instructions or have the instructions changed. b) Be aware that "norms" don't make it right.

WHERE CAN I GET THEM?

The dirty dozen posters are given free of charge as the cost to develop and print them was borne by the companies whose logos appear at the bottom of each poster. We ask each recipient for a donation towards a poster fund to be used to print a similar set for ground crew. To date 1,000 sets of these posters have been given out to aviation companies all over the world. A second run has just been completed and is available by contacting myself at:

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301-4160 Cowley Crescent
Richmond, BC V7B 1B8
Phone: (604) 666-5876
Fax: (604) 666-9507

Only by training and constant awareness can we hope to avoid the dirty dozen and their consequences.

MR. GORDON DUPONT

Gordon Dupont is interested in any work which will serve to make aviation safer. He has been a member of several aviation organizations and was the first president of the Pacific Aircraft Maintenance Engineers Association. He has been an Aircraft Maintenance Engineer and commercial pilot in Canada, the United States and Australia. He has also worked as a school teacher, principal of the Pacific Vocational Institute, Chief Engineer for Crown Forest Industries and Technical Investigator for both the Canadian Aviation Safety Board and the Transportation Safety Board. Since March 1993, he has been the Special Programs Coordinator for Transport Canada System Safety, developing and presenting programs such as Human Performance in Maintenance.

8.0 ROLE OF COMPUTERS IN TEAM TRAINING: THE AIRCRAFT MAINTENANCE ENVIRONMENT EXAMPLE

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ABSTRACT

Research on civil aircraft inspection and maintenance has shown the importance of teamwork in accomplishing aircraft maintenance tasks. Training has been identified as one of the primary intervention strategies in improving team performance. Moreover, if training is to be successful, it is clear that we need to provide aircraft maintenance technicians with training tools to help enhance their team skills and improve team performance within the aircraft maintenance environment. In response to this need, this research looked at the role of team training and specifically that of advanced technology for team training. A controlled study was conducted to evaluate the effectiveness of advanced technology for team training. The study was conducted in two phases: the instructional phase, wherein 18 subjects received training through a computer-based team training program; and the remaining 18 subjects received training using a traditional instructor-based equivalent team training program. In the evaluation phase, the subjects were divided into three member teams and performance of the teams was evaluated as they completed a routine and a non-routine maintenance task. The results of the study are reported as part of this paper.

BACKGROUND

In order for the Federal Aviation Administration (FAA) to provide the public with a continuing safe, reliable air transportation system, it is important to have a sound aircraft maintenance system.[1] The 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 the National Plan for Aviation Human Factors) has pursued human factors research.[1,2] In the maintenance arena this research had focused on 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 maintenance procedures more reliable and/or more error tolerant.

Task analyses of aircraft inspection and maintenance activities have revealed the aircraft inspection and maintenance system to be complex, requiring above average coordination, communication and cooperation between inspectors, maintenance personnel, supervisors and various other sub systems (planning, stores, and shop) to be effective and efficient.[1,2,6,7] A large portion of inspector and maintenance technician work is accomplished through teamwork. The challenge is to work autonomously but still be a part of the team. In a typical maintenance environment, first, the inspector looks for defects and reports them. The maintenance personnel then repair the reported defects and work with the original inspector or the buy-back inspector to ensure that the job meets pre-defined standards. During the entire process, the inspectors and maintenance technicians work with their colleagues from the same shift and the next shift as well as personnel from planning, stores, etc., as part of a larger team to ensure that the task gets completed.[1] Thus, in a typical maintenance environment, the technician has to learn to be a team member, communicating and coordinating the activities with other technicians and inspectors. Though the advantages of teamwork are widely recognized in the airline industry,[8] the work culture assigns responsibility for faulty work on individual **AMT**s rather than on the teams in which they work. The reasons for this could be the individual licensing process and personal liability, both of which often results in AMTs and their supervisors being less willing to share their knowledge and work across shifts with less experienced or less skilled colleagues. The problem is further compounded since the more experienced inspectors and mechanics are retiring and being replaced by a much younger and less experienced workforce. Not only do the new AMTs lack knowledge or skills of the far more experienced AMTs they are replacing, but they are also not trained to work as team members.

The earlier problem of the development of individual **AMT** skills has been continually addressed by **FAA**. For example, the proposed **FAR** Part 66 (new AMTs certification requirements) specifically addresses the significant technological advancements that have taken place in the aviation industry and the advancements in training and instructional methods that have arisen in the past decade. The FAA, through the Office of Aviation Medicine, has also funded efforts for the development of advanced training tools to train the AMTs of the future.[1,2,9] These advanced tools (e.g., Boeing 767 Environmental Control System tutor -- ECS and multimedia System for Training Aviation Regulations -- STAR) will be available to **A&P** schools. It is anticipated that the application of these new training technologies will help reduce the gap between current AMT skills and those needed for the maintenance of advanced systems.

However, the **AMT**s joining today's workforce are lacking in team skills. The Aircraft Maintenance Technology Schools (AMTS) provide the necessary technical skills for students to receive both their airframe and power plant certificates (A&P License). The curriculum for AMTS is specified in the Code of Federal Regulations, and presently does not address any instruction in teamwork skills. In fact, the current technical school environment encourages students to compete, and as a result, the AMTs are often ill-prepared for cooperative work. To prepare student AMTs for the workplace, new ways have to be found to build students' technological, interpersonal and socio-technical competence by incorporating team training and communication skills into their curriculum. Furthermore, the importance of teams has also been emphasized in the National Plan for Aviation in Human Factors [1,2,10] where both the aircraft industry and government groups agreed that additional research needs to be conducted to evaluate teamwork in the aircraft maintenance/inspection environment. Recent work has examined the effects of team training when applied to students at an Aircraft Maintenance Technology School. Using a previously designed framework for the study of team training in the aircraft maintenance environment, Gramopadhye in a pilot study found a positive correlation between team skills training and the improvement of team performance and overall task performance in an aircraft maintenance situation.[11] In addition, the study concluded that student AMTs needed to be provided with team skills instruction to prepare them for the teamwork tasks found in the aircraft maintenance environment. However, the study did not address issues related to the appropriateness of a particular training delivery system. The question that begs to be answered is: What is the best method to present team skills training?

With computer based technology becoming cheaper, the future will bring an increased application of advanced technology to training. Over the past decade, instructional technologists have provided numerous technology-based training devices with the promise of improved efficiency and effectiveness. Examples of such technology include computer simulation, interactive video discs and other derivatives of computer based application, several of which have been employed for diagnostic maintenance training.[4,12,13] Furthermore, multimedia has assisted in teaching difficult and complex skills.[14] Layton stated that the domain of aircraft maintenance is rapidly becoming the focus of computer-based training (CBT) aids.[15] With the use of desktop computers with multimedia packages, new maintenance job aids have been developed to teach technical skills to maintenance technicians. **AMT**s may learn a variety of skills from CBT that range from scheduling preventive maintenance to applying expert systems for fault diagnosis and repair. Lufthansa Airlines believes so strongly in CBT that they have instituted CBT with video overlays to update the technical skills of their maintenance technicians.[16] Andrew also described various multimedia technologies that have been effective in simulating combat situations for team training in the military.[17] Because of the advantages offered, computer-based training may have a role to play in team training in the aircraft maintenance environment. It is important, therefore, to examine the effectiveness and applicability of computer-based multimedia team training for aircraft maintenance technicians. To date, however, no one has examined the role of the advanced technology, specifically computer-based multimedia presentation, for team skills training for aircraft maintenance technicians. The express purpose of this research was to address this knowledge gap, and to determine the best methodology to improve team training for aircraft maintenance technicians.

Thus, the general objective of this research was to understand the role of team training and specifically that of computers for team training. As part of this effort, a computer-based team training software, the Aircraft Maintenance Team Training (AMTT) software, was developed and a controlled study was conducted to evaluate the effectiveness of computers for team training.[18] The study evaluated the transfer effects of computer-based team training and addressed usability issues related to using computers for team training. The methodology and results from the controlled study are described in greater detail in the following paragraphs.

METHODOLOGY

Test Site

The controlled study was conducted at the Aircraft Maintenance Technology Center of Greenville Technical College (GTC). The center houses both classrooms for **A&P** training and a fully equipped hangar for conducting aircraft maintenance and repairs. The classrooms at the Aircraft Maintenance Technology Center provide seating for 20 students. Each classroom was equipped with a 25-inch color television, video player, overhead projector, white and black boards, and a lectern. In addition, the classrooms are equipped with four Pentium 75 MHz computers and 15-inch color monitors (1024 X 768 resolution) installed with multimedia packages.

Test Subjects

The subjects for this study consisted of 12 students from a local aircraft maintenance technology program and 24 licensed **A&P** mechanics from a local aircraft maintenance facility. The subjects were compensated for their participation. The 36 subjects were randomly assigned to two groups such that each group had an equal number of subjects from the aircraft maintenance technology program and maintenance facility, respectively.

Group IBT - Instructor-based Training: received team training instruction through traditional instructor-based training (IBT)

Group CBT - Computer-based Training: received team training instruction through multimedia computer-based training (**AMTT** software)

Experimental Procedure

The study was divided into two phases: the instructional and evaluation phases.

Instructional Phase

Team Training

Subjects in the **IBT** group were trained on team concepts using a traditional instructor-based training delivery system, while those in the **CBT** group received similar training on a computer using the **AMTT** software. Every effort was made to maintain a constant curriculum and presentation sequence for both the groups. The only difference in the training between the two groups was the type of delivery system. The team skills training focused on the following four separate skills: communication, decision making, interpersonal relationship, and leadership. More details on the structure and content of the team training program can be found in Gramopadhye.[18] It should be noted that in the instructional phase, team training was provided to individuals, and teams were not formed until the evaluation phase.

Data Collection

Data was collected on subjects' perception of each team skill before and after training using the team skills protocol report. The reports in this research used elements from the Crew Resource Management/Technical Operations Questionnaire (CRM/TOQ), the modified Taggart's questionnaire, Taylor's questionnaire, and the Critical Team Behavior Form (CTBF).[19,20,21] Similarly, changes in subject's team skills knowledge was measured using a 20-question multiple choice test administered before and after training.

At the conclusion of training all subjects completed a two-part usability questionnaire. The questionnaire collected subjective satisfaction ratings on the training delivery system using a seven-point Likert scale. The first part of the questionnaire, referred to as the General Questionnaire, contained questions relevant to both the training delivery systems, and was completed by subjects in both the groups. The General Questionnaire addressed usability issues related to: content, mechanics of presentation, format, and usefulness. The second part of the usability questionnaire was training delivery system specific, and addressed usability issues related to the presentation and format. This was completed by subjects in the respective groups.

Evaluation Phase

This phase examined the transfer effects of team training (**IBT** and **CBT**) on **AMT** performance. Upon completion of the instructional phase, subjects in each group were randomly assigned to six three-member teams. Following the assignments, the teams were charged with performing two tasks representative of normal aircraft maintenance.

Task 1- Routine maintenance task: determining the center of gravity of an aircraft

Task 2 **-** Non-routine maintenance task: trouble shooting an electrical problem on an aircraft.

The order in which the tasks were performed was balanced within each group so that three teams performed the routine task followed by the non-routine task, while the order was reversed for the remaining three teams. To reflect a true maintenance environment, work cards were supplied to all the teams which provided general instructions.

Data Collection

As the teams performed the routine and non-routine tasks, their performance on the tasks was evaluated by three independent evaluators on measures of: speed, accuracy, and safety. In addition, at the conclusion of the routine and non-routine maintenance tasks, the evaluators and each individual subject completed a questionnaire evaluating their team on the application of various team skills (communication, decision making, interpersonal relationships and leadership).

Task Performance Evaluation

Routine Maintenance (RM) Task

Accuracy: Number of errors or number of times the team's procedure differed from the work card

Number of times an improper tool was used

Number of times equipment was handled incorrectly

Safety: Number of times the safety of the aircraft was in jeopardy

Number of times the safety of an individual was in jeopardy

Speed: Time to complete each sub-task

Percent of task completed within allowed time

Non-routine Maintenance (NM) Task

Accuracy: Was the problem diagnosed correctly?

Did the team locate the problem?

Did the team fix the problem?

Speed: Time to diagnose the problem

Time to locate the problem

Time to fix the problem

Total time

Safety: Number of times the safety of the aircraft was in jeopardy

Number of times the safety of an individual was in jeopardy

Instructor's Evaluation

Upon completion of the routine and non-routine maintenance tasks, the evaluators completed a verbal protocol report, evaluating the teams on various team performance measures (communication, decision making, interpersonal relationships and leadership skills). The instructor's evaluated each team on the application of team skills using a seven point Likert scale. The score for each team was obtained by averaging the scores provided by the three evaluators.

Self Evaluation

Upon the completion of the **RM** and **NM** tasks, all subjects completed a verbal protocol report that was identical to the instructor's report. This allowed the individual team members to rate the performance of their team on the application of team skills (communication, decision making, interpersonal relationships and leadership).

RESULTS

Instructional Phase

The responses on the team skills verbal protocol report were analyzed using an analysis of variance (ANOVA). Separate scores were obtained for each individual skills component after ensuring that it was appropriate to group the responses into an aggregate measure.[22] The ANOVAs showed a significant Trial effect for communication ($F(1,34) = 9.37$, $p < 0.05$) and leadership skills ($F(1,34) = 10.44$, $p < 0.05$). However, the main effect of Trial was not significant for interpersonal relationship and decision making skills. The analysis did not reveal any significant Group x Trial interaction effect or Group effect.

Similar **ANOVA**s conducted on the pre- and post team skills knowledge scores showed a significant Trial effect for communication (F (1,34) =, $p < 0.001$), decision making ($F(1,34) = 112.10$, $p < 0.001$), interpersonal relationships ($F(1,34) = 42.1$, $p < 0.001$) and leadership ($F(1,34) = 14.36$, $p < 0.001$). The

Group x Trial interaction effect and the main effect of Group were not significant.

Separate **ANOVA**s were conducted for each usability category (general categories: content, mechanics, layout, usefulness; delivery system specific categories: presentation, format). The analyses of variance conducted on the general part of the usability questionnaire did not reveal any significant differences between the groups on each of the four usability categories. A two tailed t-test was used to compare the actual mean scores versus expected mean scores (3.5) on delivery system specific issues. The tests revealed that the subjects rated both the training programs significantly high on presentation and format related issues.

Evaluation Phase

The subjects and instructors evaluated the teams on their application of team skills. **ANOVA**s conducted on the aggregated self-evaluation scores for communication, decision making, interpersonal relationships and leadership did not reveal any significant differences between the **IBT** and **CBT** trained teams for both the routine and non-routine maintenance tasks. A similar result was also observed on the instructors' evaluation of the teams on the various team skills measures. ANOVAs conducted on the various task performance measures did not reveal any significant differences between the IBT and CBT trained groups. Correlation analysis performed on the various measures showed a positive correlation between the post training knowledge test scores and the time to complete the maintenance tasks ($r = 0.4683$, $p < 0.05$), between accuracy measure and the use of communication skills ($r = 0.4322$, $p < 0.01$), decision making skills ($r = 0.341$, $p < 0.05$) and interpersonal relationship skills ($r = 0.4661$, $p < 0.0042$). Similarly, correlation analysis of safety scores revealed that the teams which had higher communication, decision-making, leadership and interpersonal relationship scores had significantly fewer safety violations ($r = -0.5702$, $p < 0.001$; $r = -0.8062$, $p < 0.0001$; $r = -0.5312$, $p < 0.0009$; $r = -0.4719$, $p < 0.0112$).

DISCUSSION AND CONCLUSIONS

The analyses of the pre- and post-training perception verbal protocol reports showed that the training delivery system had comparable effects on the subject's perception of team skills. It was interesting to note that the subject's overall (pre- and post-training) perception of interpersonal relationships and leadership skills were much lower than those for communication and decision making skills (**Figure 8.1**). The subjects that made up the test Groups consisted of either students or maintenance technicians, and as such were not composed of crew leads or supervisors. It can be hypothesized that non-supervisory technicians do not recognize the importance of leadership and interpersonal relationship skills. This lack of concern for leadership skills was first noted by Taylor.[7] In a survey of ten US commercial transport aviation maintenance facilities, Taylor found a lack of leadership skills in maintenance foremen. In addition, work currently being conducted under a grant from the **FAA** Office of Aviation Medicine has identified a need for leadership skills training for lead mechanics and maintenance foremen.[23]

Both the **IBT** and **CBT** groups showed a significant increase in the post-training knowledge test scores (**Figure 8.2**). The fact that both groups showed almost a comparable increases in test scores probably indicates the effectiveness of both the methods of delivering team training. The results are consistent with those of other researchers who have found similar results in improving team skills by training. Taylor conducted a crew resource management (CRM) training program for aircraft maintenance personnel, and found that maintenance performance measures increased after training.[24] Also, in a study to improve teamwork in engineering design education, Ivaturi found that team training instruction enhances students' knowledge of team skills.[25]

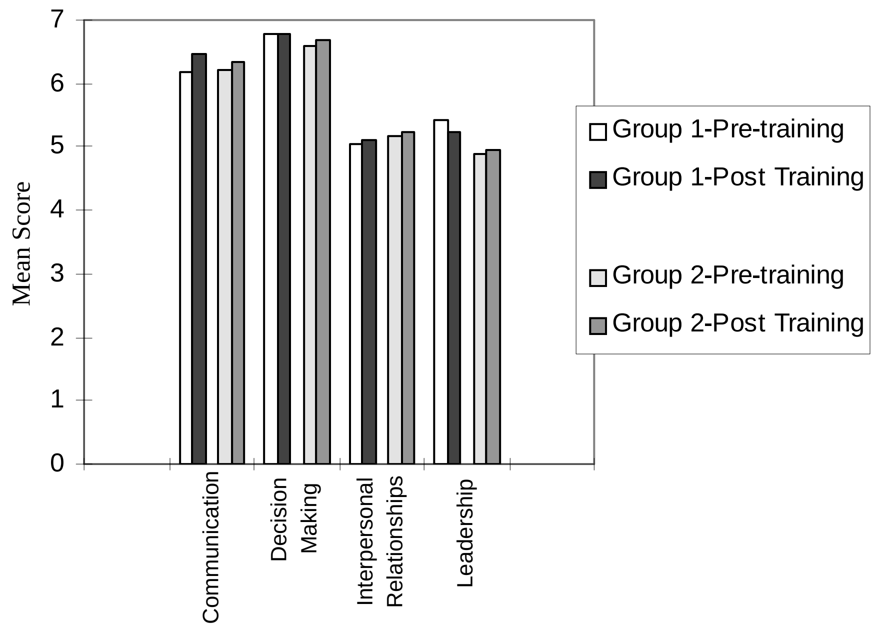

Figure 8.1 Comparison of Team Skills Perception Pre- and Post Training for Groups 1 and 2

Traditionally, team training has been delivered in a classroom environment by role playing, games, simulations, etc.[17,26] Thus, the conventional approach has been highly interactive wherein the trainees and trainers interact at different levels throughout the training process. The fact that the **CBT** (specifically, the **AMTT** software) was able to achieve the same scores as **IBT** (an equally well developed classroom team training program) bodes well for the role of computers in imparting team skills knowledge. At this point, it should be mentioned that the IBT portion of the team training program had the same content as the CBT portion and the only difference was in the method of delivery. This shows that, given the equivalent content of the two team training programs, a well designed interactive computer-based team training program can be as effective as a traditional instructor-based team training program.

The development of the **AMTT** followed an iterative design process so that the problems with the software were identified and corrected before implementation. The cycle of design, test, measure and redesign was repeated a number of times in the development process.[27] Thus, the AMTT software was developed after understanding the needs of the **AMT**, talking with experts from Lockheed Martin and Greenville Technical College, following a process of iterative design and development and eventually resorting to detailed user testing (with instructors, supervisors and AMTs). The usability and knowledge test scores clearly indicate that the resulting product was one which was well received by the users and one that helped increase their knowledge on the teamwork skills. **Figure 8.3** shows the results of the general usability questionnaire with mean scores on four separate usability issues. These results are encouraging since they indicate that the users were equally satisfied with both the training programs. Chandler found similar results using a media-rich computer software (System Training for Aviation Regulations - STAR) to teach federal aviation regulations (FARs) to **A&P** students.[28] In her study, the subjects reported a high degree of satisfaction with interactive stories and true-to-life situations presented through **CBT**. Comparable satisfaction levels between users of hypermedia and paper-based team training programs were also noted by Ivaturi.[25]

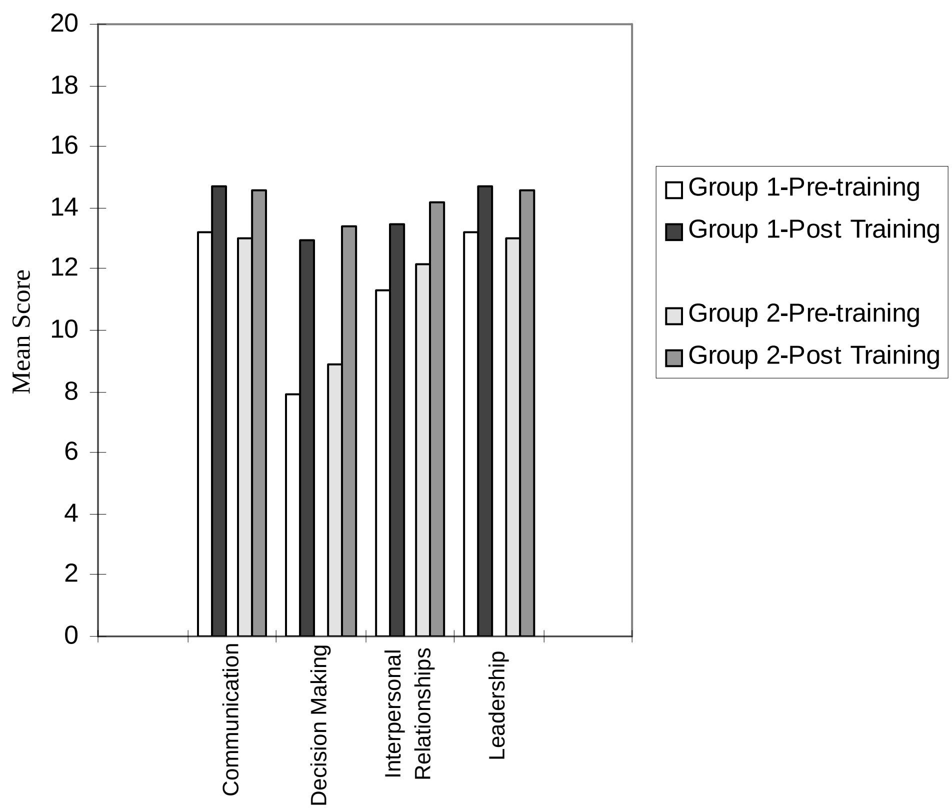

Figure 8.2 Comparison of Team Skills Knowledge Tests Pre- and Post Training for Groups 1 and 2

After analyzing the results for both the **CBT** and **IBT** teams, the results are unambiguous. It is clear that CBT (i.e., **AMTT**) was as effective in delivering team training instruction as IBT. Finally, the iterative design methodology employed in this study proved to be useful in designing an effective computer based team training software. The above results have obvious ramifications for the use of AMTT for team training in the aircraft maintenance environment. In addition to being as effective as existing instructor-based team training methodologies, use of AMTT for team training has other obvious advantages:

Standardization: **AMTT** provides a systematic and consistent curriculum. Aircraft maintenance instructors at various facilities use their own unique training strategies (lectures, classroom discussions, video examples, etc.). In addition, some maintenance instructors who are technically competent may not have sufficient team skills knowledge to train **AMT**s on teamwork. The AMTT software provides a standardized and systematic team skills training program which aircraft maintenance instructors (at certified repair stations, airline companies, general aviation stations, and **A&P** schools) can use to provide team skills training.

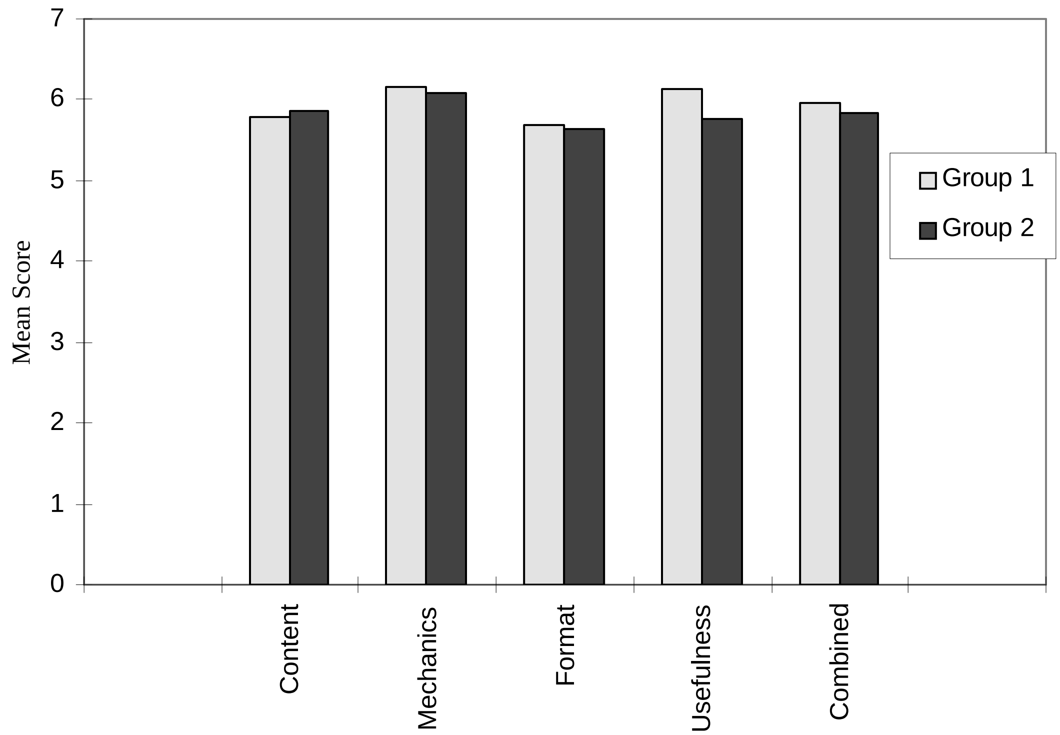

Figure 8.3 Comparison of Usability Scores for Groups 1 and 2 on Training Delivery Issues

Adaptability: Traditionally, maintenance training has been accomplished via on-the-job training or classroom training, both of which are manpower intensive. It requires careful scheduling of personnel or encumbers others in the training process. **AMTT** is adaptive, self-paced and can be done at convenient times when trainees are available and need only involve the person being trained.

Record Keeping: The record keeping capabilities of **AMTT** tracks the student's progress. This information can be used by the instructor/supervisor to design remedial training.

Cost effectiveness: Team training using **AMTT** can be cost effective because: (1) It can be delivered on-site thus eliminating travel expenses for the trainer and the trainee. (2) It can minimize down-time by providing training at times that are convenient to the trainee and the company's work schedule. In larger organizations, AMTT can be delivered to many people at multiple sites thus proving to be cost effective.

Use of advanced technology: Many facilities (e.g., **A&P** Schools and fixed based general aviation facilities) do not have access to larger aircraft. The **AMTT** software provides team skills training against the backdrop of maintaining a DC-9. Thus the trainees not only acquire knowledge and skills on teamwork, but gain an understanding of the importance of teamwork in the maintenance of wide-bodied aircraft.

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9.0 MRM: IT CAN'T BE CRM RE-PACKAGED.

Ronald J. Lofaro, Ph.D
FAA:AAR-433

INTRODUCTION

This paper makes these major points: (1) **CRM** training is neither an effective nor an appropriate paradigm for use in developing **MRM** training; (2) MRM development and delivery is repeating mistakes that early CRM made; and (3) to develop quality MRM training, we must face and deal with the basic issues and questions that - as yet - it has ignored or avoided. The rationale and the impetus for the current direction of MRM training will be stated. We will look at CRM, past and present. The basic components of CRM and its delivery model will be examined as they relate - or, do not relate - to the development of MRM training. Finally, a series of recommendations will be offered as to what the maintenance community, to include **AMT**s, can and must do to re-direct and re-develop quality MRM.

MRM FROM CRM?

A historic conference was held in Washington, DC in early 1995. This conference had over 900 top-level representatives from the Aviation Industry, Labor and the Federal Government. **DOT**/**FAA** published, in February of 1995, a seminal document based on the efforts of 6 major work groups at that conference: *Zero Accidents....A Shared Responsibility*.[1] Later in 1995, a follow-on meeting was held in New Orleans and another document, larger and more detailed, was developed. This document, *DOT/FAA Aviation Safety Plan*, provided instructions on how to accomplish the initiatives set forth in *Zero Accidents*.[2,1] The *Aviation Safety Plan* also provided a matrix for each initiative so that progress on each initiative could be easily charted and followed.[2]

In the section on maintenance and inspection of *Zero Accidents*, a facile assumption was made that the new training seen as necessary for reducing **AMT** error was to use **CRM** as a model.[1] This new training called **MRM** was to be based on existing CRM. This assumption quickly achieved the status of a fact, became almost a mantra and was not questioned -- rather, it was acted on.

In doing so, the basic issues and questions that must be faced and answered in developing quality training were, seemingly, fluffed off. This naive acceptance of what has increasingly proven to be an incorrect assumption has put **MRM** at risk -- at risk of going down some of the same garden paths of early **CRM**; at risk of being ineffective; at risk of failure.

It seems some **MRM** has taken some of the worst of early and middle **CRM**. It is true that some (most?) current MRM has a case of "the emperor has no clothes." By this, it is meant it has no basis, no foundational rationale, no clear and measurable performance objectives and no one seems willing to publicly say this. Until now.

A Chilling Experience at 35,000 Feet

I first had some of these thoughts, and fears, on a flight from **DFW** to **PHL**. As I sketched them out, I wondered if they were the product of too many long flights; too much airline food; or simply too much travel where you sometimes get into a Twilight Zone, which blurs reality and fantasy. One antidote was to make a reality-check call to an old friend and colleague. This person is a former **NTSB** accident investigator who fought for a human factors component in aviation accident investigations, a former **FAA** scientist who worked on **CRM** and decision making for pilots, a former chief scientist at the **USAF** Safety Center, who championed CRM and, in his earlier life, a maintenance chief and mechanic in the USAF. So, I called Dr. "X" (more than once) and we spent quite a bit of time kicking my thoughts and fears around. I then spoke to a CRM expert, now in maintenance/safety at a major aircarrier; to a trainer for a major flight training company; and 3 or 4 others with experience and expertise. We agreed that "MRM ain't CRM." One result of these talks is this paper.

Closer look at CRM

History & Problems:

CRM, in some form, has been with us since the very late 1970's. By 1997, CRM is an integral part of aircrew training used by the carriers, is mandated by the **FAA** (**SFAR** 58 and the 1996 changes in **CFR**14, Part 121) and the **USAF** (Air Force Instruction 36-2243). The tendency is to view CRM in terms of the status and success that it has achieved over the past 6 to 8 years. But, we also tend to forget or ignore some of both the early and current problems of CRM training. It is no secret that some of the early CRM training was far from an unqualified success. This was due both to some of the people who were allowed to develop and deliver it and to some of the course content. There were misguided and inappropriate course materials; some courses that were completely focused on "soft" skills; the view of aircrews that CRM was only a "charm school" or only a box to be checked to appease the company they worked for and/or the FAA; the "crow like a rooster" exercises used by some former sensitivity trainers, T-Group leaders and re-tread management trainers trying to stake a claim to CRM training. Early CRM training became a target of opportunity for these former trainers; for psychologists looking for a second career; for people who had peripheral, if any, experience and expertise in flight operations. A cottage industry of CRM trainers and training arose.

What followed was not unexpected. Pilots asked how this "soft stuff" could help them in the cockpit. Flightcrew saw little relationship between the course and "flying the line." Further, many gave no credibility or credence to some of the people who delivered **CRM**, people whom the airline pilots said did not have the flight deck credentials to instruct them in being a better crew. These were the two key issues: the lack of credibility for some of those delivering the courses, and, by extension, those who developed the courses and the course content itself. Not until CRM developers faced and resolved these valid concerns did CRM begin to take hold.

One major change was that many major air carriers soon involved their pilots as the prime movers in both course content and course delivery. Additionally, true **CRM** experts and some of the CRM instructors at the air carriers had united to begin addressing these vital issues: (1) What are the crew performance indicators, on a **LOFT** scenario (a realistic flight from point A to B to be flown in the simulator) that showed CRM skills? (2) What event-sets do you build into the LOFT scenario, or a check-ride, that gave the crew the opportunity to demonstrate that CRM training had an effect on their crew/individual performance? (3) How do you best develop CRM scenarios? Again, what crew and individual performances and decisions do you look for? and (4) What are the relationships between CRM trained skills and resulting flight control and safety skills and actions?

As **CRM** training began to shift its focus to the integration of CRM skills with flight control skills, as CRM focused on **LOFT** scenarios as the place where CRM skills could be observed and assessed, CRM began to achieve real acceptance in the pilot community. CRM development and LOFT development became interrelated at carriers; in **ATA** work groups and in **FAA** reports. When CRM was flightcrew-developed and taught, and had a much more specific content, i.e., content that was centered around real problems with "flying the line," then CRM gained a measure of acceptance. However, even that acceptance is not as unequivocal as it once appeared.

American Airlines, in July of 1996, set aside **CRM** as they were doing it. Their reason was that their flightcrews had valid objections to, and concerns about, CRM. "CRM was too often viewed as a number of interpersonal issues that simply do not define the problems that we face in aviation."; " CRM training will most likely always be defined and suffer in terms of the first generation of courses.".. which were seen as "touchy-feely," "getting along," and "managing human relations or resolving personality conflicts" rather than dealing with truly important concerns.[4] American's new focus will be on preparing flightcrews for the daily challenges of normal and abnormal operations encountered "flying the line." Delta Air Lines, in the same time-frame, has revamped their CRM for New Captains' course and are calling it "In Command." As with American, Delta is emphasizing leadership, responsibility and performance. In 1996, we see these two major carriers eschewing the "I'm ok, you're ok" thrust of some CRM. United's version of CRM was, and is, called C-L-R, where the C is for Command and the L is Leadership, so it seems that United has already gone past the "touchy-feely" aspects of CRM and on to the performance issues. Yet, even United is changing aspects of CRM for 1997.

In sum, **CRM** has recently undergone several changes at three major carriers. It seems CRM was neither the silver bullet nor as universally accepted as we thought. All too many of the CRM "lessons learned" are being overlooked by **MRM**. Much of the MRM that is being developed and given is focused on exactly what CRM is abandoning as ineffective, non-productive and poorly received by the target audience

CRM Components: The Three Basic Clusters and Their Categories

Communication Process and Decision Behavior Cluster

(Categories)

Briefings/Debriefings

Inquiry/Assertion

Crew Self/Critique

Conflict Resolution

Decisions

Communication

Team Building and Maintenance Cluster

(Categories)

Leadership/Followership

Focus on Tasks/Focus on Operations

Interpersonal and Group Climate

Automation

Work Load Management and Situation Awareness Cluster

(Categories)

Planning-Preparation-Vigilance

Workload Distribution

Distractions and other Avoidance

Behavioral Performance Markers

The categories within the clusters are further subdivided into behavioral/performance markers. These markers can be used as performance identification assessment tools. Each category has as many as eight performance markers (**Appendix**).

Decision-Making (DM) and Situation Awareness (SA)

At this time, DM and SA have become, (always were?), separate entities. There are conflicting views as to whether **CRM** encompasses aeronautical decision making (ADM) and SA or, whether ADM encompasses CRM and SA and so on. However, the bottom line is that good people are working these areas and there is a host of data, reports, **R&D**, articles and books on them that should be consulted and used as appropriate.

The CRM Three Phase Training Model: Initial Indoctrination; Operational; Recurrent

1. Initial Indoctrination/Awareness Phase: 4 to 16 hours. This introduces **CRM**, the history and rationale for its development, often uses one or two accidents where poor coordination or communication cost a hull and lives, and/or one where CRM is seen as saving lives (e.g., United 232).

2. Operational Phase: 2 to 3 days. The emphasis is on crew performance: the learning of **CRM** skills with the demonstration and the practice of these skills in a full-up flight simulator, by means of a **LOFT**

scenario -- which is taped, with a playback/feedback/critique session afterwards.

NOTE: The first and second phases can be, and often are, rolled into one 3 to 4 1/2 day session.

3. Operational Reinforcement: Usually, this is formally done in Recurrent training as yearly Recurrent training is mandatory for flightcrew. This phase takes into account that **CRM** skills decay over time. Therefore, (some) CRM training is often incorporated into Recurrent and, at some carriers, in seminars, practice sessions, "batting practices," etc.

NOTE: This model has evolved since 1978 or so; it still is evolving. This model may not exactly "fit" the CRM training of any given carrier, but, it should be fairly close. Further, changes in Part 121 have made **CRM** mandatory in any **AQP** program.

CRM and MRM: Similarities, Differences and Recommendations:

Before we look at the components of **CRM** to see how either they differ from, or are similar to, what **MRM** needs to encompass and, before we consider how best to use these CRM similarities, a few large, generic and significant differences between CRM and MRM need to be spelled out.

The Audience: Aircarrier crew usually have a fairly uniform level of college education, often have military training and flying experience; have a highly-prized license, the **ATP**, and are over 30 years old. They are a group which has a pride of accomplishment in what they are and do; see themselves as very special, highly trained and highly professional; and, the pilot group is "closed" to non-pilots.

The Team: While the flight crew is a team, even if an ever-changing team, the **CRM** training given them on team functioning is applicable on every leg they fly. Most **AMT**s do not work in formally organized and structured teams even if some carriers and companies are trying to change this.

The Environment and "Climate": While Part 121/135 and corporate flightcrew usually belong to a union of sorts (**ALPA** or **APA**), most **AMT**s belong to a more typical union (**IAM**). A unionized workplace in terms of restraints and constraints on what can be done for and with the workforce, must be factored into any **MRM** training development and delivery.

Assessing Learning and Skills: Another major difference between **MRM** and **CRM** is that there is no maintenance equivalent of a flight simulator or **LOFT** scenarios. There is currently no place where a realistic (but safe) hands-on assessment of what an **AMT** has learned in MRM can be done, an assessment that demonstrates whether or not an AMT has both learned new MRM skills and applies them "on the job." This may be changing as CAE now says that it has a maintenance training simulator.

FAA Regulations: Flightcrew training requirements and performance assessment are highly regulated. There have been very recent changes to **FAR** 121.427;.406;.421 that mandate **CRM** especially in any Advanced Qualification Program (AQP). Additionally, CRM training is usually given during the mandated yearly recurrent training at the major carriers.

In Sum: The **CRM** audience is extremely homogenous; they perform the same function of flying (revenue) passengers from point A to B; they have extremely similar educational and experiential backgrounds and most vital, they are legally "in charge" and responsible when they are on the flight deck. The CRM skills they learn can be assessed in **LOFT** scenarios with no danger to an aircraft or crew.

Finally, changes to 14 **CFR**, Part 121 mandates CRM training.

Very little of the above is true of an **MRM** audience. **AMT**s do very varied tasks, from engine overhaul to micro-chip replacement on a flight management computer. AMTs have differing levels of education and their prior experiences can range from the proverbial "mom and pop shop" to a Part 121 carrier. Maintenance simulator environment is being developed but does not now exist at the major carriers. AMTs do not have Federal Regulations which make them the ultimate decision-maker. However, they are responsible, ("on the blame-line"), for their actions. MRM training is not now mandated by the **FAA**.

Major "Components" of CRM and Differences from CRM; Applicability to developing MRM

CRM	**MRM**
1. Communication CRM is based on a 2/3 person cockpit crew plus the cabin crew and now, at some carriers, dispatch. These people are together 2 to 14/15 days at a clip. The cockpit crew works off **SOPS**/check lists/manuals. The focus of this component of CRM is the pre-flight briefing; crew inquiry-advocacy-assertion of courses of action; the crew self-critique at debriefing; free and open communication; conflict resolution.	At this time, few if any, carriers have implemented a team concept. The structure of a flight crew versus a maintenance crew has some similarities, except for the authority and responsibility of the Captain. The concepts of inquiry and free and open communication are a "must" in any functional organization.

Recommendations: Develop **MRM** communication modules based on tested communication concepts (active listening as a major example). Blend in a focus on the types of communication, especially in the areas of conveying the results of trouble-shooting, that **AMT**s/foreman have. In-house development of this module would best be done by an in-house team, in a very structured workshop. The team should be composed of AMTs, foremen, middle-level and upper management, plus one **CRM** expert and one non-company expert in facilitation.

CRM	**MRM**
2. Decision-Making (DM) The decisions of a flightcrew are usually time-compressed; only involve 2/3 persons; have immediate consequences. There has been shown to be a specific process/typology for Aeronautical Decision Making (ADM).[9,10] **NOTE:** This should be a separate module.	The process for making decisions by an **AMT**, or an AMT crew, ordinarily are just the opposite as those of the flightcrew. However, studies of decision-making on the job (naturalistic DM) show that each profession develops a unique DM style; one that can be analyzed, taught and enhanced.

Recommendations: Use known experts in decision-making, especially those in naturalistic, team **DM**, to develop the typology, process and training for **AMT** DM.[7]

Coordinate this effort with an across industry structured workshop to incorporate the best of **ADM**/**CRM** and the requirements of industry for **AMT**/**DM**. Let the workshop findings feed into what the experts developed above.

CRM	**MRM**
3. Situation Awareness This SA needed by a flight crew invokes an ever changing, and quickly changing, environment where loss of SA has the possibility of quickly leading to disaster.	There is little analogy in maintenance to the situation awareness needed by a flightcrew. However, just as the SA experts on the flight side have developed the concept-components-process-training for flight crew SA, it is reasonable to expect that the same thing could be done for maintenance SA.

Recommendations: Basically, the same as for **DM**. It may well be that the Situation Awareness (SA) required in the maintenance environment by an **AMT** or an AMT crew varies greatly from a flightcrew's SA. "Attentional Awareness" seems more appropriate to the maintenance environment. There has been work done in this area that can apply to developing analogous **MRM** training.

CRM	MRM
4. Workload Management CRM emphasizes managing workload and time to maximize crew efficiency; distributing the workload to maximize efficiency, and clearly communicating this distribution; active monitoring and vigilance (weather, systems, **ATC**, instruments) and clearly sharing relevant information with other crew members; planning and preparation, and finally recognizing and avoiding distractions.	This would seem to be one CRM area that holds real promise for MRM. What should be emphasized here is shift work; changeover; fatigue.

Recommendations: Develop an **MRM** workload training module. In this module, use must be made of the many studies on workload; on shift work; on fatigue. Develop the MRM workload training module (at least the requirements and content areas for this MRM component) through a process which invokes and makes full use of the experts in **CRM** in management, in fatigue, and in shift work.

CRM	MRM
5. Team Building and Maintaining the Team This cluster emphasizes leadership/ followership, concern for tasks, interpersonal relationships and group climate.	This CRM component has great potential for developing MRM analogs. But, we must be aware of the differences between flightcrew and maintenance crews. Also, this aspect of CRM has consistently been an issue with flightcrew especially the view that CRM was only a way to keep people happy; a "charm school."

Recommendations: "Leadership/followership," "concern for tasks" and task completion are very relevant to maintenance. However, the building and maintaining of a flightdeck, or "extended" (cabin crew, dispatch, other) flight ops team, and the team approach to tasks and responsibilities, would need to be modified for maintenance ops---at the worker level and above.

At this point, consideration could be given to an **MRM** training approach that was multi-level, involving middle and upper management. This could be done either in a "diagonal slice" method or separate training for management levels.

What Now?

The Basic Step

The first order of business must be to inspect and evaluate the **CRM** training model and its components, in order to ascertain what is not a part of CRM and needs to be included in **MRM** training development.

This is best done by:

(1) a small cadre of **CRM** experts to provide insight and explanation of the CRM training components

(2) a small cadre of **AMT**s

(3) a small cadre of aircarrier maintenance mid-level and also upper management

(4) a small cadre of developers and instructors for maintenance training

The Basic Questions:

(1) Who should develop the training?

(2) Who should be trained?

(3) What should be trained?

(4) a. How do you introduce the training?

b. Where should training take place?

c. How much training is required?

(5) What are the (performance) objectives?

We have the **CRM** answers for these questions, but we must be aware that over the years, the CRM answers have varied and changed and, in at least 3 major carriers, were significantly changed as late as 1996.

Recommendation and a Start Point

MRM training developers need to attempt a difficult task: To go back to Square One and, at the same time, quickly go forward. This can be done if there is a realization that what can be gotten from **CRM** training is limited. Even more important, realize that neither the expertise within the CRM community nor the "lessons learned" of CRM have been, as yet, effectively used.

The basic philosophy of **CRM** and the basic three-phased model of CRM training are good starting points and paradigms. The emphases of CRM on improved performance and safety; on how to identify what the CRM training should contain; on where and how the CRM training should be given to enhance performance; on aiding effective decision-making; on raising safety to new levels. All of these must be made part of **MRM**.

But, in order to do this, we must go back to Square One. Begin by discarding incorrect assumptions that **MRM** can be made in the image and likeness of **CRM** and still have MRM be both accepted by **AMT**s and effective in enhancing safety. Go back to Square One by not taking the quick and easy pseudo-solutions to the tough issues in developing MRM. And beware the quick "fix." Rather, work with the CRM experts ***and*** the AMTs to develop effective, quality MRM training.

As the first step past the "new" Square One, start with what it took **CRM** long years to do... deal with the "what" and the "how" of identifying the specific performances and behaviors that do make a difference in **AMT** performance. Then, develop the particular and specific training elements necessary to achieve improved AMT performance and professionalism. In this effort, CRM and maintenance subject matter experts (SME's) are the key players. Much of the burgeoning MRM training area has neither used CRM experts nor AMTs as the SME cornerstones on which to build. Further, there are powerful and effective tools (knowledge engineering) for using the subject matter experts (SMEs) as the integral part of training development.[9,10,6,12]

Step two is to design a Phase I **MRM** awareness course that is closely and inextricably linked to the **AMT**s job and function. If not, the AMTs will see MRM as a "touchy-feely" deal which their management seems to want, but has no value to their day-to-day work. In this, as in step one, **SME**'s and the knowledge engineering methodologies mentioned above can be used.

The third and most important step is to develop the content of the operational phase (Phase II) so that it is not only maintenance-specific, *but measurably improves performance and reduces error.* This will entail identifying what are the maintenance performance areas (e.g., paperwork errors, reduced air turn-backs) we are looking for improvement in. Then, identify or develop the metrics to be used to verify this improved performance.

What of the AMT?

There is both preventive "maintenance" and proactive "maintenance" to be done. On the proactive side, **AMT**s can be aware and make their company aware that MRM training is being developed and given. Indicating to their company that **MRM** benefits both the AMT and the company's bottom line--cost reduction through error reduction is one example. AMTs can keep after their company to either send them to an MRM course, or to develop and give company-specific, in-house, MRM training.

The preventive aspect comes into play thusly: If the company decides to do in-house **MRM** training, make sure that you, the **AMT**, is involved from the beginning in MRM course development. AMTs must be the subject matter experts (SMEs) used to develop MRM training--and to instruct the MRM courses. Perhaps the AMT can be teamed with a trainer in this course delivery effort. Make sure, if the company contracts out for MRM training, that the MRM contractor has personnel qualified in aviation and aviation maintenance. Make sure that the MRM course the contractor proposes to give is developed using AMTs, not simply swiped from an existing **CRM** course. And, if the contractor proposes to develop the MRM course specifically for your company, make sure you, or other AMTs are used as SMEs in the course development.

If your company chooses to send you, or you choose to go on your own to an **MRM** course, ensure that is being given by an established, reputable training company. Make sure that the training company addresses how the course was developed and who the developers were. When you take the course, not only give feedback to the training company, but to your company and your fellow **AMT**s. Spread the word.

When you evaluate the **MRM** course for feedback, please be aware of that rosy glow that comes from having a paid time off from work for training and for training that is usually given in a nice environment. Please try not to let being treated as "first-class citizens" sway your objective and critical evaluation of the course. The training company wants, and needs, accurate feedback to improve the course. Your company and friends need the feedback so that they can choose future MRM training wisely.

And finally, if the company elects to hire a contractor to come in and deliver the **MRM** training in-house, make very, very sure that someone has checked into the aviation and aviation maintenance background, qualifications and experience of the contract personnel. This action cannot be too highly emphasized.

And, stay aware as well as making your company aware, that as a colleague of mine says, there are some snake-oil sellers out there, many of whom will vouch for each other. So, try to find an objective source to consult about a contractor.

"What If?"

We must be aware that Flight Ops and flightcrew get the lion's share of "attention"--be that "attention" in the form of visibility, training, money or just recognition from their company. **CRM** could afford to make mistakes it did and to take 8-10 years to coalesce because CRM was for the flightcrew. **MRM** will not have this extended "grace period." MRM will not have the luxury of feeling its way, of having growing pains, of being allowed years to form up, of making mistakes along the way. MRM training may well have one shot; at most two, before it is asked to prove its value or disappear.

If, and until, the **MRM** training now being developed changes direction and goes back to Square One, MRM training may well fail in one or all of three ways.

1. Fail by not being seen as valuable and not accepted by the working **AMT**.

2. Fail by not making any real difference in AMT performance.

3. Finally, fail to survive long enough to make the changes in the **MRM** development process, course content and instructional personnel necessary to make it a success.

If the Aviation Industry does go back to Square One, there are three outcomes. First, **MRM** training gets better and better--as the courses being developed get more and more specific to an **AMT** and to improving job performance. Secondly, the field of MRM training is put on a solid basis and footing. Finally, aviation safety improves, making all of us proud to be a part of the improvement and a little more relaxed when we ourselves fly.

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APPENDIX

CREW PERFORMANCE MARKERS

Revision A (4/18/91)

CLUSTER	CATEGORY	MARKER	ASSESSMENT
C: Workload Management and Situational Awareness	8: Workload Distribution/ Distractions Avoidance	1) Workload and time are managed to maximize efficiency.	1 — 2 — 3 — 4 — 5
		2) Workload is managed to maximize crew efficiency.	1 — 2 — 3 — 4 — 5
	This is a rating of time and workload management. It reflects how well the crew managed to distribute the tasks and avoid overloading individuals. It also considers the ability of the crew to avoid being distracted from essential activities and how work is prioritized.	3) Time is managed to optimize crew performance.	1 — 2 — 3 — 4 — 5
		4) Workload distribution is clearly communicated and acknowledged to maximize efficiency.	1 — 2 — 3 — 4 — 5
		5) Stays "ahead of curve" in preparing for expected or contingency situations (including approaches, weather, etc.	1 — 2 — 3 — 4 — 5
		6) Ensures that secondary operational tasks (i.e., dealing with passenger needs, company communications) are prioritized so as to allow sufficient resources for dealing effectively with primary flight duties.	1 — 2 — 3 — 4 — 5
		7) Recognizes and reports overloads in self and others.	1 — 2 — 3 — 4 — 5

1	2	3	4	5
Poor Performance Significantly Below Expectations	Minimally Acceptable Performance Improvement Needed	Satisfactory or Standard Performance	Very Good, Above Average Performance	Exceptional Performance Significantly Above Standard

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He has published well over 50 articles and book chapters on Crew Resource Management (CRM); Line Oriented Flight Training (LOFT); Aeronautical Decision Making (ADM); aviator selection and classification; Air Traffic Controller selection; aviation safety; aircrew/pilot training and performance evaluation; aviation security human factors. Ron has been an invited member of the Air Transport Association's (ATA) CRM and Line Oriented Flight Training (LOFT) groups and is now on their Aviation Maintenance Human Factors sub-committee and on The **SAE** G-10 Behavioral Engineering Technology Committee. His professional affiliations include membership in the Aerospace Medical Association/Human Factors; The American Psychological Association; The Association of Aviation Psychologists and The Human Factors and Ergonomics Society.

He has three graduate degrees plus post-doctoral work encompassing clinical and counseling psychology, philosophy and education. After completing his doctorate at NYU, Ron spent 12 years as a University professor. Prior to his graduate studies, Ron served as a **USAF** flight officer.

As an aviation psychologist, Ron has worked for the past 15 years on human factors **R&D** in flightcrew training, performance and assessment; on civil aviation security, and, for the last 18 months, on human factors in aviation maintenance.

10.0 MAINTENANCE HUMAN FACTORS AND ERROR CONTROL

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INTRODUCTION

The goal of reducing human errors in maintenance operations can best be attained through a comprehensive application of human factors principles that goes beyond awareness training in resource management skills. Such an approach must consider the selection and training of personnel, the tools provided to perform the work safely and effectively, and motivational factors. Delta is working toward a full integration of human factors to increase safety in all of our operating divisions. This paper will discuss our efforts to fully integrate sound human factors principles in Technical Operations and in our airport ramp operations.

Corporate Human Factors: A Brief History

Formal human factors integration at Delta Air Lines began in the late 1980's when Crew Resource Management (CRM) training was introduced in our Flight Operations division. The goal of this training was, and continues to be, to provide our pilots with awareness and training in six "non-technical" skill areas: communication, crew coordination, planning, decision making, workload management, and situation awareness management. The introduction of CRM training, in conjunction with a concerted effort toward standardizing flightdeck procedures, was widely credited with increasing the safety and effectiveness of our flight operations system wide.

In 1995, the Corporate Human Factors group was established within the Corporate Safety and Compliance department. The primary mission of this group is to provide services that support the integration of human factors principles throughout the corporation. In addition to working with Flight Operations, Corporate Human Factors provides assistance and support for the development of human factors programs in the Technical Operations (maintenance) and Airport Customer Service (ramp operations) divisions.

The Integration of Human Factors Principles

From the applied perspective of air carrier operations, the primary goal of human factors integration in maintenance (or other operations) is increased safety through a more effective management of human errors that result in injuries and damages. Greater efficiency and improved employee morale are important and desirable by-products of human factors integration; however, safety improvement remains the highest priority.

Typically, the primary means through which human factors principles are formally introduced into an operational domain is through the development and implementation of resource management training programs. As we noted earlier, this is how human factors was introduced into our flight operations; and, as we shall describe, resource management training is an important piece of our approach to human factors integration in maintenance and ramp operations.

Delta Air Lines believes that resource management awareness training is a necessary, but insufficient, piece of a comprehensive approach to Human Factors integration. We recognize that for human factors principles to be fully integrated into our operational environment, it is necessary to look beyond resource management training and to consider other areas of application such as personnel selection, task resources, and motivational systems **(Figure 10.1)**. A high quality training program presented to poorly qualified personnel will yield marginal benefits at best. Similarly, the effective training of improper or poorly designed procedures will not result in improved performance. And, unless the desired behaviors are recognized and reinforced in daily operations, they are likely to extinguish over time.

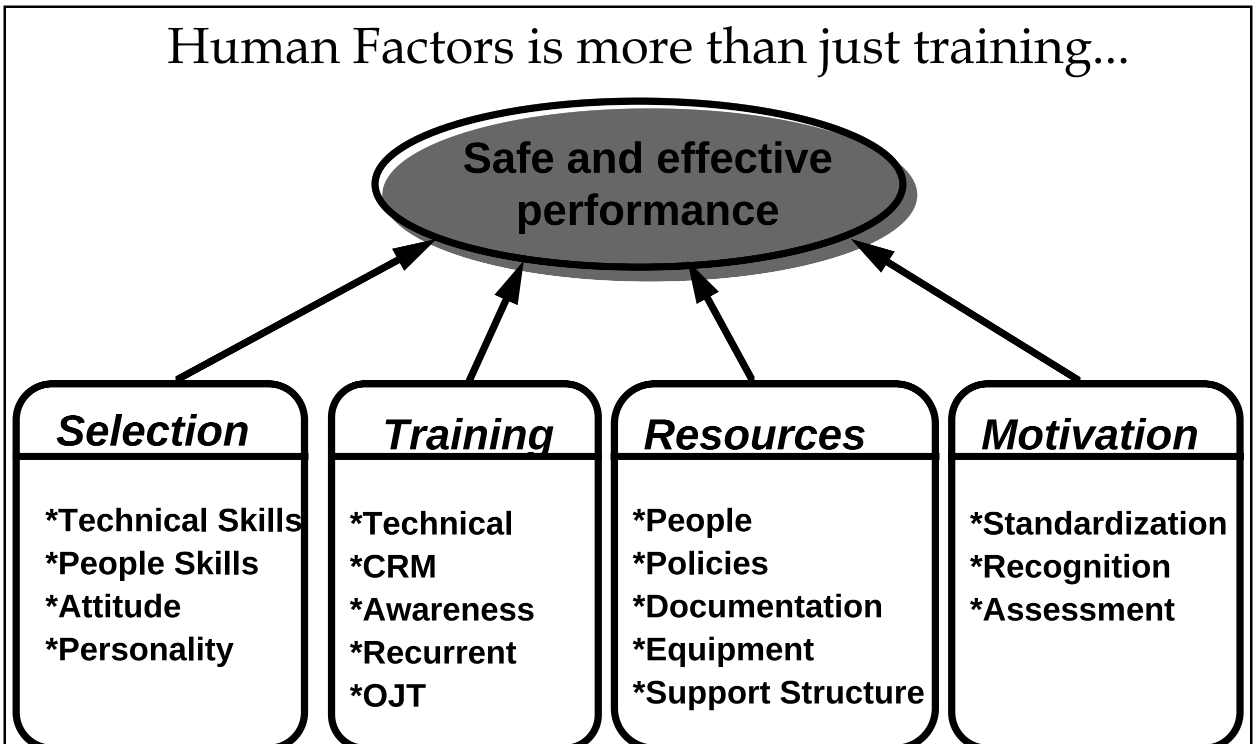

Figure 10.1 A Model for Integrating Human Factors

As we continue to work toward our goal of increased safety through the integration of sound human factors principles, we are taking advantage within each operational domain of opportunities to impact each of the above areas. It has been our experience that while the principles apply across domains, the approach to integration can vary from one domain to the next. In **Chapter 9**, Dr. Lofaro describes many of the differences between **CRM** training for pilots and **MRM** training for mechanics. We have also found that flexibility in the "packaging and delivery" of human factors principles is necessary. The next sections present the initiatives that we have undertaken to date in our maintenance and ramp operations to achieve a full integration of human factors principles.

MAINTENANCE HUMAN FACTORS INITIATIVES

Maintenance Resource Management Training

As a part of our efforts to reduce human error in maintenance, Delta is nearing completion of the development of an initial Maintenance Resource Management (MRM) training course for all Technical Operations employees. This 2-day course will provide awareness and instruction in the key resource management skills of communication, decision making, planning, workload management, situation awareness management, and crew coordination.

Consistent with a primary focus on safety, the **MRM** course will make extensive use of actual accidents and incidents as case studies for illustration and discussion. Gordon Dupont's "Dirty Dozen Errors In Maintenance" (**Chapter 7**) will be used to provide a framework for discussing how breakdowns in essential resource management skills can subsequently result in injuries and damage to equipment.

Measures of training effectiveness in terms of desirable shifts in employee attitudes, behaviors, and overall operating performance are recognized as critical to the success of the our **MRM** training program. A baseline survey of employee attitudes was developed with the assistance of Dr. Jim Taylor of the Institute of Safety and Systems Management at the University of Southern California. The survey was adapted from the Crew Resources Management/Technical Operations Questionnaire (CRM/TOQ) used by Dr. Taylor in previous research dealing with post-training attitude shifts among maintenance personnel.[1] The CRM/TOQ is derived from the Cockpit Management Attitudes Questionnaire (CMAQ), which was originally developed to assess flightcrew attitudes and subsequently modified for use with maintenance personnel.[2] The CRM/TOQ includes a battery of items designed to tap employee attitudes about leadership responsibility, communication & coordination, recognition and management of stress, and the willingness to voice disagreement. In addition, items measuring respondents' perceptions of safety practices in Technical Operations were included in the survey, as were items that capture attitudes about goal setting and goal attainment.

A similar survey will be administered to employees shortly after they have completed the **MRM** training course and at regular post-training intervals to assess the immediate and long term impact of training on attitudes. Additionally, we recognize that the goal of MRM training is not simply to change attitudes, but rather to effect behavior change. Therefore, Delta is working with Dr. Taylor and representatives from other airlines to identify and establish behavioral measures and operational performance indicators that can be used to assess training effectiveness.

Lead Mechanic Selection and Training

Perhaps no other group of employees has a greater impact on the daily performance of Technical Operations than our front line supervisors: lead mechanics and foremen. These individuals are responsible for managing resources on the hangar floor or on the flightline to ensure that Technical Operation's safety, reliability and customer service goals are met. Also, the success of behavior-based training programs such as **MRM** largely depends upon the support of front-line supervisors. To the extent that front line supervisors support and reinforce on a daily basis the behaviors taught in the training program, the program will succeed. If the principles and behavioral skills are not reinforced, the training will be only minimally effective in changing attitudes and behaviors.

It became apparent to management that, although the overall performance of lead mechanics was high, there was unacceptable variability in the performance capabilities of these key personnel within our hangar maintenance operations. Moreover, the areas in which management saw the need for improvement were not technical skills, but rather, non-technical skills such as planning, workload management, and decision making. This prompted a review of the selection criteria and training program for lead mechanics and foremen in our hangar maintenance department.

In the past, lead mechanics in hangar maintenance were nominated and selected through a majority vote of their peers. Obviously, this approach did not always ensure that the best qualified candidate got the job! Currently, candidates for lead mechanic positions are nominated through majority vote by their peers, and the top three candidates are interviewed and the selection is made by a management selection committee. While the current selection process represents an improvement over the past, we have undertaken a program of research to systematically develop selection criteria, and to develop a training curriculum that better meets the needs of our lead mechanics.

As a first step, lead mechanics in our Atlanta hangar maintenance, avionics, hydraulics, and paint departments were given an attitude survey similar to the **CRM/TOQ** discussed in the previous section (**Maintenance Resource Management Training**). The survey also included items related to preferred leadership style and several open response questions pertaining to topics such as challenges of the job and perceived training needs. As an independent effort, we have also asked managers in each of the participating departments to evaluate their lead mechanics on a variety of performance dimensions. The survey responses will be correlated with the performance assessments in an attempt to identify desirable attitudinal characteristics.

Currently, we are in the process of encoding and analyzing the survey data. We have completed preliminary content analyses on the responses to the open ended questions, and the pattern of results on those questions appear to support our expectation that the most challenging aspects of being a lead mechanic, and the challenges respondents were least prepared for, are not technical issues. The tabulated responses to the questions, "What is the most challenging part of your job?", "What aspects of your job do you feel you were least prepared for?", and "What are the most important skills you need to be effective in your current position?", reveal that interpersonal and other resource management issues are reported to be the most challenging **(Table 10.1)**.

Table 10.1 Responses to Survey Questions from a Sample of Lead Mechanics

What is the most challenging part of your job?	No. of responses

Human relations/dealing with people	22
Meeting "ready times"	12
Motivating mechanics	7
Coordinating different departments	5
Workload (# of aircraft)	4
Dealing with the corporate 'system'	4
Staying current with technical issues	3
New hire employees	3
Time management	3
Constant changes	3
Doing everyone's job	2
Other (1 each)	4
What aspects of your job do you feel you were least prepared for?	
Human relations/dealing with people	23
Paperwork	12
Computers	11
Lack of training	5
Many skills to know (avionics,eng.,etc.)	4
Policies and procedures	3
Other (1 each)	4
What are the most important skills you need to be effective in your current position?	

People skills	30
Communication skills	27
Technical skills	17
Computer skills	10
Listening skills	6
Organizational skills	5
Decision making skills	5
Management/supervisory skills	5
Leadership skills	4
Coordination skills	3
Motivational skills	2

The responses of the lead mechanics to this set of questions reinforces our awareness that there is an additional set of non-technical skills that lead mechanics must master to become effective leaders. As our data and our anecdotal experiences have shown us, technical proficiency is necessary but not sufficient for effective leadership. As a result, we are conducting further investigations to identify the specific behavioral components in each of the skill areas that contribute to being an effective lead mechanic. Our findings eventually will be fed back into the training curriculum for new lead mechanics, and will enable us to develop a more refined set of tools for identifying and preparing promising candidates for lead mechanic positions early in their careers.

Maintenance Error Reporting Programs

As we stated earlier, the goal of our human factors efforts is to reduce the human errors that result in maintenance-related injuries and damages. It is therefore critical that we develop valid and reliable measures of system performance that relate to that goal and of the behaviors that drive that performance. We are participating in a working group of the Air Transport Association's Subcommittee on Human Factors in Maintenance and Inspection that is focusing on identifying system performance indicators related to human error management.

We are also currently in the process of reviewing the functions and capabilities of our existing incident reporting and tracking system, our Quality Assurance auditing processes, and our Continuous Analysis and Surveillance (CAS) program to determine whether features of these programs can be tailored and consolidated to capture the behavioral antecedents and systemic failures that contribute to incidents and accidents. In addition, we are considering the use of available off-the-shelf incident reporting and tracking systems such as Boeing's Maintenance Error Decision Aid **(Chapter 3)** and the Aurora Mishap Management System **(Chapter 6)**.

It is also important that we develop mechanisms and a safety culture that promote two-way communication in the identification, reporting, and resolution of issues related to maintenance error in the workplace. This effort will require that we address our internal disciplinary systems, the role of regulatory authorities, and emerging use of the Aviation Safety Reporting System (ASRS) by our maintenance personnel. A grass roots culture must be nurtured within our organization that will support the open reporting of errors and incidents without fear of a "cop on the beat" response from management. We are optimistic that one way in which we can foster a more open reporting culture is through the use of our Continuous Improvement Teams (CIT) program. These teams focus on identifying and implementing process and workplace safety improvements within Technical Operations. We believe that the CIT program can be applied to identifying, reporting, and resolving human factors concerns as well.

RAMP HUMAN FACTORS INITIATIVES

Although the focus of this workshop and these proceedings is the application of human factors principles to maintenance operations, we believe it is worthwhile to briefly discuss some ongoing human factors initiatives in our airport ramp operations. While the general model that drives our human factors efforts on ramp is the same, the operating and training environments for ramp personnel present a different set of constraints and opportunities for integration.

For example, the aircraft handling activity that surrounds the arrival or departure of an airplane is relatively scripted and constrained in time and space. Therefore, the accomplishment of the task is relatively easy to observe and evaluate--in contrast to many maintenance tasks, which require the coordinated activity of several departments over a period of hours, days or weeks. As a result, one of the initiatives described below involves the real time coaching and evaluation of resource management skills on the ramp. Such a program would be difficult to implement in many maintenance operations, but may have potential for application to certain tasks (for example, engine changes). The following sections are therefore provided to illustrate other methods through which human factors might be applied to reducing human error.

Ground Operations Manual (GOM)

In the Spring of 1996, Delta introduced a Ground Operations Manual (GOM) to increase the procedural standardization of airport ramp operations. Prior to the release of the GOM, it was recognized that there was considerable variability in the performance of aircraft handling procedures throughout the system and that this variability contributed to an unacceptable rate of preventable ground damage events. It was common for new employees to learn procedures through verbal coaching on the job. Many station-specific procedures were never written down and were passed along orally from experienced to inexperienced employees. This teaching technique worked effectively as long as Delta maintained an experienced, stable work force. However, when cost-cutting initiatives were introduced in the early 1990's, many of the highly experienced employees accepted early retirement offers and left the company--taking with them this "corporate knowledge." This, in combination with an increased use of contract services, resulted in a disruption to the previously reliable transfer of procedural information. It soon became apparent that a more explicit means of providing procedural guidance was needed; thus, the GOM was developed.

The **GOM** describes the role expectations--in terms of specific, observable behaviors--for each member of a ground crew engaged in aircraft handling procedures on the ramp. It was recognized early on that behavioral expectations needed to extend beyond technical performance, and should also include expectations for performance in traditional resource management skill areas. As a result, the first chapter in the GOM is entitled, "Human Factors" and provides explicit behavioral expectations in the areas of: communication, crew coordination, workload management, planning, situational awareness, and decision making. For each of these skill areas, a definition of the general concept, a behavioral objective, and specific behavioral expectations for Team Leaders/Lead Agents and all team members are included in the GOM **(Table 10.2)**.

Table 10.2 Example of a Human Factors Skills Section from the Delta Ground Operations Manual (GOM)

Communications

Definition: The exchange of thoughts, messages or information by speech, signals or writing.

The activity, both verbal and non-verbal, that is used to transfer information between members of the team.

Speak up for anything you see that is unsafe, irregular or not in accordance with procedure. Stop the operation if necessary. Any deviations from briefings or procedures should be communicated immediately.

Some keys to proper communications are:

Team Leader/**AIC/ALA**

- Establish and reinforce communications with all team members
- Conduct briefings on operational requirements and expectations
- Ensure that all team members understand their roles
- Communicate changes in a timely manner

All Team Members

- Listen actively and ask questions when unsure
- Use standard terminology and signals
- Give and accept constructive feedback
- Know what is expected of you

Classroom Training

With the development of an explicit set of observable behaviors for each of the skill areas in the **GOM**, we have established a set of behavioral standards that can be trained to. As a next step, we began the development of training programs designed to increase awareness and build skills in each of the six resource management areas. Our goal is to introduce and reinforce resource management concepts and skills throughout the entire training career of our ground operations personnel.

New Hire Training

All new hire employees on the ramp are required to attend a basic ramp operations training course. Resource management skills are being integrated into this course to provide awareness and skills development from the first day on the job.

Ramp Resource Management Training

This course is being developed for all current ramp employees and management, and will provide a general overview of the resource management concepts and skills covered in the **GOM**. The course will highlight -- using actual accidents and incidents -- how failures in the skill areas can result in injuries, aircraft ground damages, and a negative impact on customer service.

Huddle for Excellence Recurrent Training

All Delta ground crews involved in handling aircraft in the gate area are required to conduct a "Huddle for Excellence" prior to the arrival or departure of each flight. In this "huddle," proper aircraft handling procedures are reviewed, task assignments are made, and the gate area is checked for **FOD** and ground service equipment. As part of the "Huddle for Excellence" program, all personnel are required to attend annual recurrent training on aircraft ground handling procedures. We are using this annual recurrent training as an opportunity to reinforce ramp resource management skills and to address human factors areas of special concern.

Resource Management OJT

Recently, we successfully completed a trial program at our Atlanta hub which involved the coaching and assessment of resource management behaviors on the job (OJT). A team of selected ground operations personnel were provided resource management skills training and instructed on observation, assessment, and coaching of resource management skills. Using a resource management behavioral assessment form developed for use on the ramp, this team spent a week in each gate area evaluating and coaching the performance of ground crews. At the beginning of the week, the team conducted a pre-training assessment of the ground crews observed. The team then spent four to five days working with and coaching the ground crews on the desired behaviors. At the end of the week, a post-training assessment was conducted and a follow-up assessment was conducted one to two months later.

Preliminary analysis of the behavioral assessments suggests that the **OJT** coaching resulted in sustained increases in the use of desired resource management behaviors; and, the desired behavioral changes appear to correlate with reductions in ground damage incidents. We are currently working on further developing this program and expanding participation to stations outside of Atlanta.

We are encouraged that this program can potentially provide ongoing reinforcement of resource management skills. Additionally, the performance assessments obtained by the coaching teams can provide a basis for tracking performance improvements and undesirable behavioral trends over time. This information can be used to revise or enhance our training programs and procedures, or to identify additional resource needs related to ramp operations.

SUMMARY

The initiatives that we have undertaken thus far in our maintenance and ramp operations represent the beginning of a comprehensive approach to reducing human error through the integration of human factors principles. This approach recognizes that, to be successful, we must extend beyond resource management training and into areas such as personnel selection, policies and procedures, and recognition/evaluation programs.

It has been our experience that human factors principles apply across operational domains. However, an organization must be flexible in its integration methodology. An initiative that works well on the hangar floor may not work well or apply easily to the ramp or in the component shops.

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Employed since July 1995 as Manager, Human Factors in the Corporate Safety and Compliance Department at Delta Air Lines. Among his responsibilities at Delta is the development and application of Human Factors principles and training in each of the operating divisions. Prior to coming to Delta, Dr. Predmore was a Research Specialist in the Office of Research and Engineering at the National Transportation Safety Board (NTSB) in Washington, D.C. He was project manager and principal author of the NTSB's 1994 study on Commuter Airline Safety, and co-manager on the NTSB's 1994 study on flightcrew-involved accidents. Dr. Predmore received a Ph.D. in Social Psychology in 1992 under Dr. Robert Helmreich at the University of Texas. He conducted graduate research on flightcrew communications, the development and evaluation of Crew Resource Management (CRM) training programs, and pilot selection methodologies.

11.0 A PROACTIVE ERROR REDUCTION SYSTEM

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A PROACTIVE APPROACH TO ERRORS

Considerable effort has been expended by airline personnel and human factors researchers in trying to identify errors in aviation maintenance. The aviation maintenance environment is a large and complex socio-technical system with many opportunities for error and well-established safety systems to prevent error propogation. Inspectors and mechanics must utilize documentation, tools, and other personnel to detect, document, and repair faults within the constraints imposed by both the physical environment and the organizational environment. Since it is the inspectors and mechanics themselves who are ultimately responsible for identifying necessary faults needing repair, and for judging whether repairs are adequate, many errors can be identified at some level as a human error.[1] Thus, high importance has been placed on identifying human errors in the maintenance system, and for reducing the possibility for future errors.

The aviation industry and the FAA have identified reducing human error by as a major contributor to improving the safety and reliability of aviation. The FAA's Office of Aviation Medicine (**FAA/AAM**) has been conducting research throughout the 1990's on Human Factors in Airline Maintenance. Researchers, ourselves included, have been examining all facets of the airline maintenance environment in an effort to improve performance, reduce errors, and match the abilities of the mechanics with their work, by giving them better tools with which to perform their jobs.

During the last six years, various maintenance and inspection processes have been analyzed through observations, task analyses, and other research efforts to identify potential errors in the system. Audits have been developed for both inspection and maintenance tasks to help identify problems in the system which may result in errors.[2] Mechanics have been surveyed, and human factors task forces formed, to help identify more subtle socio-technical problems existing in the maintenance system. In addition, analysis of historical error data has allowed hazard patterns of typical errors to be developed, and latent failures in the maintenance system to be identified. The challenge is to fuse these disparate elements into coherent error management systems.

As a starting point for this integration, in 1995, our team examined many errors that are committed in the maintenance environment, including: ground damage incidents, paperwork errors, on-the-job injuries (**OJI**), rework situations, late finds, etc. For each of these error outcomes, we were able to use a small number of repeating patterns of behavior to classify the errors. Where the data would suport it, we used event trees to relate these patterns to underlying human (and other) factors, i.e., root causes. We concluded that there is a relatively small set of common root causes which can lead to different error outcomes in the maintenance environment. Thus, by eliminating (or reducing) these common root causes, it will be possible to prevent mechanics from committing a large number of errors. In order to eliminate the underlying causes of problems, it is necessary to make changes in the maintenance system. The "blame and train" approach is often not sufficient, as it affects only one or two individuals in the system rather than the system itself.

There has also been significant interest in improving the manner in which airline maintenance personnel record errors and track their incidence by location and over time. The Maintenance Error Decision Aid (MEDA), developed by Boeing for use by the airlines, is one tool that has been introduced to help airlines track low-level errors in the maintenance environment. MEDA was initially intended to allow airlines to share error data with the rest of the industry, which would allow airlines to learn from each other. However, this feature was not widely accepted by the industry, since few maintenance departments were willing to release their error information publicly. However, MEDA does provide maintenance personnel with an additional tool for tracking errors.

In fact, considerable time, effort, and money is spent in the identification and tracking of some errors. For example, there are clerks whose entire job is the checking of paperwork for errors, and programs have been set up within airlines to investigate errors when they occur. Other airlines have invested heavily in the purchase of commercially available error reporting systems.

Our previous research has indicated that airlines typically have many error reporting systems in use simultaneously. Injuries, ground damage, paperwork errors, etc. are all recorded in separate error reporting systems. Some errors, such as rework situations, may not even be explicitly captured in any of the existing error reporting systems. However, maintaining separate reporting systems based on error outcomes is not efficient in monitoring error root causes, since many error outcomes result from a similar set of root causes. For example, if a mechanic drops a wrench on his foot it is recorded as an **OJI**, but if the wrench is dropped on the aircraft, it is recorded as a ground damage incident. Maintaining different reporting systems requires significantly more effort to identify, and ultimately address, common root causes. In particular, the potential savings associated with an intervention may be considerably underestimated if only a single error outcome is counted.

Another result of our previous research is that the same types of errors occur repeatedly in the airline maintenance environment. These errors are often predictable, and are not unexpected by either the mechanics or management. Maintenance personnel are often familiar with these errors, and management often have tools available to help them identify error-prone situations. However, similar errors continue to occur in the airline maintenance system. This leads to the conclusion that the difficulty is less how to recognize the human factors problems (actual and potential errors), than how to move from recognition and analyses of the problem to usable solutions. Help is needed in guiding maintenance personnel in making changes in the system before errors can repeat.

A Proactive Error Reduction System (PERS) has been developed to meet this need of airline maintenance personnel. PERS can be used to foresee, and thus prevent, typical errors. The system is essentially a database of solutions, which have been shown to successfully address problems in the airline maintenance system. Users can search the database to find potential solutions, either to errors that have occurred, or to known potential error causing situations.

Goals of PERS

Three distinct functions were identified to ensure **PERS** is an effective error management tool: an error reporting/tracking function, a means of predicting future errors, and a way to find alternate solutions to error problems. First, PERS must include an error reporting system which, like current reporting systems, allows errors to be investigated and recorded. The error reporting system function should allow many error outcomes to be recorded in one unified system, so that common root causes can be identified and tracked. The system should guide the error investigation to ensure the details of the error, including root causes, are being identified and captured. Interfaces to existing error reporting systems (e.g., **MEDA**) may facilitate acceptance of PERS by airline maintenance departments already using such systems.

Second, **PERS** should allow users to import data other from sources, which are **not** triggered by known errors. Thus, other proactive investigation tools (e.g., Audits, **MESH**, etc.) can be used to identify potential error-causing situations, and PERS can be used to help prevent these errors from actually occuring.

Finally, **PERS** is a way of linking a database of maintenance errors with a database of known solutions. It will contain alternative solutions that can be implemented to help reduce the occurrence of these errors. Users will be able to search this database directly, to find possible solutions for problems that are known to exist in the maintenance environment, regardless of whether an error has actually occured. Within the solution search, information regarding cost, typical implementation time, and success stories should be provided to the user, to allow more educated choices to be made when choosing how to address problems.

These second and third characteristics of proactivity and solution-orientation are what differentiate **PERS** from existing error investigation system. **Figure 11.1** shows the conceptual structure of PERS, and its central role in an error management system. The multiple entry points are shown at the top, with proactive ones on the left and reactive (event-driven) ones on the right. From either potential or known problems, a set of contributing factors are derived and used to find actual or potential Hazard Patterns. These Hazard Patterns and contributing factors are used with the solution database to find appropriate solutions. The user assesses potential solutions against selection criteria to find a subset of usable solutions, which then become part of an on-going error control and management system.

PERS DEVELOPMENT

The three functions of **PERS** (Goals of PERS) have been considered as three distinct modules in the PERS program, and their development will be presented in turn, although the core of the PERS program ensures that these modules can interact correctly. The interface to other data sources has not been considered in this phase of the program, except in the recognition that 'gateways' must be left open for such data transfer to occur. For example, PERS must be able to recognize output from proactive tools such as audits, to provide solutions that can prevent errors from occurring. PERS must also be capable of importing data from other error reporting systems, to allow solutions to be found for errors that have already occurred and that have been recorded in an alternate form.

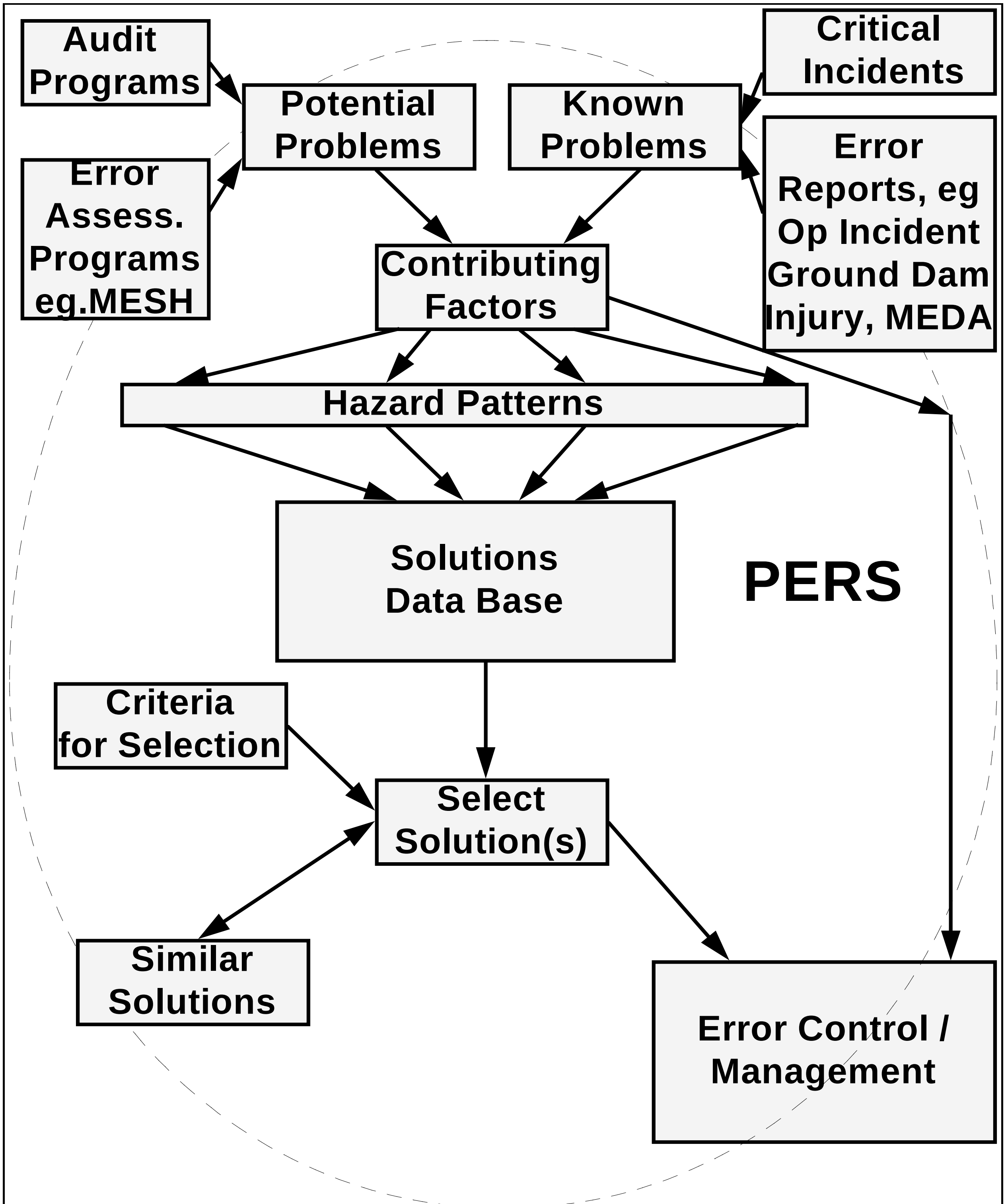

Figure 11.1 Conceptual Structure of PERS

Error Reporting System

The development of a unified error reporting system is not a trivial problem. It is necessary to balance the need for extensive information about an error, with practical usefulness in an airline maintenance environment. A system must contain enough narrative information to allow root causes to be identified and classified, but should not necessarily require a two day investigation of each error that occurs. It is important, however, to remember that the information gained from an error reporting system reflects the effort that was expended in recording the information. More time and energy spent capturing and recording an error usually results in a richer error report, containing more useful information and leading more obviously to root causes and hence to solutions.

In developing an error reporting system, it is necessary to consider who will be completing the error investigations: maintenance personnel, or human factors professionals, as the tools for these users may look completely different. For example, human factors professionals may be better able to answer general questions based on a human factors model of causal factors (**TOME**, **SHEL**), e.g., "Describe how the environmental factors contributed to the error." On the other hand, maintenance personnel may be better suited by questions more tailored to the actual error, e.g., "Was it raining while the task was being performed, and if so, how did the rain affect task performance?" Since most airlines do not have sufficient human factors personnel available to investigate all errors that occur, the second approach may be better suited for the airline maintenance environment.

It is also important to consider the types of responses that will be required of the error investigators. Answers can range from selecting a suitable response from a predetermined list (checklist approach), to requiring investigators to write long narratives describing the situation. Our analysis of existing error databases has indicted that narrative responses usually provide more, and more usable, information than checklist responses. For example, the checklist approach to **MEDA** has restricted the amount of information recorded about an incident to a point where it is even difficult to reconstruct the chain of events leading to the error. However, narrative responses require personnel to write lengthy descriptions, and writing is not a skill most airline personnel enjoy using. In addition, narrative responses take longer for the investigator to complete, and the data is more difficult to utilize. Narrative responses must be carefully analyzed, and the root causes extracted from the narrative, before the data is in a useful form.

A Unified Error Reporting System was developed as part of our previous research. This system, in paper form, leads users through a narrative based investigation system tailored for particular error outcomes. The questions for each error outcome have been developed based on analysis of historical error data, and on the common root causes identified for each type of error. This analysis helps to focus an error investigation on the factors that have been shown to typically result in that type of error. A computerized version of this system will be developed for use in the **PERS** system.

Solution Database Development

In order to make **PERS** a proactive error reporting system, users should be provided with information on how to prevent potential errors from occurring. The objective was to gather a large database of errors from the airline maintenance environment, along with solutions that have been used by airlines to address these errors. This would allow users to learn from the mistakes of others, and to improve their system before predictable errors can occur.

Unfortunately, it has been a very difficult task to collect this solution information. We have found that few airlines have maintained detailed records of solutions that have been implemented, and even fewer have performed follow-up analyses of these solutions to judge how successful they have been at preventing future errors. Some airlines have implemented solution generation as part of their current error reporting systems, by requiring investigators to recommend solutions at the end of an error investigation. For example, investigators of ground damage incidents are required to make a few recommendations as to how to prevent future incidents. However, these recommendations tend to take the "blame and train" approach, in which the particular maintenance personnel involved in the incident are reprimanded, and additional training is suggested for all personnel. Such a strategy has proven singularly ineffective in reducing systemic errors.

In addition, airlines have implemented wide-scale programs intended to address human factors problems within the organization. Maintenance Resource Management (MRM) progams, Task Analytic Training (TAT) sessions, and Total Quality Management (TQM) techniques, such as teams, project ownership, etc., are being used, and their successes documented, as global solutions to problems that are known to exist in airline maintenance systems. Solutions to specific problems, however, are not as well documentated.

It is important the solutions in the **PERS** database reflect more than obvious solutions to known problems. For example, including a solution to "improve communication" will not be useful to address a problem identified to be "lack of communication between leads on consecutive shifts." A better approach is to include specific solutions that have been shown to work in other airlines, or even in other industries. An example of a more specific solution to the lack of communication problem is to "overlap shift start and end times, and require the two leads to walk around each aircraft to ensure a complete turnover of current work information." We are most interested in airline specific solutions, since airline personnel trust this information more than solutions from other industries. However, other solutions from other industries will be included where applicable to the aircraft maintenance domain.

The collection of solutions to populate the database is on-going, and it is envisioned that this will in fact be a continuous process. We are still working with our airline contacts to obtain information about solutions that have been implemented, and as much detail about these solutions as is available. In addition, we are investigating best practices within the airline industry, to allow recommendations to be made for potentially error-causing situations that have been identified according to the human factors literature. So far, all of the documented solutions from the **FAA/AAM Human Factors in Aviation Maintenance conferences** have been collected and included.

PERS STRUCTURE

An overall structure for the **PERS** software has been developed, leaving "gateways" to the modules of the program which will be developed in the future. Most of the effort concentrated on the solution search aspect of the program, with emphasis on ground damage incidents. Ground damage was chosen for this intial phase, since detailed analysis of these incidents has been previously conducted.

The solution search module of **PERS** has three main components. First, the event leading to an actual error, or to a potential for error must be described. Then, the latent and active failures contributing to the error are identified, and finally possible solutions are suggested to address these failures. The initial screen (**Figure 11.2**) allows the user to select the appropriate module.

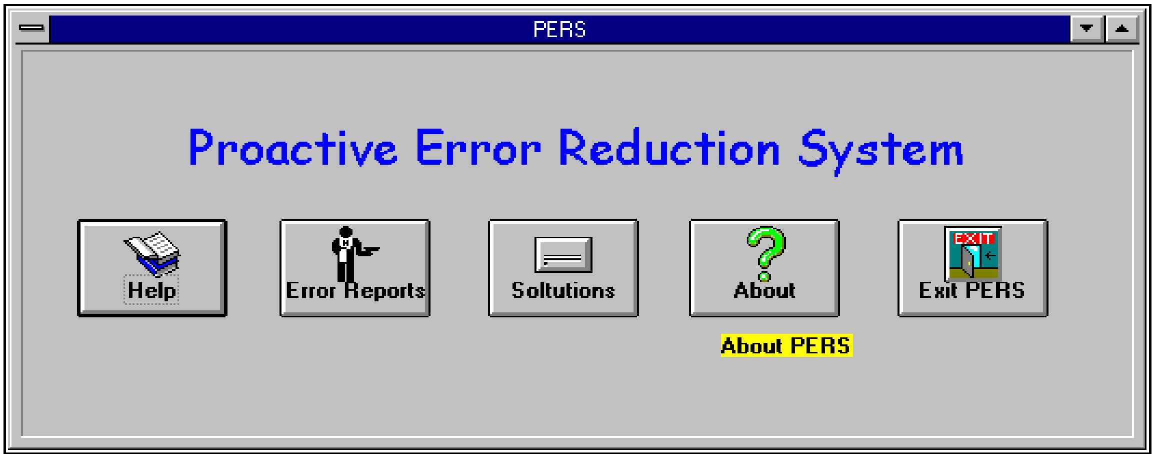

Figure 11.2 Modules of PERS

Error Description and Failure Identification

Ground damage includes damage to aircraft which is caused by airline personnel. It includes damage that is preventable. Damage caused by hail, bird strikes, part failures, and even foreign object damage (FOD) are not recorded as ground damage in the database we analyzed in 1995 covering 130 ground damage incidents recorded by a technical operations department of a major airline over a three and a half year period. (This restricted coverage, e.g. not covering FOD, is one of the problems **PERS** was designed to overcome.) It was determined that there were only twelve distinct patterns of error outcomes that covered all of these incidents (**Table 11.1)** each of which was considered to be a Hazard Pattern. For example, the center of gravity of the aircraft may change unexpectedly, resulting in Hazard Pattern 1.2.1.

Next, each of the incidents were analyzed to determine the specific latent failures that contributed to the incident, and scenarios were developed for each hazard pattern which illustrate the common factors between all of the incidents.

From this detailed analysis, typical event trees leading to the twelve hazard patterns were developed, and the common latent and active failures leading to these error outcomes were identified (**Figure 11.3)**. These event trees were used as a framework to guide users to potential solutions for errors often resulting in ground damage incidents. The user is able to navigate through these trees as the event is described, ending at a list of the common failures (root causes) that often contribute to the event.

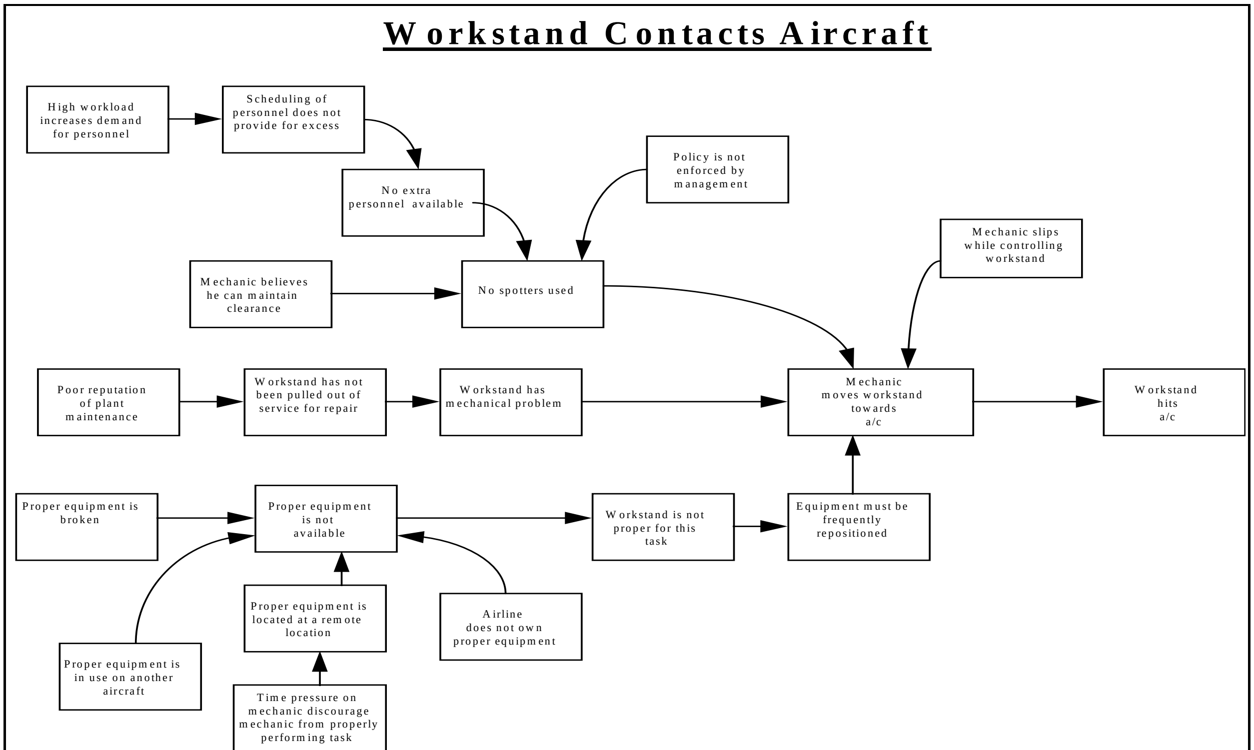

Figure 11.3 Example of Hazard Pattern Event Tree

Table 11.1 Ground Damage Incident Hazard Patterns

Hazard Pattern	Number of Incidents	% of Total

1. Aircraft is Parked at the Hangar/Gate/Tarmac	81			62.3
1.1 Equipment Strikes Aircraft		51		
1.1.1 Tools/Materials Contact Aircraft			4	
1.1.2 Workstand Contacts Aircraft			23	
1.1.3 Ground Equipment is Driven into Aircraft			13	
1.1.4 Unmanned Equipment Rolls into Aircraft			6	
1.1.5 Hangar Doors Closed Onto Aircraft			5	
1.2 Aircraft (or Aircraft Part) Moves to Contact Object		30		
1.2.1 Position of Aircraft Components Changes			15	
1.2.2 Center of Gravity Shifts			9	
1.2.3 Aircraft Rolls Forward/Backward			6	
2. Aircraft is Being Towed	49			37.7
2.1 Towing Vehicle Strikes Aircraft		5		
2.2 Aircraft is Not Properly Configured for Towing		2		
2.3 Aircraft Contacts Fixed Object/Equipment		42		
2.3.1 Aircraft Contacts Fixed Object/Equipment			13	
2.3.2 Aircraft Contacts Moveable Object/Equipment			29	
Totals	130	130	130	100%

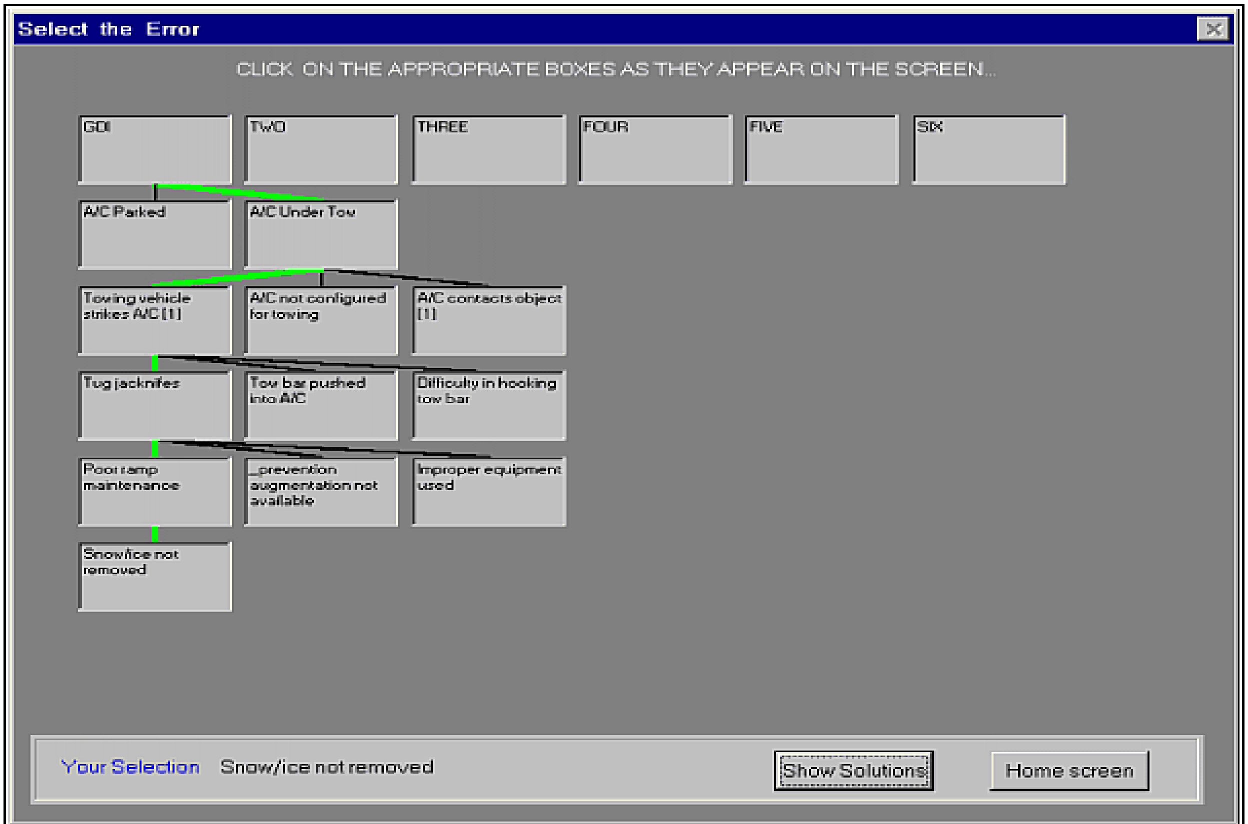

Figure 11.4 GDI Event Description Screen

This approach eliminates the need to carefully investigate each ground damage incident, since the detailed analysis has already been performed, and allows the user to move quickly to possible solutions. **Figure 11.4** shows the point in the **PERS** software where the user can choose the form of analysis.

Similar detailed analysis of other incident types must be conducted in the next phase of this project.

Solution Search

Once an event has been described and the root causes identified, the user is able to examine possible solutions to each root cause. More detailed information about each solution, including cost, time to implement, and success stories will also be presented, when this information is available. This additional information will allow users to make educated decisions on how to address problems within their facility.

The solutions are indexed within **PERS** according to causal trees that have been developed. These causal trees describe latent and active failures that may exist, and are independent of errors that have occurred. The causal trees have been developed based on a combination of error classification schemes. The contribuing factors from **MEDA**, performance shaping factors from human reliability analysis in the nuclear industry,[3] causal error taxonomies from safety literature,[4,5,6] and latent failures identified in previous research[7] were reviewed, and some information from each was combined to develop causal trees. The causal trees are a comprehensive classification of all factors that may contribute to an error. Five different causal trees were developed, addressing issues of: Management/Supervision, Communication, Equipment / Tools / Parts, Environment, and Knowledge/Skills/Training. **Figure 11.5** illustrates one of the causal trees developed for **PERS**.

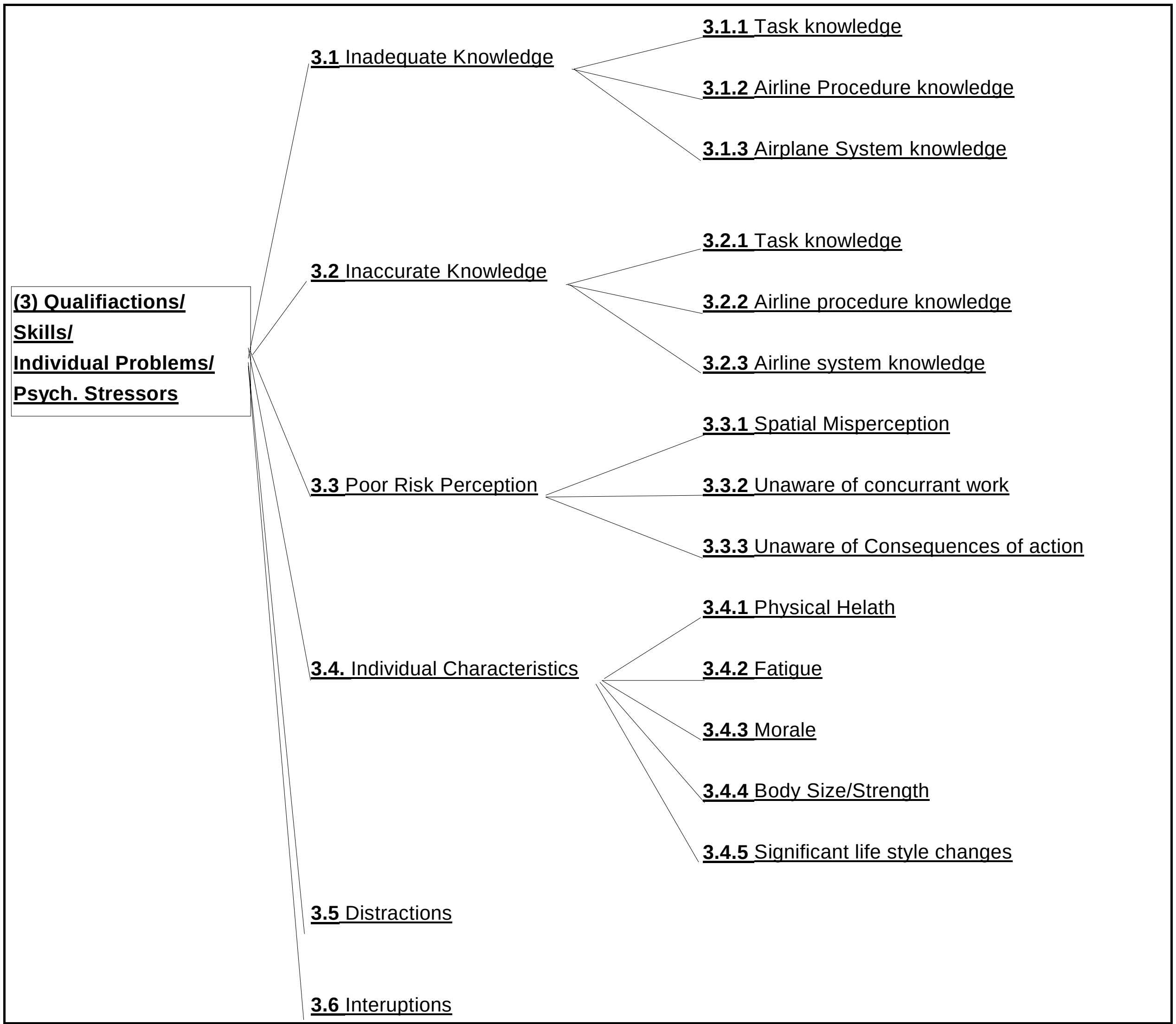

Figure 11.5 Example of a Causal Tree

Each of these causal trees has been embedded in the **PERS** software, and solutions are tagged to address particular points on these trees. **Figure 11.6** shows a typical solution search, with possible solutions identified, in this case derived from prior **GDI** investigations. More information will then be provided about each of these potential solutions.

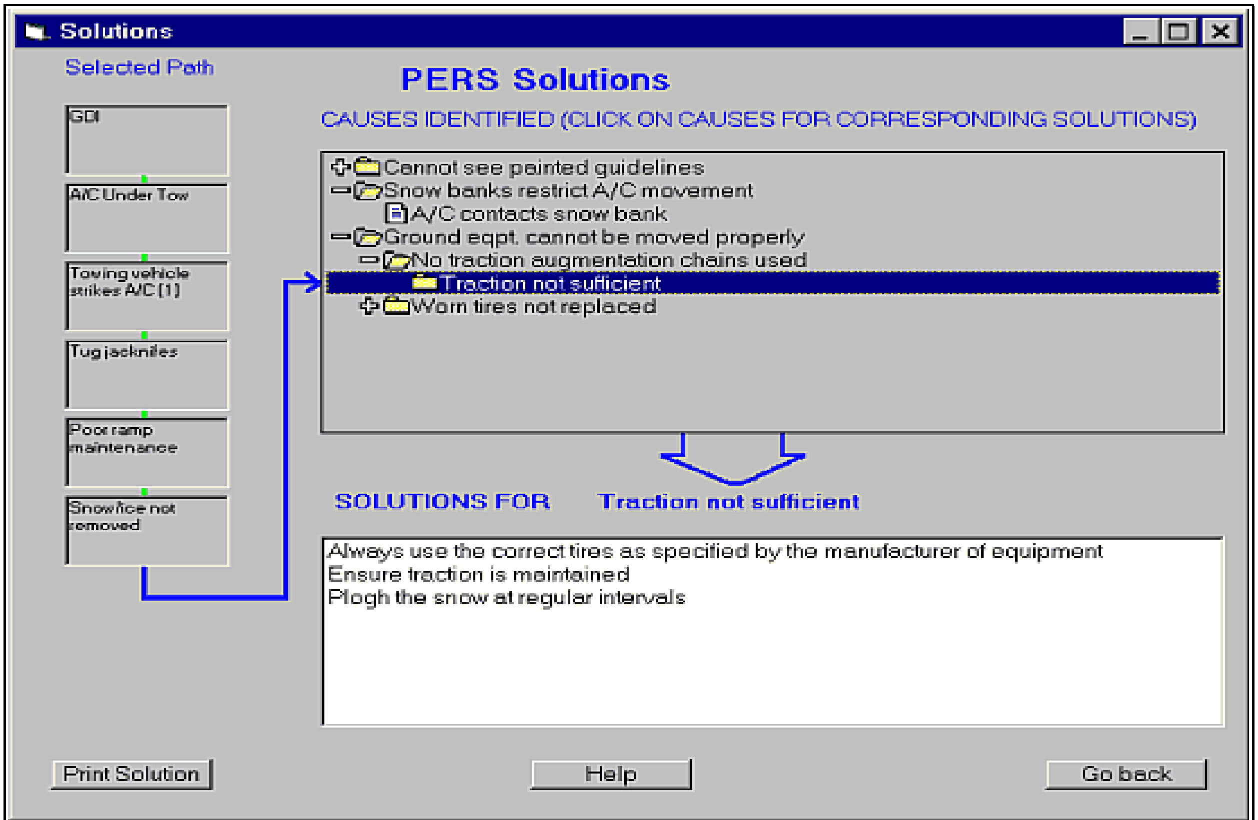

Figure 11.6 Solution Search Screen

In many cases, there may not be solutions that exist for all levels on the causal trees. In this case, the software should allow the user to examine solutions associated with the next higher level on the tree. Thus, users should be able to navigate the causal trees while examining solutions.

USING PERS

A User's Manual for **PERS** is currently under development. In addition, PERS will include a complete on-line help system which will allow users to find information about navigation through the software, as well as technical information which will help in using PERS to find solutions to known problems.

FUTURE PERS PLANS

The solution search module in **PERS** is based on hazard patterns that have been developed, based on detailed analysis, for error outcomes. Since this analysis was previously performed for ground damage incidents, this module was included in the current version of PERS. Obviously, ground damage incidents are not the only errors that occur in an airline maintenance environment. Future versions of PERS must allow other solutions for other error outcomes to be identified. The detailed analysis to devlop hazard patterns for these other error outcomes will be completed in the next phase of PERS development.

In the current version of **PERS**, gateways have been left open for interfacing with existing error reporting systems (**MEDA**, **MESH**, etc.), as well as for the development of an error reporting system within PERS itself. These links will be further developed in the next version of PERS, and the interface between the error reporting system and the solution search modules will be developed.

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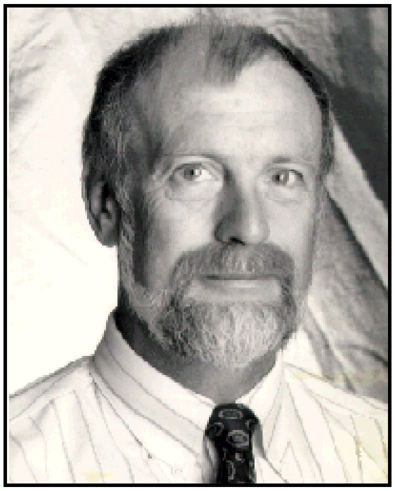

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12.0 REDUCING FAR ERRORS THROUGH STAR

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INTRODUCTION

Federal Aviation Regulations (FARs) are legal documents written precisely to define the regulations pertaining to aviation. Below is an example of a typical paragraph found within the FARs.

> "(a) A certificated mechanic may perform or supervise the maintenance, preventive maintenance or alteration of an aircraft or appliance, or a part thereof, for which he is rated (but excluding major repairs to, and major alterations of, propellers, and any repair to, or alteration of, instruments), and may perform additional duties in accordance with § 65.85, 65.87, and 65.95. However, he may not supervise the maintenance, preventive maintenance, or alteration of, or approve and return to service, any aircraft or appliance, or part thereof, for which he is rated unless he has satisfactorily performed the work concerned at an earlier date........"[1]

Given this type of legal writing it is not easy for most people to extract the intent of a regulation. In addition, information relevant to a task is often distributed across many parts of the **FAR**s. Because of this extensive cross referencing between FAR sections, it is not always obvious where one needs to look to get a complete sense of a regulation. Errors resulting from non-compliance with the regulations are due to personnel not understanding the functional purpose of the FARs nor the role they play in ensuring compliance with these regulations. In short, personnel lack the "big picture" of how the FARs govern the daily operations of aviation maintenance.

STAR is designed to help aviation personnel acquire the big picture. This is accomplished by incorporating multimedia-rich presentations and storytelling techniques within several different learning environments. Two versions of the STAR program are described in this paper. The first version, called STAR-AMT, is designed to be an instructional companion to the **FAA**'s course on Aviation Maintenance Regulations for Aviation Maintenance Technicians (AMT). The second version, called STAR-ASI, is designed as an on-the-job training aid for Aviation Safety Inspectors (ASI). A description of how these multimedia-rich presentations and storytelling techniques have been incorporated in each of the learning environments is presented along with a summary of an evaluation of the STAR-AMT program conducted in November 1995.

STAR-AMT

Philosophy And Approach

Learning in Context

Part of the difficulty in teaching the **FAR**s is that **AMT** students perceive the subject to be very dry. Indeed, some of the tasks expected of the students can be pretty tedious. However, there are many opportunities to convey the complexity and subtlety of the information in interesting ways. "War stories" from AMTs currently out in the field are one way to make the material more interesting and meaningful to the student. Stories are well suited for capturing tacit instructional knowledge, because storytelling is a more natural way for people to convey ill-specified practices.[2]

Another way to make the material more meaningful is to immerse the students in situations that confront them with "real world" decisions related to their jobs. By placing the application of the **FAR**s in context, students have a much better chance of constructing for themselves a scheme for how the FARs operate functionally in aviation.[3] When students are given the opportunity to learn in context, the concepts are acquired more rapidly, durably and are more easily transferred to new situations.[4] Both "storytelling" and "situated learning" place the information to be learned in contexts that the student can more easily relate to and remember.

Media-Rich Presentations

Media-rich presentations are a third approach to making the subject of the **FAR**s more interesting. Multimedia has other pedagogical advantages as well. According to Park and Hannafin, multiple, related representations improve both encoding and retrieval.[5] Learning improves as the number of complementary stimuli used to represent learning content increases. For example, when concepts are encoded in both verbal and visual forms, they are retained in memory longer and are more easily accessed, because the two types of information complement each other in the activation, representation, and development of related information.[6] Thus, complimentary information presented through multiple types of media is most favorable for conceptual retention.

Multiple Vantage Points to Complex Information

When teaching subtle information such as aviation regulations, there are advantages to providing students with many vantage points to the same body of information. Experiencing complex material repeatedly under different circumstances provides multiple opportunities to gain a deep understanding of the subject.[7] Each vantage point not only covers different aspects of the same material, but also reinforces different kinds of study skills. In this way, students are not only provided with multiple ways of viewing the information, but also with multiple opportunities to learn. In addition, information conveyed through one learning environment may best fit one student's style of learning, while the other learning environments fit other people's learning styles. Thus more people benefit when multiple approaches to the subject are taken.

STAR-AMT offers several different categories of learning environments: overviews, scenarios, challenges, and resources. Each category contains one or more learning modules for students to explore. Overviews show students how **FAR**s are organized, how different parts are related to each other, and who is responsible for what aspects of those regulations. Scenarios are interactive stories that place students into a true-to-life situation where the regulations are often subtle. Challenges require students to exercise certain skills they will need to develop in order to efficiently search the regulations and understand what they find. Resources are comprehension aids such as a glossary. These aids provide "as needed information" that can be explored in their own right or used in conjunction with other, more formal learning environments. Each learning environment could be a stand-alone application. Together they provide multiple vantage points for students to arrive at a deeper understanding of aviation regulations.

The Learning Environments

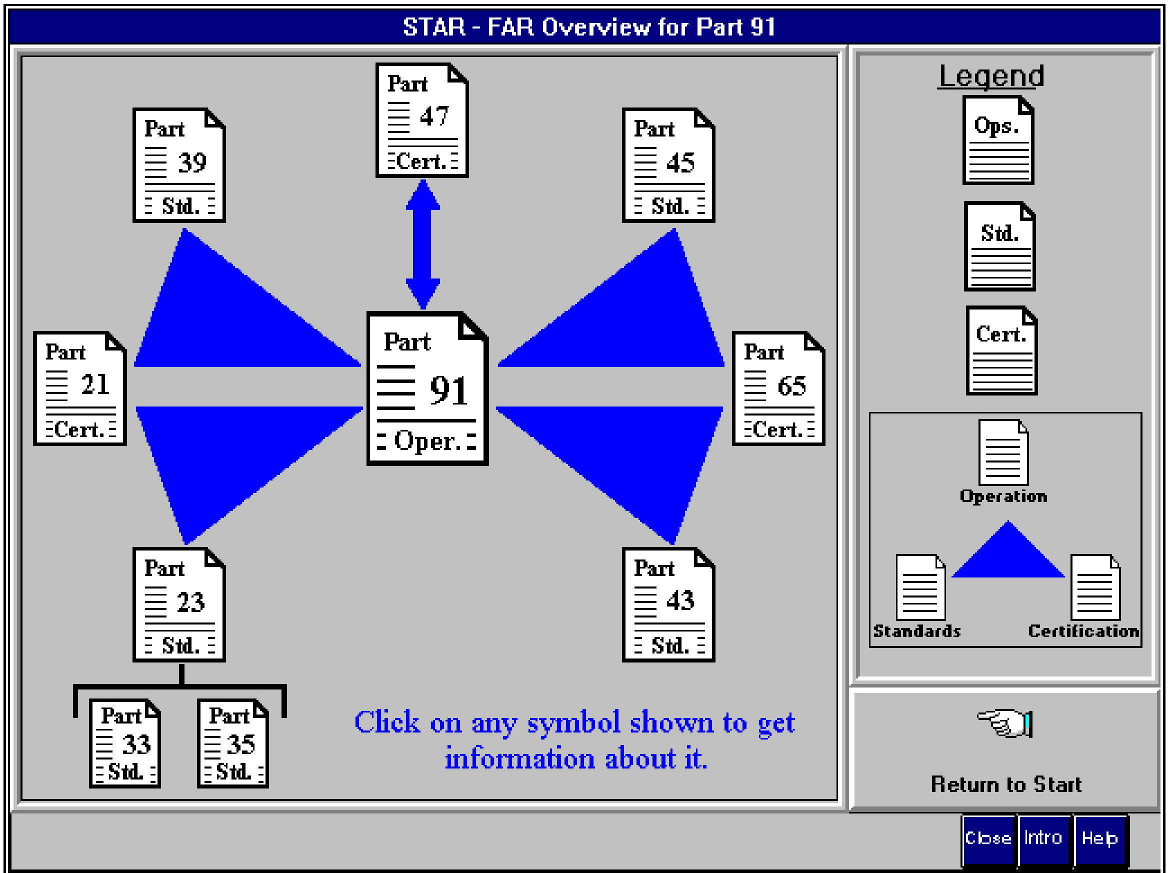

Figure 12.1 Overview

Though the users have control over their exploration of **STAR-AMT**, there is a logical progression for moving through the curriculum. Overviews give students the overall structure of the **FAR**s and are best viewed first. Scenarios anchor students in real world situations,[8] and Challenges are designed to provide students with a self-testing mechanism for assessing their knowledge of the material, as well as to promote the integration of material covered in the other learning environments. Resources are designed to augment and support the other training activities. Each learning environment is described below.

Overviews

Overviews are intended to show students how **FAR**s are organized, how different parts are related to each other, and who is responsible for what aspects of those regulations **(Figure 12.1)**. Students are presented with a graphical scheme for how the FARs most relevant to their work are related to one another.

Included in this scheme is a general description of each FAR part, what type of regulation it embodies, and how these different types of regulations interact with each other. General concepts are presented first followed by a specific example. Relationships between concepts are then highlighted. Each concept is presented through an audio narration with textual complement. As each new piece of the overview is presented, it flashes to indicate to the student that this is the next relevant concept. Students may observe the sequential building of the conceptual graph or they may explore different portions of the graph independent of any order.

Scenarios

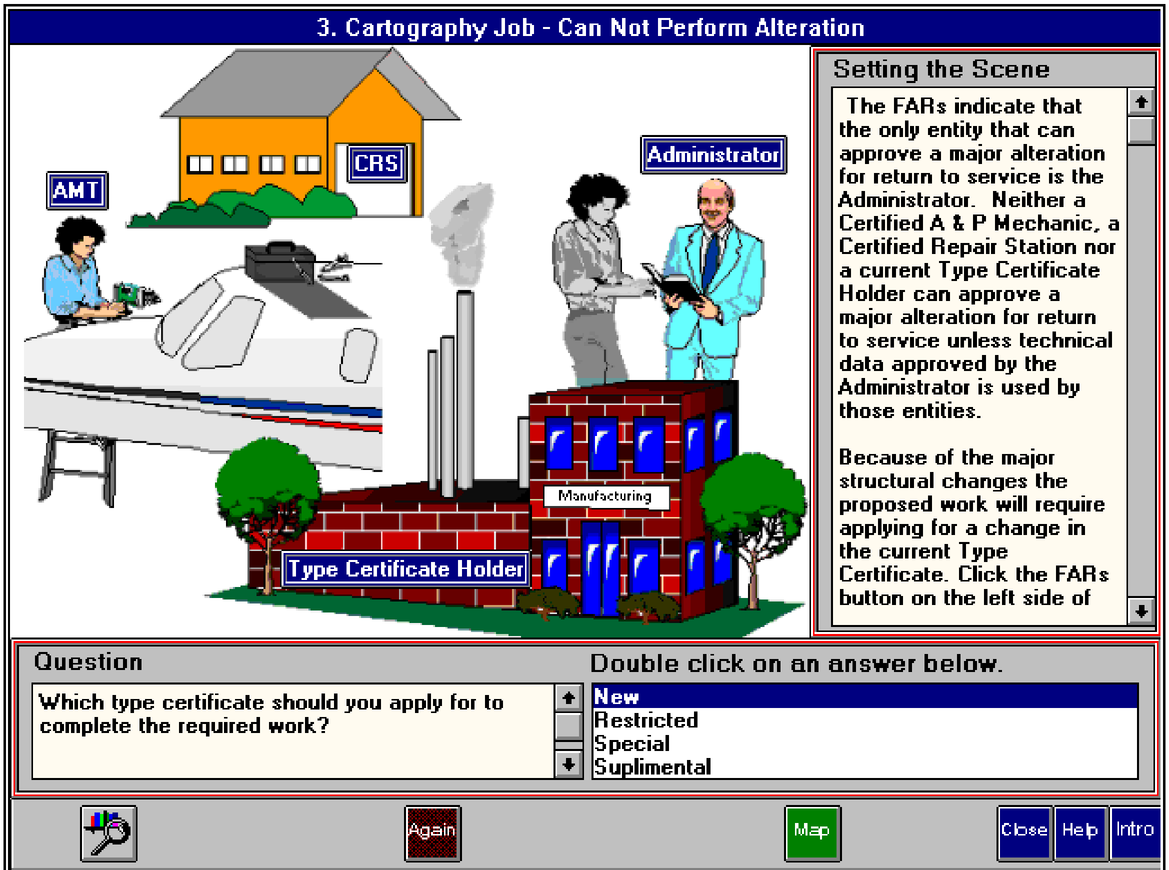

Figure 12.2 Scenario

Scenarios are essentially interactive stories **(Figure 12.2)**. In the opening scene of each scenario, students are presented an unclear situation where several actions are possible. They are asked a question about what they should do and are presented with several actions that they could take. Each scene is portrayed through a graphic picture or photograph and the new situation is told through text and narration. The graphic picture sets the visual scene and the narration tells the story.

Once a student chooses an answer, a new scene in the scenario is presented. The new scene reveals, through commentary and animation, the consequences of the action chosen and the rationale for why the student should or should not have made that choice. Students are then asked a new question and presented with new options until they reach the end of that story line in the scenario. Students may access a map to help them orient and navigate through the scenario. As a student moves from one scene to the next, the map updates to reflect the student's progress.

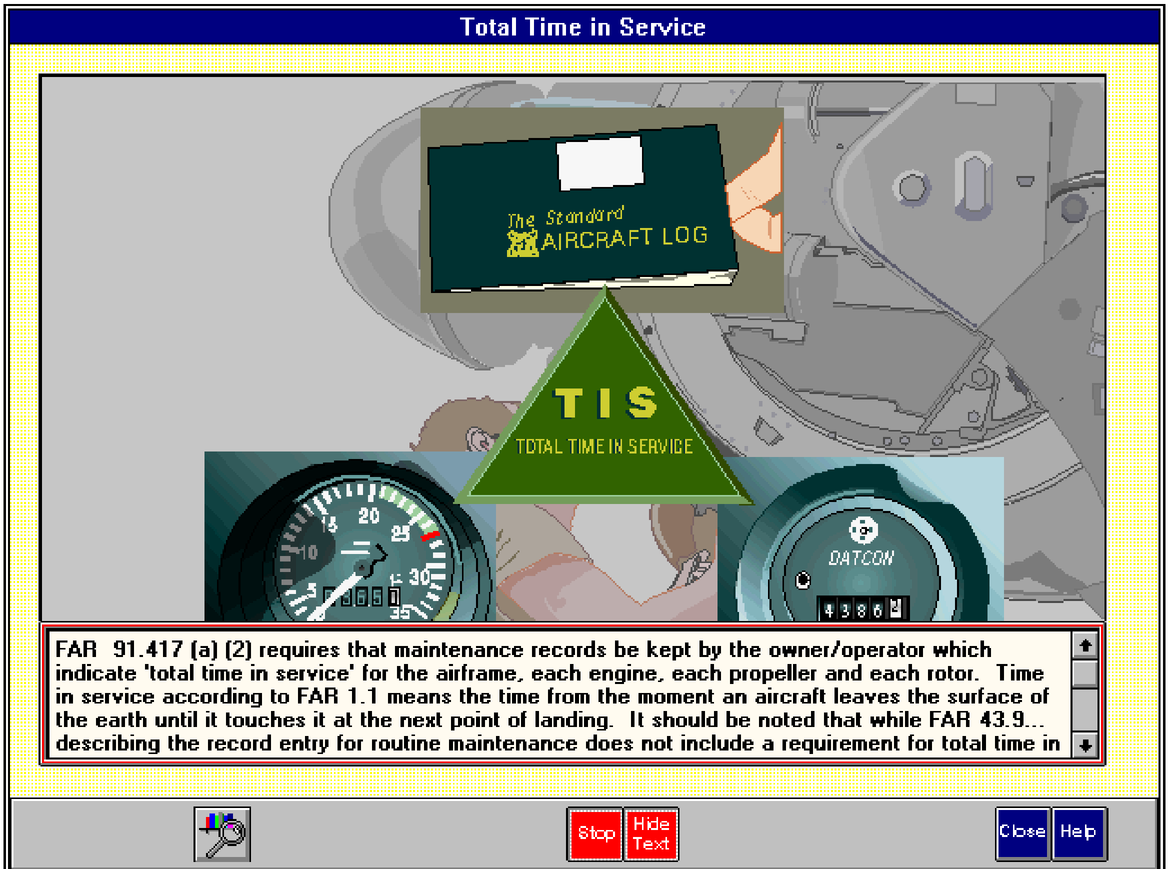

Figure 12.3 Informational Media

Associated with each individual scene is supporting informational media **(Figure 12.3)**. This supporting media augments students' understanding of the scene by providing commentary about the **FAR**s or background to general aviation concepts. The informational media is intended to fill in students' understanding of the current situation. Students are encouraged to explore the additional information provided within each scene. Some of the information could influence their subsequent decisions with respect to the question they are about to answer. Other information is provided to round-out their general knowledge of the subject.

Resources

Resources are comprehension aids such as a glossary. These aids provide as-needed information that can be explored in its own right or used in conjunction with other, more formal learning environments. There are three modules in the resource learning environment. The document browser is designed to provide searching and viewing documents in their entirety. It has full-text searching capabilities both within and among documents. The glossary defines and exemplifies commonly found terms in the **FAR**s. Associated with each term are exemplars of how the term is used in a FAR passage, as well as how the term is commonly used in the field. Where appropriate, graphics are provided that enhance the meaning of the term. Informational Media are multimedia presentations designed to supplement the **STAR-AMT** learning environments with related concepts and commentary about the FARs and aviation.

Challenges

Challenges are designed to provide students with a self testing mechanism for assessing their knowledge of the material as well as to promote the integration of material covered in the other learning environments. Challenges can vary in complexity. They can be of the "self-test quiz" variety - where students practice quick responses to specific facts; or they can be of the "project" variety - where to solve a challenge entails a deep understanding of both the search process and the regulations themselves. Associated with many challenge questions is informational media explaining the rational for the correct answer to the question.

STAR-AMT EVALUATION SUMMARY

Method

The November evaluation of **STAR**-**AMT** sought to discern not only whether or not learning occurred but also what kind of learning occurred. The sample was composed of two classes of five students each from an **FAA** Part 147 school who were currently taking the Federal Aviation Regulations (FARs) and documents research class. All ten students worked with the computer application. Pre- and post tests were taken before and after the treatment and comparisons were made between each student's gain or loss in their overall scores and for scores within each test segment. The study was conducted over a one week period. Each student was provided with a 486 multimedia PC with CD-ROM capability and ear phones.

Both the pretest and the post test were composed of five sections. The first three sections were short answer questions covering material in the Overview, the New Technicians' Scenario (scenario 1) and the Special Inspections' Scenario (scenario 2). Section four was composed of standardized multiple choice questions found in typical tests for **AMT** certification. The questions were similar in content to the content covered in **STAR**. The last section was a series of true/false questions covering Privileges and Limitations of AMTs. Privileges and limitations are one of the overriding themes in the STAR-AMT curriculum. The total points for each of the tests were based on a scale of 110.

When making distinctions between the two classes in the results section below, one class will be referred to as the morning class and the other class as the evening class.

Results

Figure 12.4 shows the overall test scores for both groups. The subjects in the morning class are S1 to S5 and the subjects for the evening class are S6 to S10. Most students showed improvement from the pretest to the post test though the evening group shows a more substantial gain than the morning group. When viewing the average test scores between sections both groups showed substantial gains for the sections about the first and second scenarios and a moderate gain in the section on privileges and limitations. The evening group showed dramatic gains in the overview section but the morning class did not. As a group their scores were below their performance in the pretest. The performance for the two groups on the standardized questions remained about the same. The performance of eight of the ten students remained the same and relatively high (getting all five questions correct or missing only one) between pre- and post test. Two students did worse on the post test (missing 2 of the 5 questions).

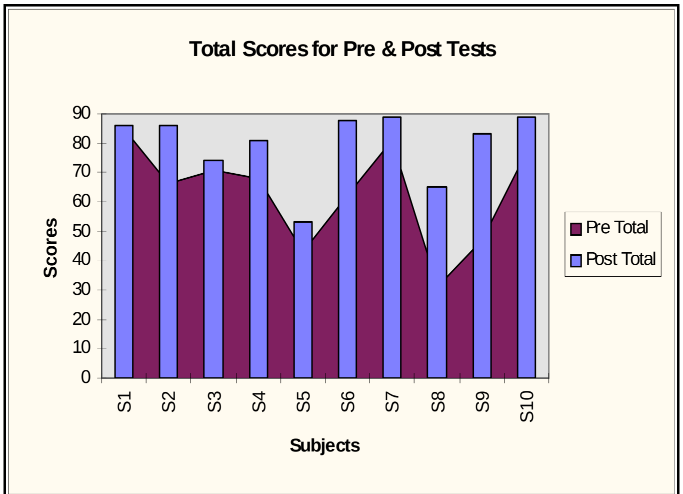

Figure 12.4 Pre- and Post Test Results

When analyzing individual test scores, four of the ten students showed a gain of 20 or more points between pre- and post test (**Table 12.1**). Three students showed a gain of ten or more points and two students showed gains of less than ten points. Greatest gains were seen among subjects who had scored less than 70 points on the pretest. In a couple of cases more than 30 points were gained from one test to the next. Gains were less dramatic for those scoring over 70 points on the pretest, either showing a gain of about ten points or in two cases showing no gain between tests.

Table 12.1 Individual Gains or Losses Between Pre and Post Test

Name	Pre Total	Post Total	Difference
S9	47	83	36
S8	31	65	34
S6	62	88	26
S2	66	86	20
S4	68	81	13
S10	77	89	12
S5	43	53	10
S7	81	89	8
S3	71	74	3
S1	85	86	1

Discussion

Even though the sample size is small, performance trends are positive. The most dramatic gains were experienced by those who scored poorly during the pretest. **STAR** seems to be particularly well suited for curriculum review or remedial work, particularly for students who have not as yet grasped the "big picture."

Two of the subjects who benefited the most from the STAR experience were students for whom English was not their primary language. The pervasive use of audio narration complementing the text may have given the added scaffolding foreign students needed to boost their comprehension levels. This may indicate that **STAR-AMT** could be beneficial for training of the international aviation community in US Federal Aviation Regulations and is an area where further studies would be informative.

Students acquired concepts most readily from material presented in the scenarios and in the case of the evening group, the overview. These improvements did not translate into better performance on the standardized questions. Since, however, most of the students performed well on both pre-test and post test on the standardized questions, a ceiling effect may be in evidence here. The desired outcome would be to show that **STAR-AMT** contributes to improvements in understanding both the big picture and achieving high scores for standardized test questions. This small sample size for both students and number of questions shows improvement only in the targeted curriculum "understanding the big picture." A much more extensive study addressing differences in curricular and testing styles for STAR-AMT and standard curriculum (as represented by standardized tests) will need to be done before an informed discussion can be presented.

STAR-ASI

From Training Aid to Job Aid

STAR-AMT has been designed to be a training resource to complement instruction rather than to replace it. Any part of the program could be used within the context of a lecture presentation, or as a reference, or for independent study. Even the scenarios were designed to be explored rather than just stepped through. The structure of STAR is flexible to complement different styles of teaching. While there are many strengths to this approach, there are also some weaknesses. Independent exploration encourages self-directed learning, but at a cost of homogeneity of learning across individuals. While students are exposed to the general body of knowledge from several different vantage points, there is less control over the particular information that an individual acquires. As an on-the-job training aid, however, this browser-oriented design approach is advantageous.

For **STAR-AMT**, resources augment and support training; for STAR-ASI, the emphasis is reversed - training augments and supports resources.[9] Even in the context of on-the-job training, the primary activity and concern of each Aviation Safety Inspector (ASI) is having the right information at the right time to do his or her job well. Sometimes that may be learning how to conduct oneself during an inspection; other times it may be reminding the ASI which forms are needed for a particular inspection. In either case, STAR is designed to handle both needs.

STAR for Aviation Safety Inspectors is composed of the same general components as the STAR program for **AMT**s. Three of the learning environments - scenarios, resources and challenges - are identical functionally, with new content simply replacing old content. A new learning environment, Task Flow Charts for inspections, has been implemented in place of the Overview learning environment. Below is a description of this new learning environment.

Inspection Task Flow Charts

Each inspection is considered to be a task **(Figure 12.5)**. For their on-the-job training, the airworthiness group had developed task flow charts that show the logical steps for each inspection task, including decision points (e.g. Has a **FAR** been violated?). By simply implementing these flow charts on the computer, the **STAR** team has been able to create an interactive version of that representation. Now a new recruit not only has a visual representation of each inspection procedure, but also can investigate each step in the procedure. All other learning environments can be launched from a step in a task flow chart. Depending on the instructional objective, one has the option to ask a quiz question, show what a form looks like, attach relevant passages from an Order or a FAR Part, comment on what an inspector's responsibilities are, or create a mini scenario. Task Flow Charts give each inspection procedure a structure; the dynamic nature of the computer provides informational depth to that visual structure.

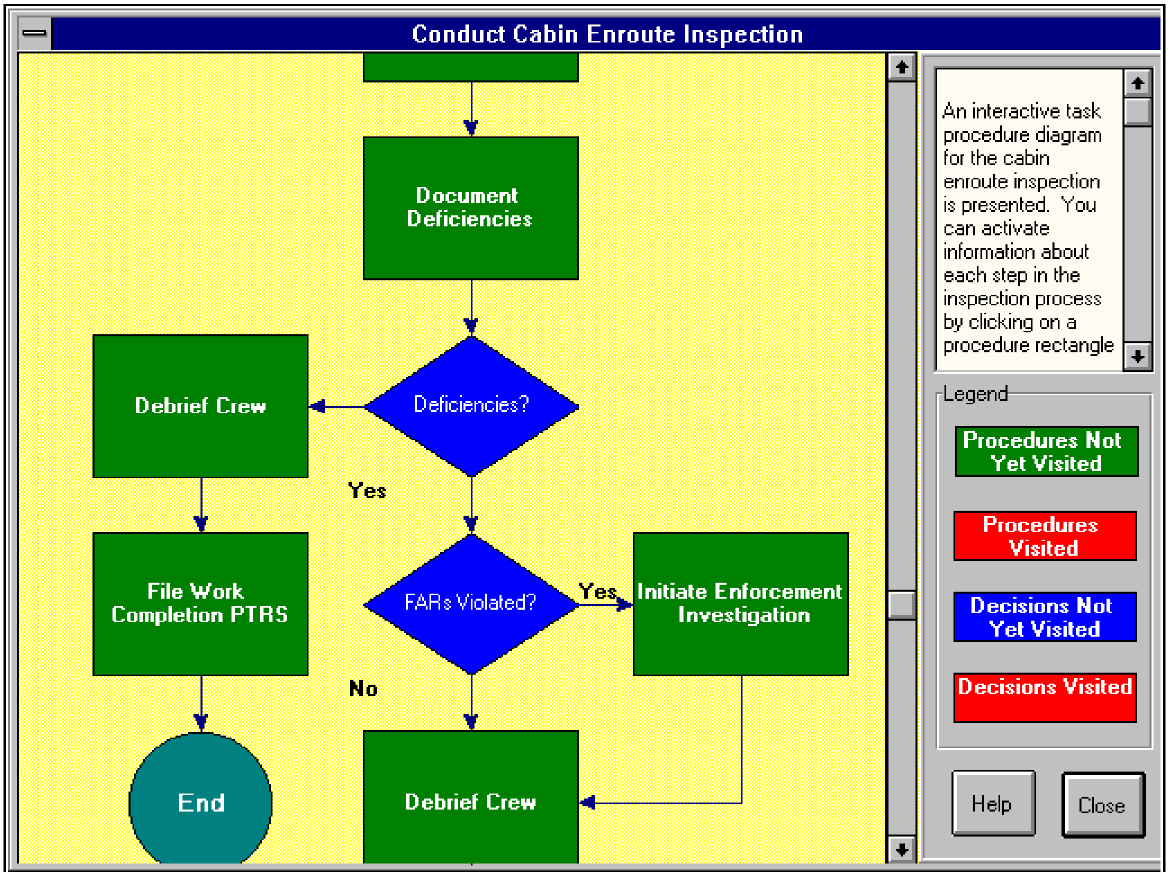

Figure 12.5 Task Flow Charts

This structure can be used in several ways, depending on the experience of the user and his or her present needs. For a new recruit, the flow chart is a training aid that he or she can step through, see the organization of the inspection, quiz him or herself, look up terms, or read relevant documentation; he or she can view sample forms and review how and to what purpose they are used. A veteran can review the steps of an inspection not done in a while before venturing out into the field. Or they might use it purely as a reference to look up which form they are suppose to use or the meaning of that acronym they never really learned. Scenarios which target new recruits more than veterans might never be touched by veterans. However, a mentor might employ the scenarios as a vehicle for discussions with new recruits.

Conclusion

In complex domains, the curricular goal should not be that everyone knows the same thing, but rather that everyone supports the same general conceptual scheme of the domain with some variation in the details of their common understanding. **STAR** represents a more open exploratory approach to training than the more lock step approach most commonly seen in the training of procedural knowledge. In an open approach, students are provided with a mechanism for acquiring a global understanding of a domain. As an individual builds a conceptual map, that individual will incorporate different details to support that conceptual map. Thus, while each individual will acquire an understanding for "the big picture," the details that support that global understanding will vary. This approach to knowledge acquisition supports and perpetuates communication within the knowledge community. Common domain themes support the tacit assumptions of the "truths of the domain" under which everyone is operating, while variation in details promotes ongoing discussion of and refinement of the community's collective knowledge. As long as the conceptual scheme is sound, and the details incorporated within the scheme are sound, then the variation in the details of knowledge between individuals is actually a strength rather than a weakness within the community. The STAR approach contributes to the reduction of errors resulting from non compliance with the regulations by training personnel to understand the functional purpose of the **FAR**s and the role they play to ensure compliance with these regulations. STAR gives aviation personnel the "big picture" for how the FARs govern the daily operations of aviation maintenance.

ACKNOWLEDGMENTS

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Dr. Chandler has twelve years experience in educational technology. Dr. Chandler was awarded a Ph.D. in curriculum and instruction, an MS in computer science and an MS in computer science education from the University of Oregon. She received a BA from Denison University with a double major in Biology and Philosophy. Her dissertation work was on the facilitation of theory-oriented problem solving through the use of process highlighters in computer simulations. Prior to joining Galaxy Scientific, Dr. Chandler spent three years as a research scientist in the **AI** lab at Georgia Institute of Technology. There she designed and managed the development of a case-based browser to aid elementary teachers in science instruction.

Since arriving at Galaxy Scientific two years ago, Dr. Chandler's principle project has been the design and development of the System for Training of Aviation Regulations (STAR). STAR is a multimedia application that employs a scenario-based approach to train personnel in complex domains. The original version of STAR has been developed for Aviation Maintenance Technicians in training. STAR has recently been repurposed to function as an on-the-job aid for Aviation Safety Inspectors. Her most recent project with Galaxy is the design and development of a distance Learning Center for the **FAA** Office of Aviation Medicine through the World Wide Web.

13.0 REDUCTION OF MAINTENANCE ERROR THROUGH FOCUSED INTERVENTIONS

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It is well-known that a significant proportion of aviation accidents and incidents are tied to human error. In flight operations, research of operational errors have shown that so-called "pilot error" often involves a variety of human factors issues and not a simple lack of individual technical skills. In maintenance operations, there is similar concern that maintenance errors which may lead to incidents and accidents are related to a large variety of human factors.

Although maintenance error data and research are limited, industry initiatives involving human factors training in maintenance have become increasingly accepted as one type of maintenance error intervention. Conscientious efforts have been made in re-inventing the "team" concept for maintenance operations and in tailoring programs to fit the needs of technical operations. Nevertheless, there remains a dual challenge: 1) to develop human factors interventions which are directly supported by reliable human error data, and 2) to integrate human factors concepts into the procedures and practices of everyday technical tasks.

VARIETIES OF HUMAN FACTORS INTERVENTIONS

In flight operations, three phases of human factors training (or Crew Resource Management training) are typically implemented: awareness training, practical training and integrated training. Generally speaking, awareness training takes place in the classroom as initial indoctrination while practical training involves the use of line operational simulation during annual recurrent training. Integrated training refers to the incorporation of crew resource management training into the technical training requirements and evaluation. Clearly, there are areas where technical operations may follow a similar approach, but there are also important task differences which should be carefully considered so that training is tailored to be as operationally relevant and effective as possible.

As mentioned above, significant progress has been made by maintenance organizations with respect to the implementation of human factors training. Such training usually takes an "awareness training" format and provides an introduction to human factors concepts as they apply to maintenance operations. However, the counterparts to line operational simulation and integrated training have yet to be determined by the maintenance community. For the purpose of this talk, we shall simply call the human factors training in the practical and integrated phases an operationally-based intervention (e.g., "Operational MRM" as in **Figure 13.1**) since it is designed to address the operational issues of everyday tasks. In addition, we propose two other maintenance error interventions in which human factors are integrated into specific practices and procedures: 1) structured on-the-job training, and 2) procedure re-design. These are not substitutes for awareness training; merely different types of interventions which are intended to reduce maintenance error by incorporating human factors into the practice of everyday technical tasks.

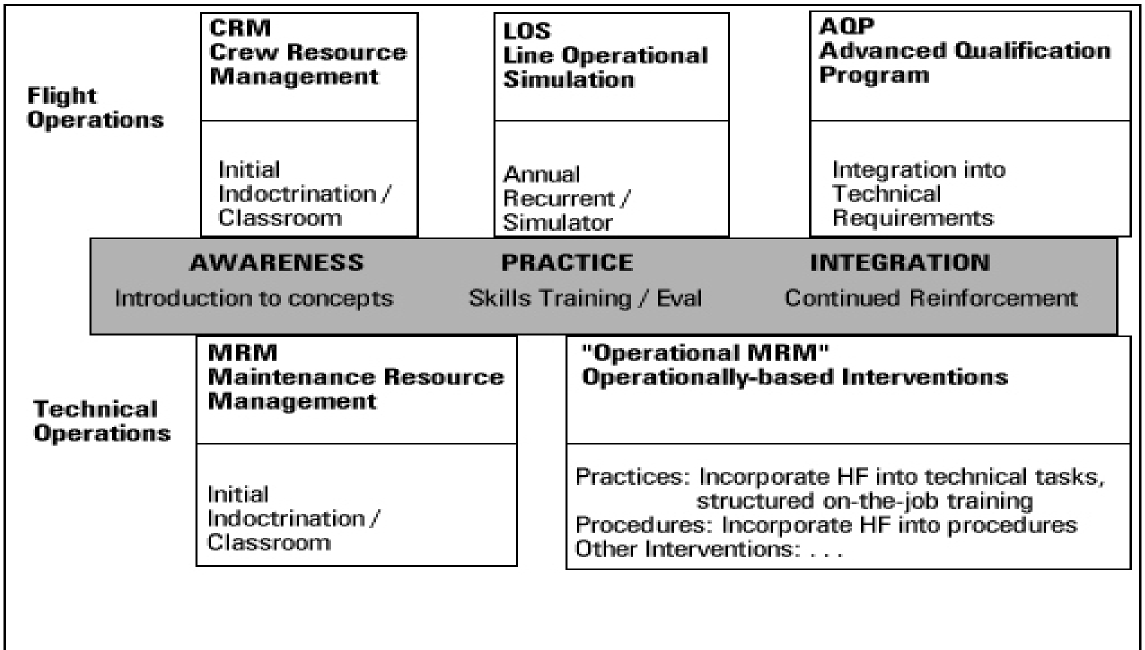

Figure 13.1 Varieties of Human Factors Interventions: Technical Operations compared to Flight Operations

FOCUSED INTERVENTIONS

In order for these to be *focused* interventions, however, we must begin with the identification and characterization of problem areas derived from a reliable operational error database **(Figure 13.2)**. A systematic analysis of operational errors which analyzes and describes the contribution of human factors to specific processes is then possible. It is essential to achieve a clear understanding of the numerous and often complex turns of events which can lead to unsafe, inefficient and expensive outcomes. Once human error information is collected, analyzed and understood, focused interventions may be developed which match specific problems. For example, information from the Aviation Safety Reporting System (ASRS) incident database helps to identify general, industry-wide human factors issues while the Maintenance Error Decision Aid (MEDA) helps in the analysis of specific incident events. On the basis of an operational errors analysis, focused interventions may be developed which are direct countermeasures. For instance, many of the topics in human factors training are taken directly from incident and accident data which illustrate human factors problems and error chains. But problem targets may also suggest interventions which are directly tied to operational practices and procedures. In these cases, alternative interventions such as TATS (Task Analytic Training System), a program of team-driven, structured on-the-job training, and human factors enhanced procedures may be appropriate.

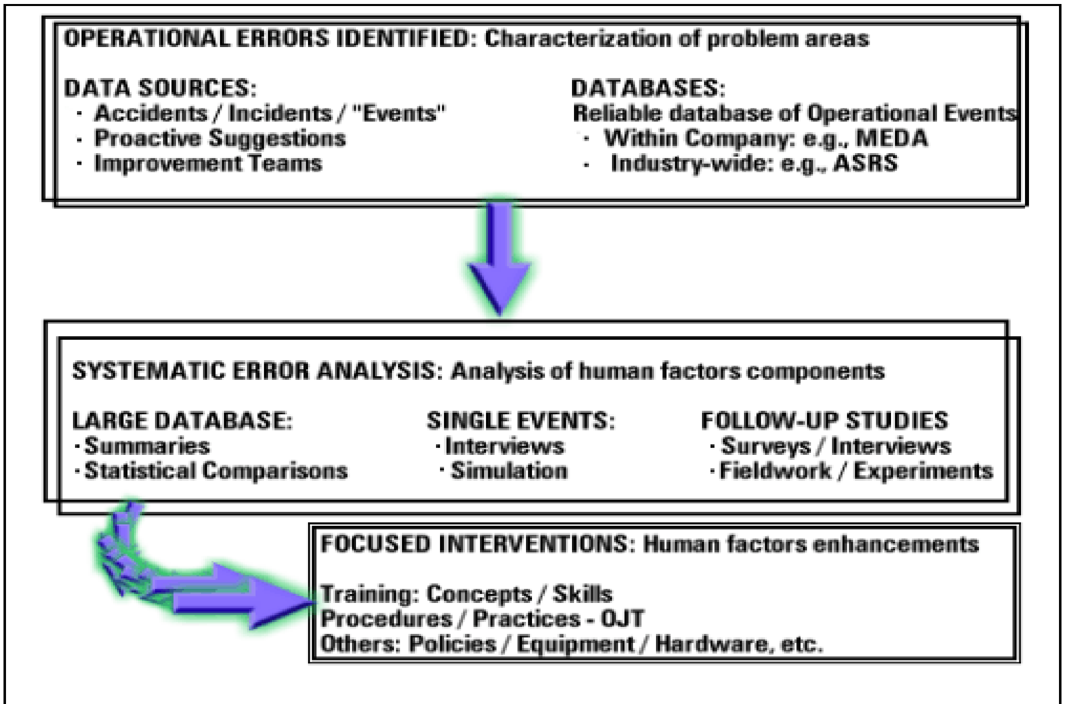

Figure 13.2 From Operational Errors to Focused Interventions

OPERATIONALLY-BASED INTERVENTIONS

TATS is a performance-based system that involves full workforce participation in its design, development and implementation.[1] It was originally developed to provide comprehensive, structured, on-the-job training. Through incorporation of basic human factors principles such as decision making, communication, team building, and workload management, either directly or as a function of the workforce participation involved, the TATS process has proven successful in providing not only better training and procedures, but overall improvement of attitude and morale. Major elements of the program include: 1) needs identification, 2) job task analysis, 3) writing and verifying training procedures, 4) training implementation strategies, 5) employment of tracking mechanisms, 5) debugging, evaluating, and establishing a maintenance/audit plan. Since TATS produces a workforce whose performance can be observed and measured against explicitly defined standards, it is an effective intervention against unreliable, error-prone practices which can be inadvertently perpetuated when on-the-job training is an unstructured, unmonitored buddy system.

Just as **TATS** may enhance maintenance practices, human factors principles may also be incorporated into maintenance procedures themselves. Procedure evaluation and re-design for the purpose of human factors enhancement provides another type of focused intervention which targets specific maintenance problems. We shall describe a study in which a Boeing engine-change procedure, revised by Repp, was analyzed and systematically compared to its predecessor.[2] On the basis of coding each procedural change in terms of its structure and function, we were able to catalogue the ways in which procedure changes were linked to human factors elements (e.g., workload distribution, planning and communication, situation awareness, crew coordination, and safety considerations. As this project nears completion, we intend to produce a guidelines document for operators to incorporate human factors into their own procedure design enhancements.

In summary, we describe how maintenance error may be reduced through human factors interventions which target specific procedures and practices. We hope to demonstrate that the key to leveraging the impact of these solutions comes from focused interventions; that is, interventions which are derived from a clear understanding of specific maintenance errors, their operational context and human factors components.

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DR. BARBARA G. KANKI

After receiving a Ph.D in Behavioral Sciences from the University of Chicago, Dr. Kanki began her tenure at **NASA** Ames Research Center as a researcher of crew communication and coordination in both aviation and space systems. For more than 10 years, she has been a principal investigator in the Crew Factors group whose purpose is to enhance system safety through training and procedural design based on team process analysis. The research utilizes a variety of methods including high fidelity simulation, surveys, interviews and on-site field techniques. While much of her work has been directed toward commercial transport flight crews, this work has expanded to other parts of the aviation system, most notably including maintenance operations and air traffic management. On the space side of the house, Dr. Kanki has also conducted crew research in ground support operations such as shuttle maintenance and payload integration.

MS. DIANE WALTER

Diane Walter is founder and president of Human Performance Applications, a Seattle-based consulting firm specializing in competency-based on-the-job learning systems. She was until recently, a Maintenance Human Factors Engineer with Boeing Commercial Airplane Group. Prior to coming to Boeing, she created and developed the Task Analytic Training System (TATS). Over the past eight years, TATS has been implemented by Boeing inspectors, mechanics, engineers, and pilots. During the last two years, four of Boeing's customer airlines have used the TATS program.

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14.0 PRACTICAL CONSIDERATIONS OF MAINTENANCE HUMAN FACTORS FOR LINE OPERATIONS

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INTRODUCTION

The diverse nature of operations within today's complex aerospace industry gives rise to dramatically different maintenance structures. While the dynamics of aviation maintenance operations and the associated technician human factors issues which impact safety and efficiency have been the focus of international efforts to reduce accidents and incidents, little recognition has been given to the varying effects imposed by unique maintenance environments. The fact that aviation maintenance assumes many forms and that each environment is dependent on the context imposed by the nature and purpose of the specific maintenance operation results in human factors issues which are situationally dependent. It should be evident to the reader that the assessment of systemic and technician communication issues as viewed from the general aviation maintenance environment are dramatically different from similar issues evaluated from the airline heavy maintenance operation perspective. Within the general aviation environment, technicians deal less often with "shift turn-over" and "referred" maintenance communications. Likewise, situational awareness becomes dramatically different when viewed within the context of "hangar maintenance" as opposed to similar issues imposed by the "line maintenance" perspective.

In order to effect pragmatic solutions within any industry setting, the study of human error and its relationship to the human dynamics of the technicians who perform maintenance within the context of that structure, the assessment and derived solutions must carry with it the contextual specificity of human factors unique to that environment. To gain insight into the unique applicability of aviation maintenance human factors within a single maintenance environment, a longitudinal study of major airline "line maintenance" operations was initiated at Purdue University. Limiting the study's assessment to one maintenance environment provided valuable insight into many of the dynamics which drive human error during the receipt, line maintenance, and dispatch of large aircarrier aircraft.

DESCRIPTION OF THE RESEARCH STUDY

The nature of the research study design was one of a "pilot study" designed to identify, define, and classify human factor issues which impacted human error within the "line maintenance" environment. As such, the design did not collect empirical data which was statistically rendered but rather collected anecdotal information and observations which could be used to structure future inquiry. While statistical "significance" of the study could not be evaluated, numerous "apparent" issues important to human errors incurred during line maintenance operations were exposed by the study. The study was a multifaceted design which encompassed observations at numerous line operation locations of four aircarriers over a year and a half period. The research project was conceived and supervised by faculty with extensive aviation industry maintenance experience. While some research observations were performed by faculty researchers to insure the appropriateness and validity of the observation methodology, student researchers were used to make the majority of observations. All student researchers were required to complete a human factors course and receive training in observational research techniques prior to participating in the project. One facet of the research involved pairing student researchers with aircarrier line maintenance technicians and allowing them to "job shadow" the technician for an entire shift. After completing the shift, researchers recorded their observations on prepared "observation forms" to insure representativeness of the data. Another facet of the research involved having student researchers "shadow" maintenance managers at different levels of the operation including the Vice President level. This allowed the researchers to assess the impact of management decisions and policies on individual technician human factors issues. The use of student researchers as observers resulted in an unexpected level of openness and sharing of feelings by technicians. It is assumed that this resulted from the fact that technicians perceived the students as less "threatening" than internal evaluation teams or consultants.

Error Classification Taxonomy

It was felt by the research faculty that a central construct for the evaluation of the observational data was necessary in order to effectively structure the classification and analysis of the various impacts of human factors issues on error generation and propagation within the line maintenance environment. The literature defines several taxonomies for classifying and analyzing human errors.[1] Generally, human errors may be classified by their origin, type, level, or the purpose to which the resulting error analysis will be used. The central construct used for classifying, categorizing, and analyzing the observational data of this research project involved a hierarchical structure of error origin and type. Error origin was chosen as the primary classification criteria since it leads directly to the development and application of practical solution methods.

The origins of human errors are generally differentiated by whether the error was caused by the individual involved in the incident or by faulty design of equipment or procedures used by the individual which compelled them to make the mistake. This classification scheme focuses on determining whether the source of the human error was "inside" the technician (endogenous) or originated from "outside" the technician (exogenous).[1] Endogenous errors are attributable to such factors as individual choice of aberrant behavior, poor judgment or decisions, and lack of adequate training. Exogenous errors are errors generated by circumstances such as incorrect or inadequate policies or procedures, poor equipment designs, and tooling or working condition limitations or stressors. Determining the origin of the error not only provides for a sound method of classification, it also provides insight into appropriate methods for addressing the remediation of those errors. Exogenous errors require corrective action such as changes in policies or procedures, redesign or repair of equipment, changes in workstation or work place design or layout, and the control or reduction of the effects of work related stressors. Endogenous errors indicate a need for training or motivation of technicians.

Once categorized as to the error's origin, the data was further classified as to the type of error committed so that an understanding of the error mechanism might be achieved. Error types represent "categories of error distinguished by differences between actual and desired behavior."[1] This classification scheme differentiates between such types of causes of undesirable outcomes as errors of commission, omission, intrusion, substitution, repetition, and sequencing. Subdivided in this way, observed behaviors provide valuable insight into the source, nature, and causality of human error events. This, in turn, allows some measure of understanding which may be used to formulate intervention strategies and may eventually lead to the potential predictability and/or possible prevention of such errors.

STUDY RESULTS

Observational data from the various facets of the study were combined and viewed collectively in order to evaluate each of the observed human factors issues from several relevant perspectives. The numerous human factors identified in the study were then grouped into categories of seemingly similar influence. Once similar influences were formulated and the categories delineated, the human factors issues were evaluated as to their observed impact of "Dirty Dozen" items. This was done because of the salient nature of the "Dirty Dozen" items to industry wide error reduction strategies and safety efforts. Although all of the observed issues could not be presented in the short format of this paper, the following groups of issues were among the most prominent factors identified during the study.

Unchangeable Constants

Among the most prominent and frequent of human factors which influenced error generation within line maintenance operations were environmental factors which are beyond pragmatic control. Issues such as weather conditions, lighting, high levels of auditory noise, intense visual noise and work related stressors as well as shift induced issues such as circadian rhythm were not addressed in this paper despite their importance. This was due to the fact that these issues were considered to be readily apparent, characterized as "no brainers" by one industry official, and widely addressed. Rather, the focus of the paper centered on observed issues which are less recognized as contributing to error and the erosion of safety within line maintenance operations.

Facility Design

An evaluation of the collective observations suggested that the physical design of the facility where line technicians worked had the greatest diversity of influence on the potential for error generation within the line maintenance environment. Observations determined that facility design directly influenced ten of the twelve "Dirty Dozen" items used throughout industry for evaluating the potential erosion of safety and the propensity for error generation.

In most cases, facility design seemed to be an afterthought with regards to its influences on the technician and the daily operations of line maintenance. Observations at numerous line maintenance stations across the United States found that the overlooked concept of facility design, more specifically the functional design and use of line maintenance zones and ready rooms, had a notable impact upon human factor characteristics that influenced aircraft related errors. Managers concerned about implementing effective error management techniques within the line maintenance environment would be well advised to evaluate the collective effect facility design has on operational safety and effectiveness. Specifically, considerations in ready room and gate design can have a major impact on human factors issues such as communication, complacency, knowledge, distraction, team building and effectiveness, fatigue, resource availability, assertiveness, awareness, and the development of normative behaviors.

For the purpose of illustration, consider two contrasting facility designs observed during the study and their impact on human factors issues. The diagram in **Figure 14.1** shows the general facility layout of one line maintenance operation area observed during the study. An evaluation of the station's historic record of safety, efficiency, and errors demonstrated that its propensity for error generation was much lower than other observed stations. In fact, the airline characterized this station as one of its best stations. The research team attributed much of the station's success to intrinsic design features of the facility's physical layout.

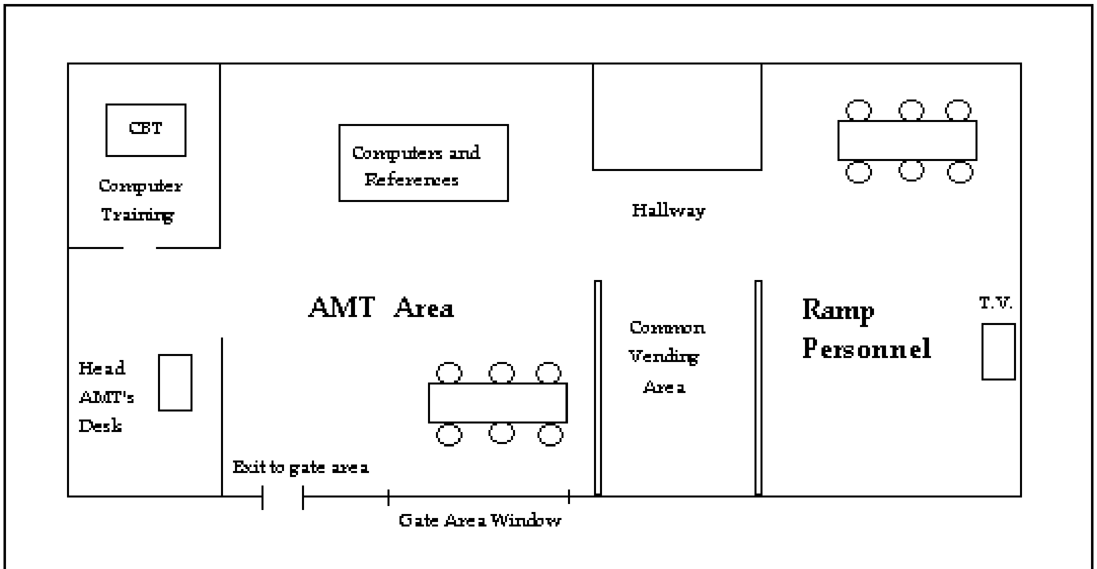

Figure 14.1 Station A - An effective facility design

The technical workforce at this station was determined to exhibit characteristics which included a well developed team-centered work culture composed of highly motivated technicians who possessed exceptional situational awareness and fostered good communications. Of particular interest in this design, and probably the most critical facet of the facility's influence on the technicians, was the physical separation of the maintenance technicians from the ramp service personnel. The maintenance technician and ramp personnel ready rooms were physically separated by a common lunch/vending area. The open hallway between the two areas allowed easy access for either technicians or ramp personnel should they need information from or need to coordinate activities with the other workforce. The lunch/vending area represented a common meeting place which allowed members from both groups the opportunity to socialize with each other if they desired. The availability of tables and adequate space in each of the separate ready rooms also allowed technicians the opportunity to congregate in a homogeneous technical group if that was preferred. Most maintenance professionals preferred to continue their interaction with other technicians within the ready room area producing a communal structure which promoted greater communication, group problem solving, and informal training.

A key effect of the separation with access which the design provided was the retention of the professional identity of each group without a feeling of alienation. While both groups maintained relatively the same work goal, that of on-time dispatch of the aircraft, these goals were approached from very notably different perspectives and with different task and time priorities. In contrast to stations where groups were mixed as a result of the design of the structure, there appeared to be a more composed and concerted focus on the immediate and long-term tasks for the day. Technicians demonstrated a greater perception of their importance to successful operations, exhibited a greater sense of self-worth, and showed a willingness to develop team qualities and shared responsibility and effort, as well as a marked difference in their ability to proactively assess and plan for future operational needs.

Another important facet of the facility's design was the immediate access to an array of various reference materials and computer terminals at the rear of the ready room. This provided immediate and unimpeded access to the information necessary to effect appropriate and timely repairs and servicing. Tool rooms and computer based training terminals were located immediately off of the **AMT** ready room in an adjacent room. The easy access to tools facilitated more efficient resolution of non-routine repairs. The ready availability of training material resulted in a greater utilization by technicians with the resultant effect of a more highly educated and knowledgeable workforce.

It was interesting to note that the homogeneity of the technical workforce fostered by the facility's design resulted in conversations which tended to be predominately technical in nature. Shared experience, group problem solving, and informal training between technicians were widely evident throughout the ready room environment. The technical nature of interpersonal communications remained prominent even when the conversation was not work related. Such communications ranged from the use of home computers to sharing various training tapes and materials. The lack of distracting interruptions from non-technical individuals also seemed to create an environment which promoted creativity. One maintenance technician proudly provided a demonstration of a checklist computer program he had developed specifically for a common gate check performed at this station. The group's desire to maintain an atmosphere free of non-technical distractions even carried over to their use of the television in their work area. Despite the fact that a television was provided in the maintenance technician common gathering area, it was seldom on or, when it was on, was normally tuned to a news or weather program.

Two structural features in the layout of the ready room appeared to play a key role in the level of perceived team function and job focus. One feature was the location of the head maintenance technician's desk adjacent to the main door which led to the gate areas. The head maintenance technician, charged with supervisory duties and task flow, was separated from the technicians only by a waist high partition as they moved back and forth from their gates. This facilitated greater interaction and communication directly between the technicians and the maintenance supervisor. This face to face interaction not only provided greater oversight of tasks but also generated greater communications regarding problems encountered. It also provided an immediacy regarding the status of the various aircraft at the gates which provided a heightened situational awareness.

The active presence of an established team leader, the maintenance supervisor, created greater team identity and generated a constant flow of communication which seemed to be a factor in maintaining the high degree of job focus and task related conversation among group members. The interactive nature of technical communications between all maintenance technicians in the room insured that technical problems or questions were immediately subject to the scrutiny of the whole group. This often resulted in a cohesive resolution of the issue due to the large knowledge and experience base shared by the technicians, which included the team's leader. Difficulty with flight departures had an immediate communication path to the head maintenance technician. Also an important facet of this face to face interaction was the team leader's ability to assess nonverbal cues which could alert him to difficulties or changes in the attitudes of his workers. Human gestures and body languages could be continuously monitored by the team leader for signs of frustration, exhaustion, anger, etc.

The second important feature noted in the facility's design was the placement of a large plate glass window which allowed a panoramic view of much of the gate area and transiting aircraft. By providing an unobstructed view of the gates and the arriving and departing aircraft, all of the team members were able to assess the status of line maintenance operations on a continual basis. Team situational awareness for each flight interaction appeared to begin much sooner and was maintained at a much higher level than by technicians at facilities with dissimilar designs. This heightened awareness promoted greater team action and operational coverage. In cases where one technician was unavoidably delayed for an arriving flight, an adjacent gate technician or other team member was observed to immediately initiate the arrival duties. Situational awareness at the facility seemed to transcend attribution as an individual trait and, instead, took on the nature of being a team characteristic. Providing a direct view of the gate and maintenance work areas not only allowed prompt detection of some early error chain events, but also caused appropriate interventions to be initiated to insure that they did not lead to an incident or accident. This team identification of error events not only provided greater potential for error detection but also provided the additional benefit of facilitating a greater awareness of the causes of errors by each technician and greater vigilance among all of the team members.

Finally, the facility design of Station A had a dramatic effect on the level of distractions impacting technicians working in that environment. Distraction from environmental "noise", auditory, visual, and informational, was reduced by separating the two work groups. Because of the separation from ramp personnel, non-work related discussion and overall noise levels were notably low. Visual distractions caused by personnel "through-traffic" within the ready room were significantly reduced. The distraction caused by a constant bombardment of unrelated information, such as sports scores, idle chit-chat, joke telling, television shows, etc., was not present within the technical ready room at this station. Instead, a professional atmosphere prevailed which concentrated on the exchange of technical and operational information. The resultant task-focus of the group resulted in a work environment devoid of distractions.

Figure 14.2 shows the diagram of a facility design which, except for minor work area arrangement differences, appears very similar to the ready room of Station A. Although this design contained much of the same equipment and resource materials available at Station A and had a similar compliment of technical and ramp personnel, the overall effectiveness of the station and its propensity for generating error were dramatically different. One of the most notable differences in the facility's design was the use of small one or two-person work stations at the individual gates which were intended to provide maintenance technicians an accessible work station near the aircraft for operational convenience during receipt and dispatch of the aircraft. Upon closer examination, however, it is evident that the configuration of the ready room for this station was considerably different than that of Station A. These subtle differences had a dramatic effect on the level of technical communications, distractions, team orientation, and situational awareness of maintenance technicians working within this environment.

By contrast, the work area illustrated in **Figure 14.2** represents the general facility layout of a line station which had a history of low technician effectiveness and frequent error generation. Again, the research team ascertained that the facility design had a dramatic effect on many human factors influencing technicians at the station.

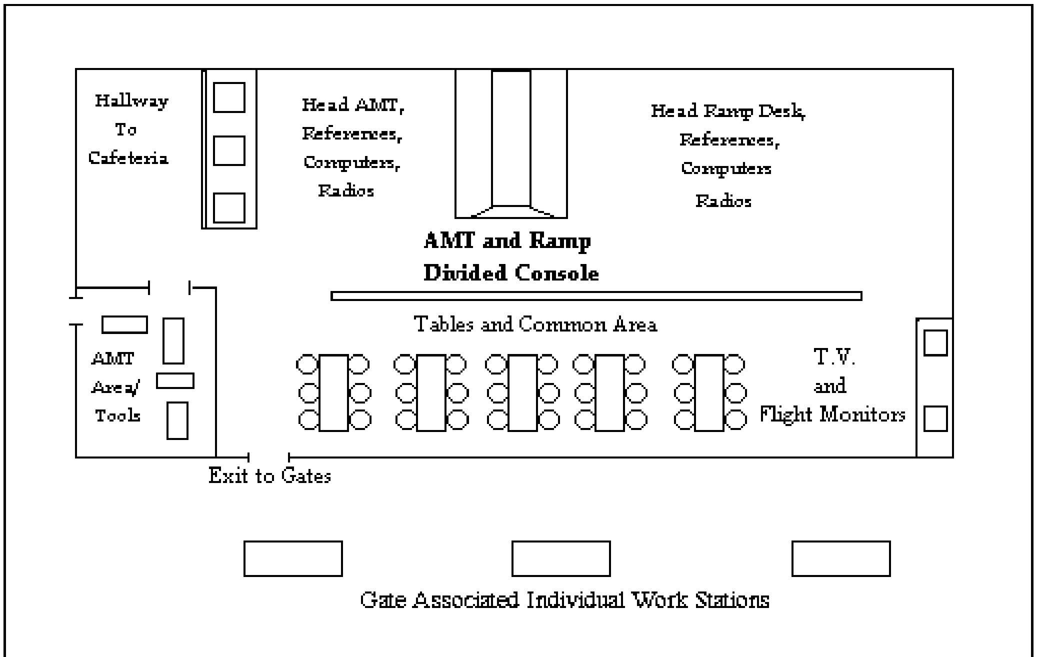

Figure 14.2 Station B - A less effective facility design

During the observation, the most readily apparent difference was the use of a common gathering area for both ramp personnel and the maintenance technicians. Despite the fact that this room was large by comparison to that of Station A's, moving around within the room was somewhat difficult due to the placement of the large number of tables and the associated flow of human traffic from the combined workforce. It was observed that technical discussions were all but non-existent among maintenance technicians when they were present in this common ready room. The number of technicians who utilized the ready room was also quite small. It was interesting to note that members of these two professional populations elected to congregate in homogeneous groups and seemed to avoid inter-group interactions. Despite the fact that no facility layout feature segregated the two groups, the combined employees at the station naturally polarized into groups of similar profession. This resulted in a division of the ready room with ramp personnel on one side and what few technicians were present on the other.

Station B's facility design also resulted in a greater level of environmental noise which served as distractions to the technicians. Commercial television shows on the ready room's TV were a focal point for the majority of ramp personnel in the common room. By contrast to the television in Station A, this television's volume was kept quite loud and the programs watched were not informational, news or weather, but rather sports and entertaining programs. The elevated volume of the television had the additional effect of forcing interpersonal conversations to become loud and animated. The distraction posed by the ready room environmental noise had the observable effect of forcing technical discussions among maintenance professionals to be very abbreviated. In almost every case, technicians who wished to discuss technical problems or issues were seen retreating to bathrooms, tool rooms, or the ramp area to have those discussions.

Reference materials, manuals, and operations computer terminals utilized by both populations were arranged on a work bench in a common area located in the back of the ready room behind a long partition. Both the ramp service supervisors and the head maintenance technician shared a divided console in this same area. The resultant heavy traffic generated by both ramp and technical workers interfacing with their supervisors produced associated confusion and high levels of auditory noise. These factors deterred technicians from using technical manuals and operational status computers and represented a barrier to timely and adequate interaction with the maintenance supervisor. Interaction between individual technicians and their maintenance supervisor as well as among technicians were characterized as "laborious" and "impossible" in this environment. Several observations involving numerous shifts indicated that maintenance technicians rarely utilized the reference area. This fact had a direct impact on the utilization of necessary technical information for non-routine repair, a factor which directly influenced error generation. It was noted that technicians avoided this area even during break periods and meals. Instead, technicians preferred to remain on the ramp area often "living" in the temporary work areas adjacent to the gates or forced to convert tool rooms into "makeshift" ready rooms. The net effect was to cause technicians to become "loners" and destroy any tendency to become involved in team building activities. A by-product of this tendency was the implementation of radio communication between individual technicians and the maintenance supervisor by one airline. When technicians were asked by the carrier what things were the most distracting influences in their environment, many technicians listed their radio as the most distracting force with which they had to contend.

As mentioned previously, in an effort to find refuge from the confusion and noise of the ready room, technicians disbursed to various locations throughout the ramp area. Technicians not seeking the camaraderie of fellow maintenance professionals most often reverted to isolating themselves in the temporary work stations at the gates. This totally destroyed any tendency of the technical workforce to build teams and dramatically reduced the cooperative problem solving and work support efforts. It also eliminated the ability for technicians to "check" or "follow-up" on each other's work. This had a dramatic effect on the potential for error generation and the reduction of "safety net" solutions to potential problems.

Technicians who stridently pursued interactions with other maintenance professionals often had to resort to extreme and imaginative solutions for establishing a communal gathering place. At stations where there were no exclusive gathering areas for the maintenance technicians, they literally "carved out" makeshift meeting areas for their technical groups. Common areas often converting into makeshift maintenance technician gathering areas included parts delivery stations, ramp vehicle garages, closets, parts or tool rooms, and various storage rooms. In the design shown for Station B, technicians converted a tool room adjacent to the ready room into a technical meeting area. This effectively established a quiet environment with less distractions where technicians could converse about technical issues and collectively generate solutions to technical problems. The room also served the purpose of defining a professional boundary which discouraged non-technicians from interfering with the group focus. It was observed that even though the door to the room was always open, no ramp personnel entered with any regularity.

While these makeshift gathering areas allowed technicians to reestablish team identity and focus, they extracted a severe penalty in several other ways. Most notable was the dramatic reduction in their ability to maintain situational awareness with the status of line operations at the station. This was due in large part to the fact that the room had no windows and technicians had no view of the gate area. Isolation from the ready room and their supervisor also resulted in a dramatic reduction in operational information. It even removed the visual cues generated by changes in the tempo of activity among others which could alert them to situational changes and conditions requiring their intervention. Removal of the technician from the ready room to the makeshift gathering area or to the temporary work station at the gate had the additional effect of making it extremely difficult for the maintenance supervisor to monitor activity, provide guidance, and coordinate work assignments. These factors had the net effect of increasing the probability of error generation at the station.

Since the makeshift gathering area was very small, most of the technicians at the station were forced to remain at their gates, isolated from the other technicians. Possibly as a result of this relative isolation, many maintenance technicians developed detectable levels of conflict between themselves and other gates, other shifts, and ramp service personnel. While technicians readily assisted other technicians when asked during especially troublesome problems or conditions, teamwork and problem solving would cease as soon as the problem was resolved. Absent was the spontaneous offering of assistance noted at Station A.

Work Station Design

Closely aligned with the issues related to facility design was the location and design of workstations within the line maintenance environment. Inadequate or improper workstation design can not only lead to injury of the worker but has also been proven to contribute to human errors.[2] Like facility design, little effort or thought seemed to have been expended in providing adequate or appropriate workstations for line maintenance technicians. While researchers recognized that the line mechanic's principle workstation, the aircraft, has severe constraints which limit the extent and kind of intervention which can be exercised in supporting aircraft related workstation ergonomics, the fact remains that researchers found little consideration for many station related work areas. Of the seventeen line stations visited during the course of the study, only one gave evidence of any forethought and design accommodation for the ergonomic needs of the technician. It is interesting to note that this exception appeared to be the result of input by the technicians themselves during the design phase of the station.

At all of the stations observed during the study, there appeared to be inadequacies in the understanding, preparation, and design of technician work areas and support equipment. Work area access, lighting, ventilation, temperature and humidity control, and layout were often neglected. In fact, at over sixty percent of the stations, principle work areas had been established by converting parts delivery stations, storage rooms, vehicle garages, closets, or other areas inadequate for the purpose. In addition, work benches, maintenance fixtures, and other important features of the workstation were often "home made" from scrap or leftover materials found around the area. Needless to say, these designs gave no consideration to technician address of the work platform, reach, height, or other important workstation ergonomic parameters.

Even in areas where design had been a consideration, the ergonomics of the work area were generally inappropriate or incomplete. As an example, in reference material and computer areas, the equipment most often was not configured for ergonomic access by technicians and seldom conformed to ergonomic standards. Old or inadequately configured micro-film and fiche readers, computer monitors, and other important informational tools often represented ergonomic hazards for the technician.

The "makeshift" or "make do" attitude perpetuated by the inadequacies of work area design seemed to spill over into other line maintenance environments. Technicians were often observed using paint cans, milk crates, boxes, and other items as stools for reaching work or installing or removing ground service electrical plugs, even when the appropriate equipment was readily available. When a work platform was needed, a fork-lift would do if it was more readily available. These inappropriate solutions often resulted in inadequate work address, poor vision, extended reach, and other ergonomic factors which could lead to injury or error generation.

Technician Motivation and Self-Concept

Research has determined that the mental state and motivation of the worker plays an important role in controlling work related human errors.[3] How technicians perceive themselves and the importance of their contribution to the overall operation are important considerations in error propagation, safety, worker effectiveness, and efficiency. Observation of line maintenance technicians resulted in the identification of several important issues which impact their perception of self-worth and have a significant impact on their level of personal motivation. The influence of these issues upon the technician's attitude toward their work and general motivation was quite evident in their general appearance, demeanor, interface with other professional groups, and attention to detail.

Lack of Professional Status

Almost without exception, line maintenance technicians were very troubled by feelings that the aviation maintenance professions are grossly undervalued and unappreciated by everyone. These feelings seemed to be reinforced daily by management, other aviation professionals, and even the general public. From the beginning, it became quite obvious that the lack of respect afforded the maintenance professions deeply disturbed most technicians and significantly affected their feelings of self-worth, their feelings about the importance of their contribution to safety and operational effectiveness, and their personal motivation. It would have been easy to dismiss these observations as simply "disgruntled workers" if it were not for the fact that the issues were continuously discussed and caused obvious pain and concern for technicians. The impact that such feelings had on complacency, communication, assertiveness, work related stress, and the development of norms is obvious.

Many issues which affected the technician's feelings of self-concept and influenced their motivation were generated by the aviation workplace. While technicians generally professed that their contributions to safe and efficient flight operations were just as important as those of the pilot, they seemed to unanimously agree that they were not afforded the respect or considerations which pilots receive. These feelings most often manifested themselves in a technician's attempt to dissuade the student researchers from pursuing a career in aviation maintenance. Instead, they would point to the aircraft's flight deck and say "you want to be up there, in the left seat." Repeatedly throughout the study at numerous locations, technicians would relate that management viewed maintenance as "a necessary evil." They obviously felt that their contributions were neither appreciated nor respected.

Career related factors which also influenced their feelings of self-worth were the absence of any discernible career ladder, a stratified pay scale, limited or no feedback about their performance, and the fact that in many environments they are tied to other vastly dissimilar workforce groups during contract negotiations. Most professions have a clearly defined career ladder against which a professional might evaluate their career progress. Milestones along a career ladder are often marked by significant pay incrementation, new certification, the development of new knowledge and skills, or other notable indicators of professional advancement. Flight crews have a very discernible career ladder marked by changes in flight crew status, pay increases, aircraft type ratings, and recurrent training opportunities. Maintenance professionals, on the other hand, have none of these indicators of success.

A recent salary study of maintenance professionals working for airlines showed that pay increases were received by maintenance technicians during their first five years of employment with the carrier.[4] After that time, most technicians could expect to receive little or no increase in pay. In addition to a stratified pay scale, the maintenance professions offer little in the form of a structured knowledge or skill development opportunities. For most technicians, having an **A&P** license is the terminal certification which can be obtained. There are no formal means for recognizing any further certification or education.

It was surprising to the researchers to see the enthusiasm and anticipation generated among technicians by the formation of the International Society of Aviation Maintenance Professionals (ISAMP) and its recognition of recurrent training as a requirement for membership status in the organization. The vast majority of technicians observed in the study indicated that they desired training and educational opportunities. In most cases, they gave the impression that training was viewed as a reward and that they did not have the opportunity to learn as much as they thought they needed to do their jobs effectively.

Most technicians indicated that they did not feel that they received the respect they deserved. They often indicated that "management" did not listen to their suggestions or concerns. Since many of them felt that they had valuable insight into operational problems, they took this as a personal affront. Technicians also felt that in the minds of managers they were tied inexorably to other less skilled workforce groups who did not share the weighty responsibility for flight safety.

Perception of Public's View of Maintenance

Technicians are also troubled by their perception of how the general public views aviation maintenance and maintenance technicians. The study indicated that they generally feel that the public does not understand the importance of aviation maintenance, the extensive skill and knowledge possessed by technicians, or the high degree of reliability of aircraft maintenance and its contribution to airline safety. Technicians perceive that they are held in such low esteem by the public that more than one technician confessed that they did not tell friends or neighbors what they did for a living. At one station, a technician offered a copy of Webster's New Collegiate Dictionary as evidence of why the public had such perceptions. The second definition under "grease monkey" in the dictionary reads "an airplane mechanic." At every station, technicians could be heard bemoaning the image presented by the aircraft mechanic, Lowell, on the popular television situation comedy "Wings."

Their concerns seem to be warranted. A study of public perception currently being conducted at Purdue seems to indicate that the public has little knowledge of the true nature of aviation maintenance and holds aviation maintenance technicians in low esteem. While the survey is only in its initial phase of distribution, early results of the survey indicate that about seventy percent of the respondents think the primary cause of aircraft accidents is maintenance related error. When asked what career field aviation maintenance technicians are most similar to, they most often respond "automobile mechanic."

Inter-professional and Intra-professional Conflicts

Throughout the study's observations, the researchers were struck by the frequency and intensity of interpersonal conflicts which seemed to pervade the work environment. While many of these conflicts seemed to have their roots in the technician's feelings of self-worth or the level of respect they felt they received, these conflicts represented a formidable barrier to effective teamwork, communication, and work related pressures and stressors. These issues, especially the disruption of effective communication and teamwork, were viewed as major influences on error propagation and operational safety.

Flight Crew / Technician Issues

The effective communication of maintenance discrepancies is critical to effective and efficient resolution of maintenance problems. For this reason, the communication between flight crews and maintenance technicians was a critical focus of the research study. Although all of the airlines professed to have good relations between their flight crews and maintenance professionals and invariably had "standard procedures" which dictated that the maintenance technician would meet and debrief the flight crews with regards to maintenance problems on the aircraft whenever possible, the study observations found that technicians most often avoided contact with flight crews. In fact, it was not uncommon for technicians meeting arriving flights to stand at the bottom of the stairs to the aircraft and wait until the flight crews had left the aircraft. When technicians did meet and debrief the flight crews, the interface was often marked by tension and communication was often kept to a bare minimum.

Conflict often arose over disagreement as to the dispatchability of the aircraft, whose "airplane" it was at a particular moment, or what was an appropriate "fix" for a specific problem. The fact that many of these issues were not "real issues" was evidenced by the fact that several technicians were observed who had a history of conflict free interactions with flight crews. These technicians made it a point to establish good lines of communication with the flight crew immediately upon arrival and maintained contact with them throughout the ground operation. These technicians were observed to have fewer "could not duplicate" and "no fault found" results when evaluating maintenance discrepancies and had a lower rate of "deferred" items and dispatch delays.

Management / Technician Issues

Throughout the observations, it was apparent that many technicians harbored a mistrust of management which fostered conflict. Most technicians felt that management would provide resources to maintenance operations only when absolutely necessary. They felt that maintenance was perceived as a "necessary evil" and that expenditures of resources for maintenance needs and training were a very low priority. Technicians felt that management did not listen to their suggestions and concerns and that they had no impact on management decisions. When training programs or changes in procedures were implemented, technicians often viewed them as the current "flavor of the month" and gave them little opportunity to prove their worth. The prevailing attitude among technicians was that management stifled creativity and original thought. These feelings often manifested themselves as poor communications, complacency, breaches in established procedure, and work related pressure and stress. In no case was management observed to be perceived as a member of the "team."

Zone, Shift, and Work Function Issues

Poor cooperation, communication, and teamwork were not limited to relations between professional groups. Researchers observed a significant level of conflict between groups of technicians. These conflicts often took the form of conflict between "zones" or gates, shifts, or hangar maintenance work groups. Especially prevalent were conflicts between line maintenance groups and technicians working in the hangar. The rift was so great between these technicians that it was often characterized as a "wall" or "canyon." These barriers to effective communication, coordination of work effort, and the assignment of blame for incomplete work or damage to the aircraft often resulted in undetected human errors and an erosion of safety.

SUMMARY

While this two year study of airline line maintenance operations provided valuable insight into many of the dynamic human factors which impact human error generation, operational efficiency, and safety, it is by no means comprehensive or complete. The research study was intended to be a "pilot" study to identify areas for further study. To this end, the project was very successful and enlightening. The findings presented in this paper are by no means all of the issues identified during the course of the project. Many additional human factors were observed to have a dramatic impact on the potential for human error generation as well as operational efficiency, work culture dynamics, and safety. The findings presented in this paper represented some of the most prominent "atypical" human factors issues observed during the study which influenced a worker's propensity to originate human errors while performing aircraft maintenance tasks.

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2. Konz, S. (1995). *Work Design: Industrial Ergonomics* (4th Edition). Scottsdale, AZ: Publishing Horizons.

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4. FAPA (1992, October). Wages of Technicians at the Airlines. *PAMA News,* 9.

DR. GARY EIFF

Dr. Gary Eiff (top left) is an Associate Professor in the Aeronautical Technology program at Purdue University. His principle area of instruction is avionics systems and human factors. He has over 30 years of aviation maintenance and avionics experience, primarily in the Corporate/General Aviation community. He is also a Commercial and Instructor rated pilot with over 4,000 flight hours of experience.

DR. DENVER LOPP

Denver Lopp (top right) is currently an Assistant Professor at Purdue University in the Department of Aviation Technology. His areas of instruction include transport category aircraft maintenance, airline/airport management, and aviation law. Prior to arriving at Purdue, Mr. Lopp had a career ranging from maintenance management to corporate finance at a major air carrier. Outside of the field of aviation, Mr. Lopp owns and operates a multi-state commodities clearing firm.

MR. MIKE LAPACEK

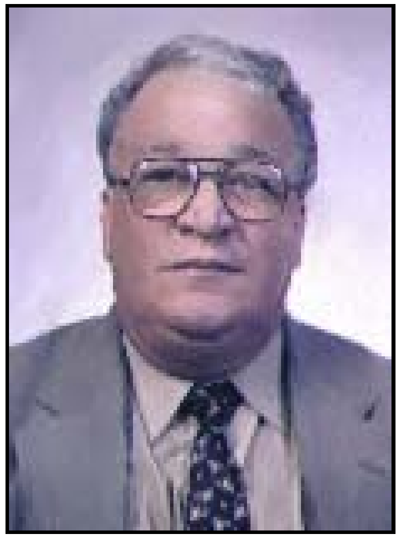
Mike Lapacek (below left) is currently a graduate student in aviation human factors at Purdue University. He is an instrument rated commercial pilot and is working on his airframe and powerplant license. Mike has been a team leader for human factors research projects throughout the past two years. Mike is expecting to receive his Masters of Science degree in 1998.

MR. TIMOTHY ROPP

Timothy Ropp (below right) is a graduating senior in Aeronautical Technology. Tim plans to continue his studies and pursue a Masters of Science degree at Purdue upon completion of his maintenance related Bachelors degree. Tim has an A&P license and has been a team member and project leader in various human factors research efforts at Purdue.

SUMMARY PANEL DISCUSSION TEAM

JOHN J. GOGLIA



John Goglia is an internationally recognized expert in aviation maintenance and aircraft operations. In August 1995, he was sworn in as a Member of the U. S. National Transportation Safety Board. He is the first working **A&P** mechanic to serve on the Safety Board, with over thirty years of aviation experience.

Before his Senate confirmation, he was based with USAir and was the recipient of the prestigious 1994/Industry Aviation Mechanic of the Year Award. With a wealth of experience, Member Goglia is a leading advocate regarding the evaluation of human factors in the aviation workplace. He developed the Maintenance Resource Management Program, combining management, labor, regulatory agencies and academia into what has become the premier human factors program in aviation maintenance.

Mr. Goglia served as the Governor's appointee to the Massachusetts Workers Compensation Board and to the Boston Area Second Airport Site Selection Board. Mr. Goglia served as Team Coordinator of the International Association of Machinists and Aerospace Workers' (IAM) Accident Investigation Team and for over 21 years he served as the IAM's Flight Safety Representative. He was the IAM's principle specialist on aviation issues, service as liaison to the **FAA**, **NTSB**, **DOT** and other executive branch agencies as well as the U. S. Congress. He represented the IAM on the aviation Rulemaking Advisory Committee, which evaluates and recommends changes regarding aviation safety and operational regulations.

Member Goglia served as Chair and a founding member of the National Coalition for Aviation Education, an aviation industry organization that advances aviation education among America's youth and aviation workforce. He was an original member of the Steering Committee to establish International Society Aviation Maintenance Professionals, a professional society dedicated to advanced safety and professionalism throughout the aviation maintenance industry. He is an internationally known speaker and author addressing aviation safety issues, lecturing at world symposiums and serving as contributing editor to several industry periodicals. In 1960, John learned to fly in a Piper J2-J3 and, for over ten years, he was owner/operator of an aircraft service company.

MR. RAYMOND GOLDSBY

Mr. Goldsby's aviation maintenance career spans nearly 40 year of operations, management, training leadership, and consulting experience. Thirty four of those years were with a major air carrier in maintenance operations. Rays primary focus has been in the maintenance training arena.

He remains active in industry affairs; having served on the **FAA** Pilot and Aviation Maintenance Technician Shortage Blue Ribbon Panel (Chair of **AMT** Activities), **FAR** Part 65 **ARAC**, **ATA** Maintenance Training Sub Committee (Former Chair), and is currently Co-Chair of San Jose State University Aviation Advisory Council.

Mr. Goldsby participated in developing the Training Section of the Human Factors Guide for Aviation Maintenance. He was the primary author of the 1996 **FAA** report Training and Certification in the Aircraft Maintenance Industry and is often called upon to speak, or be a presenter, at industry meetings. He has completed four years of college, holds an Associate Degree in Business Management, and an **FAA** Airframe and Powerplant Mechanic Certificate.

DR. WILLIAM B. JOHNSON

Dr. Bill Johnson has a unique combination of qualifications. He is an Aviation Maintenance Technician, a pilot for 30 years, and a Ph.D. He has also served as a Designated Mechanic Examiner for the **FAA**.

Dr. Johnson is the Vice President of the Information Division for Galaxy Scientific Corporation in Atlanta. His Division specializes in human factors, technical information and digital documentation systems, mobile computing, and computer-based job-aiding and training systems. He is the Galaxy Program Manager for the Human Factors in Aviation Maintenance research program sponsored by the **FAA** Office of Aviation Medicine.

Dr. Johnson is a member of the International Society of Air Safety Investigators, the Human Factors and Ergonomics Society, and the International Air Traffic Control Association. Johnson served on the committee to write the *US National Plan for Human Factors in Aviation*. He has over 100 publications related to Human Factors, Technical Training, and Job Performance Aiding.

DR. WILLIAM T. SHEPHERD

See Introduction for picture and bio.

LIST OF INVITED EXHIBITORS

FAA RESEARCH PROJECTS

STAR - System for Training Aviation Regulations

Dr. Terry Chandler

PERS - Proactive Error Reduction System

Mr. Gopinath Megashaym

TRACS - Turbine Repair Automated Control System

Mr. Philip Hastings

AMTT - Aviation Maintenance Team Training

Dr. David Kraus

Human Factors Web page and Electronic Documentation

Mr. Craig Earon

NASA RESEARCH PROJECT

Dr. Linda Connell

SAN DIEGO MIRAMAR COLLEGE

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Mr. John Todd

AIRCRAFT TECHNICAL PUBLISHERS

SUMMIT AVIATION

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FLIGHT SAFETY INTERNATIONAL

Mr. Keith McGann

CIMLINC

Mr. Bob Dickey

SIEMANS-NIXDORF

Mr. Jim Crawford

AGENDA

The 11th FAA/AAM Meeting on Human Factors in Aviation Maintenance and Inspection "Human Error in Maintenance"

Wednesday and Thursday, March 12-13, 1997
Holiday Inn On The Bay
San Diego, California, USA
(Estimated Attendance: 200+)

Tentative Agenda

All sessions will be classroom-style seating.

Tuesday, March 11

3:00-5:00 PM **Registration**

Wednesday, March 12

7:00-7:30 AM	**Registration**
7:00 - 8:00	**Continental Breakfast**
8:00-8:30	**Session I** **Opening Remarks** Dr. William T. Shepherd Federal Aviation Administration Office of Aviation Medicine
8:30-9:10	**Keynote Address** Mr. Guy Gardner Associate Administrator for Regulation & Certification Federal Aviation Administration
9:10 - 10:00	**Title: Approaches to Controlling Maintenance Error** Professor James Reason University of Manchester, UK
10:00 - 10:30	**Break/ Demonstrations**

10:30 - 11:15	**Session II** **Title: Maintenance Error Decision Aid: Progress Report** Dr. William Rankin Boeing Customer Service
11:15 - 12:00 PM	**Title: Human Error and Accident Reduction (HEAR)** Mr. Matthew Wright Qantas Airways Limited
12:00 - 1:30	**Lunch (Mexican Buffet)/Demonstrations**
1:30 - 2:15	**Session III** **Title: Error Control Systems at Northwest Airlines** Mr. David Graham Northwest Airlines
2:15 - 3:00	**Title: Moving toward 100% Error Reporting in Maintenance** Mr. David Marx Aurora Safety Systems, Inc.
3:00 - 3:30	**Snack Break/ Demonstrations**
3:30 - 4:00	**Session IV** **Title: The Dirty Dozen Errors in Maintenance** Mr. Gordon Dupont Transport Canada
4:00 - 4:30	**Title: Reducing Error through CBT Team Training** Dr. David Kraus Galaxy Scientific Corporation
4:30 - 5:00	**Title: MRM: It's Not CRM Repackaged** Dr. Ron Lofaro FAA Technical Center

5:00 - 7:00 **Reception in Exhibit Area**

hors d'oeuvres, cash bar

Thursday, March 13

7:00-7:30 AM	**Registration**
7:00 - 8:00	**Continental Breakfast**
8:00 - 9:15	**Session V** **Title: Maintenance Human Factors and Error Control** Dr. Steve Predmore Delta Air Lines
9:15 - 10:00	**Title: A Proactive Error Reduction System (PERS)** Professor Colin Drury State University of New York Buffalo
10:00 - 10:30	**Break/Demonstrations**
10:30 - 11:15	**Session VII** **Title: Learn FARS and Reduce the Errors: A System for Training Aviation Regulations (STAR)** Dr. Terry Chandler Galaxy Scientific Corporation
11:15 - 12:00 PM	**Title: Reduction of Maintenance Error through Focused Interventions** Dr. Barbara Kanki NASA AMES Research Center
12:00 -1:30	**Lunch (Deli)/Demonstrations**
1:30 -2:15	**Session VI** **Title: Practical Considerations of Maintenance Human Factors for Line Operations** Dr. Gary Eiff, Dr. Denver Lopp, Mr. Mike Lapacek, Mr. Timothy Ropp Purdue University

2:15 - 3:00	**Summary Panel Discussion**
	The Honorable John Goglia, National Transportation Safety Board
	Mr. Ray Goldsby, Flight Safety
	Dr. William B. Johnson, Galaxy Scientific Corporation
	Dr. William T. Shepherd, FAA Office of Aviation Medicine
3:00	**Meeting Adjourned**

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