Meeting 5: The Work Environment in Aviation Maintenance (1991)

Proceedings of the Fifth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection

Report of a meeting

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FOREWORD

The safety and operating efficiency of the U.S. air carrier fleet depends on a dedicated and productive maintenance workforce. Can maintenance productivity be affected by features of the maintenance work environment? The answer is an unqualified "Yes."

Ample evidence demonstrates that workplace improvements can produce significant pay-off. The Occupational Safety and Health Act of 1970 mandated a number of safety improvements in American industry. The result was a three-fold reduction in the occurrence of work-related fatalities in less than 20 years. Just as safety benefits from workplace improvements, so does productivity. Efforts in which better working conditions and better work equipment have been introduced show comparable improvements in organizational productivity. Obviously, the work environment is important in determining how well work is done.

The Federal Aviation Administration (FAA) and the air carrier maintenance community are very interested in seeing that the work environment for maintenance is as good as can be provided. The FAA and industry are in agreement that workplace improvements can lead to enhanced safety and to a more efficient maintenance workforce. From the perspective of either outcome, the American public and American industry are beneficiaries.

This meeting brought together representatives of airline maintenance departments, aircraft manufacturers, employee unions, the Federal Aviation Administration, safety and health organizations, academic institutions, and others concerned with air carrier maintenance. Their expertise and contributions concerning the many features of the work environment are greatly appreciated. I wish to thank all of you who attended the meeting and especially those who gave presentations. A range of topics was discussed and information of real value for maintenance operations was provided.

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

EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) sponsored a two-day meeting in June 1991 as part of a series of meetings to address human factors in aircraft maintenance and inspection. At this meeting, the focus was on "The Work Environment in Aviation Maintenance." Industrial experience teaches us that the environment in which work takes place is important and can have a considerable effect on quality of work. For safety reasons and for economic reasons, any initiatives that might enhance maintenance productivity should be implemented.

The objective of this meeting was to examine the aviation maintenance work environment. The topic of "work environment" was addressed in its broadest sense with subject areas including the physical environment of the workplace, variables relating to specific demands imposed by maintenance labors, the evaluation of workforce productivity, and industrial safety and health concerns.

The meeting was attended by representatives of commercial aviation, air carrier maintenance, occupational safety and health, and academic institutions. Based on presentations given and ensuing discussions, the following recommendations are presented:

Physical Parameters

Recommendations

1. The adequacy of illumination in maintenance may well a problem. Studies should be made to determine the significance of current illumination levels and to identify optimum lighting procedures for use within and under aircraft. Solutions should be capable of implementation at major air carriers and for the smaller regional/commuter airlines.
2. Work in air carrier maintenance areas generally does not require hearing protection. However, where noise levels do exceed 85 dBA, care should be taken to ensure that appropriate hearing protection is provided and used. This will aid the work, reduce the possibility of damage, and lessen the potential for later claims for hearing loss.
3. The procurement of work support systems by air carriers would benefit from a set of human factors standards for these systems. These standards should be reviewed and approved by representatives of the air carriers before being adopted.

Workplace Variables

4. The occupational specialty of Aviation Maintenance Technician is changing significantly as new and advanced aircraft are introduced. To remain apace of these changes, the Federal Aviation Administration (FAA) should maintain a continuing review and update process for Parts 147 and 65 of the Federal Aviation Regulations (FARs).
5. As skill requirements for maintenance and avionics technicians increase, the supply of candidates, which may be minimal in any event, could decrease further and have serious impact on the ability to staff air carrier maintenance operations. A detailed manpower modeling study of the aviation maintenance technician occupation should be conducted.
6. Studies of industrial shift work show that night workers may be somewhat less proficient than day workers. However, no fixed guidelines exist for determining the best shift work arrangement. If problems appear, the best solution is one in which management and workers examine the issue together, outline available options, and decide on the best course of action.
7. The volume of paperwork, and the time required to process it, remains a problem in air

carrier maintenance, as viewed by maintenance technicians. Introducing more flexibility into current procedures might help. Mechanics might be authorized to release an aircraft on their own signature with a fixed deadline following this for completion of required paperwork.

8. The management of maintenance paperwork would benefit through increased standardization. The FAA should consider developing a standard set of paperwork requirements for each airplane. This would remove differences associated with individual airlines and with individual FAA regions.

9. Maintenance technicians now spend considerable time inputting information into the computer. A study of the technician/computer interface is recommended to develop procedures for minimizing the time required for data input.

10. Increased automation in air carrier maintenance benefits everyone. Means should be explored, possibly through committees of the Air Transport Association (ATA), to ensure that the technology being developed at this time at major air carriers can flow freely and expeditiously to regional/commuter carriers.

Worker Productivity

11. Air carrier maintenance managers should review maintenance operations to determine the extent to which work teams exist now and ways in which this concept might be fostered. To the extent that work teams can be defined and team identification established, maintenance productivity could be enhanced.

Safety and Health in the Workplace

12. Every airline, of whatever size, should have a standard operating policy which establishes a joint management/labor health and safety committee. This committee should meet on a regularly scheduled basis and have appropriate authority to review health and safety issues in the workplace.

INTRODUCTION

This report presents proceedings of the fifth in a series of meetings sponsored by the Federal Aviation Administration (FAA) to address issues of human factors in aviation maintenance and inspection. Each meeting in this series has addressed a particular topic of relevance for air carrier maintenance. This two-day meeting, in June 1991, was directed to "The Work Environment in Aviation Maintenance." Industry experience has shown that a safe and supportive work environment is essential for an effective workforce.

The topic of "work environment" was addressed in the broadest sense through presentations given by some 16 individuals representing a wide range of interests in commercial aviation, air carrier maintenance, occupational safety and health, and personnel research. Subject areas of interest included the physical environment of the workplace, variables relating to specific demands imposed by maintenance labors, the evaluation of workforce productivity, and industrial safety and health concerns. The purpose throughout was to consider ways to enhance workplace safety and the effectiveness of the maintenance workforce.

"Conclusions and Recommendations" of the meeting are presented just after the "Welcome Address" and "The FAA Human Factors Program" presentations. These conclusions and recommendations are based on a panel session held at the end of the meeting plus a review of the transcripts of each presentation and the ensuing discussions.

An edited version of each presentation, taken for the most part from tape transcripts, is presented as Appendix A.

MEETING WELCOME

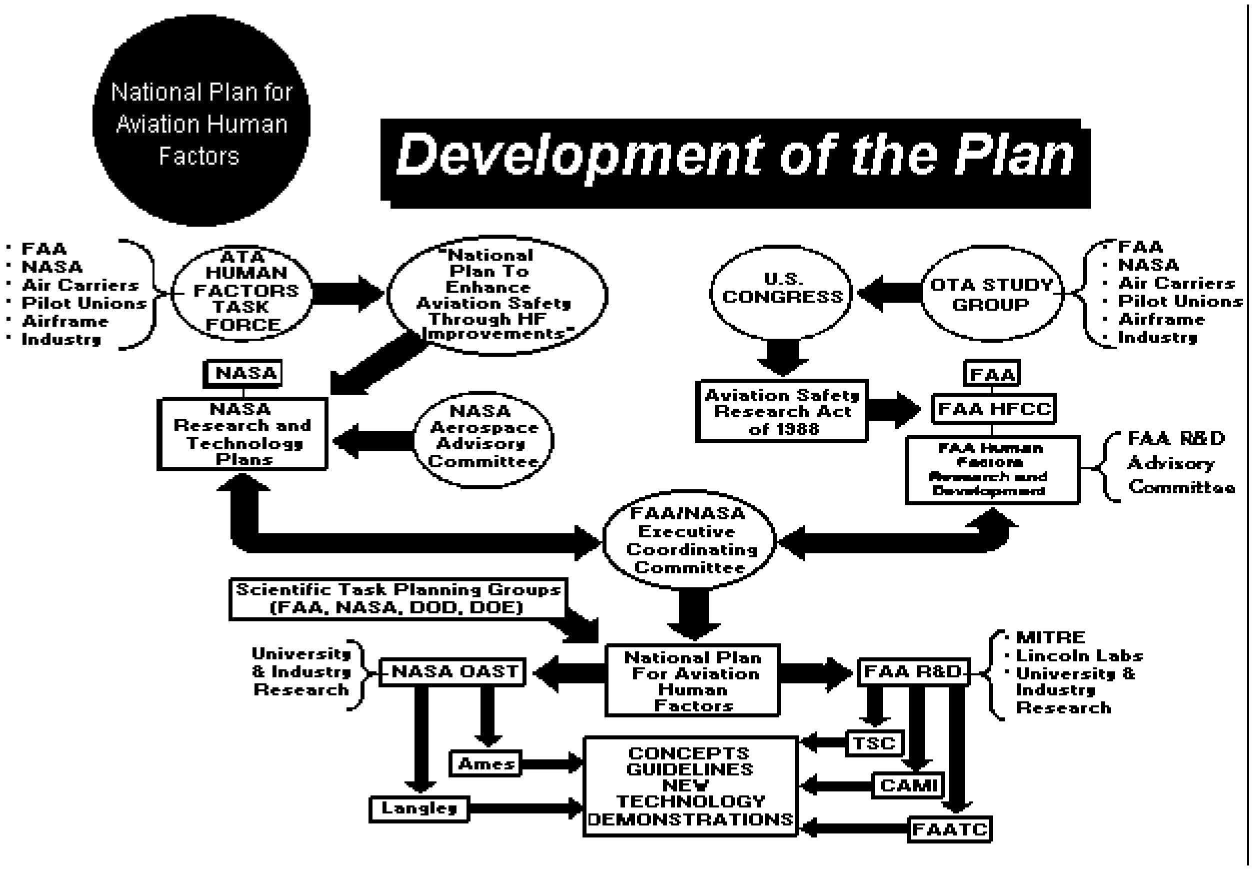
Phyllis Kayten, Ph.D.
Deputy Scientific and Technical
Advisor for Human Factors
Federal Aviation Administration

It is a pleasure to be asked to address this *Fifth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection.* We have, over the past three years, come a long way, and I am pleased to see so many familiar faces who have been with us over the span of these five meetings.

The fact that so many of us return to this meeting attests to our commitment to identifying the important human factors issues, and seeing that the FAA and industry make the identification and implementation of solutions a high priority. It is also a testament to the great job Dr. William Shepherd, Dr. James Parker and Ms. Diane Christensen have done in organizing all five meetings.

The newly heightened awareness of maintenance human factors issues -- which is reflected by these meetings -- is occurring at a particularly opportune time. Over the past two years, the FAA has been involved in a large-scale effort to coordinate all Government and industry efforts in aviation human factors. Last December, the FAA published the draft *National Plan for Aviation Human Factors.* One section of the Plan is devoted to maintenance human factors.

The National Plan is a result of several related catalysts (Figure 1): The United States Congress Office of Technology Assessment's *Safe Skies for Tomorrow: Aviation Safety in a Competitive Environment* (1988), concluded that human factors-related research was not well coordinated among Government agencies and that research funding was inadequate considering the magnitude of the problem. The Air Transport Association of America (ATA) "Human Factors Task Force" offered similar conclusions and proposed the development of a "National Plan to Enhance Aviation Safety Through Human Factors Improve- ments."



A

Figure 1

As a result of these efforts, the U. S. Congress in November 1988 enacted "The Aviation Safety Research Act of 1988" (Public Law 100-591), that called for the FAA to augment its research efforts in human factors and to coordinate programs with those of the National Aeronautics and Space Administration (NASA).

The two-volume, 900 page, *National Plan for Aviation Human Factors* is the first step toward a coordinated national program and is the result of a major effort by the FAA in partnership with NASA, with significant assistance from the Department of Defense (DoD), the Research and Special Projects Administration's Volpe National Transportation Systems Center (RSPA/VNTSC), Department of Energy (DOE), and industry. This plan is also a key element of the recently released U.S. Department of Transportation (DOT), National Transportation Policy.

The primary purpose of the plan is to identify and plan the technical efforts necessary to address the most operationally significant human performance issues in aviation as a guide to future project planning, budget formulation, and implementation. The plan also serves to coordinate research programs at various Government laboratories to prevent both gaps and redundancies in efforts. It also communicates research needs to academic and industry "centers of excellence." Perhaps most important, the National Plan will provide a means by which human factors knowledge is transferred to Government and industry.

The National Plan is a highly visible, well supported effort, both inside and outside the agency. Administrator Busey has called for the institutionalization of human factors within the FAA (Figure 2). Some of the steps we are taking toward the institutionalization of human factors include: 1) a Human Factors Coordinating Committee (HFCC), chaired by the Chief Scientific and Technical Advisor for Human Factors, with representatives from all associate and assistant administrators, to track human factors concerns and plans for each organization; 2) increasing the number of human factors specialists in all key agency organizations; 3) developing human factors training courses for agency personnel; and 4) reviewing and modifying all agency orders to assure proper consideration of human performance dimensions.

NATIONAL PLAN FOR AVIATION HUMAN FACTORS

- The "institutionalization" of human factors
- Emphasis on technology transfer and the development of useful products
- High levels of visibility and management support
- Increases funding of human factors R&D
- Expansion of human factors workforce
- Human factors specialists as members of all design teams
- Formal human factors requirements in all RFPs and in certification standards
- Human factors training for managers and system designers

Figure 2. National Plan Implementation

The technical agenda for the National Plan was developed by Scientific Task Planning Groups (STPG's). The STPG's were chosen by FAA's Human Factors Coordinating Committee. STPG's were organized to address five areas: (1) Flight Deck, (2) Air Traffic Control, (3) Aircraft Maintenance, (4) Airway Facilities Maintenance, and (5) Flight Deck/ATC Integration.

The STPG's met simultaneously at a series of three week-long research planning retreats, approximately five weeks apart. As a result, some overall coordination of the research planning effort was maintained between environments. And that is significant, since human factors issues in one environment -- cockpit display design for example -- often impact the human in another environment -- for example, aircraft maintenance.

The aircraft maintenance STPG included many of the regular participants at these meetings (Figure 3): Dr. Colin Drury, SUNY Buffalo; Dr. William Johnson, Galaxy Scientific Corporation; Dr.

William Shepherd, FAA; Dr. James Taylor, USC; Mr. Dave Hunter, previously from ARI, and now with the FAA; Mr. Robert Johnson, Wright-Patterson Air Force Base, and several others.

National Plan for Aviation Human Factors

FLIGHTDECK	ATC
Dr. R. Helmreich, Chairman	Dr. R. Simpson, Chairman
U. of Texas	Mass. Inst. of Technology
Dr. R. C. Graeber (NASA-Ames)	Dr. L. Tobias (NASA-Ames)
Mr. B. Scott (FAA-NASA-Ames)	Dr. C. Manning (FAA-CAMI)
Dr. K. Dismukes (NASA-Ames)	Dr. K. Cardosi (VNTSC)
Mr. G. Steinmetz (NASA-Langley)	Dr. E. Buckley (FAATC)
Dr. D. Schroeder (FAA-CAMI)	Dr. R. Roske-Hofstrand (NASA-Ames)
Mr. G. Lyddane (FAA-ANM-100)	Dr. E. Salas (USN)
Mr. T. Metzler (US Army)	Mr. V.D. Hopkin (RAF-IAM)
Dr. J. Reising (USAF)	Dr. G. Adam (MITRE)
Dr. M. Ritchie (FAATC)	Ms. M. Picardi (Lincoln Labs)
Dr. S. Huntley (VNTSC)	
Mr. Roger Green (CAA/RAF-IAM)	

FLIGHTDECK/ATC	MAINTENANCE
Dr. W. Rouse, Chairman	Dr. J. Taylor, Chairman
Search Technology, Inc.	USC
Mr. A. Lee (NASA-Ames)	Dr. W. Shepherd (FAA)
Mr. M. Burgess (FAA-NASA-Langley)	Dr. C. Theissen (Rutgers U.)
Mr. H. Bergeron (NASA-Langley)	Mr. H. Bachner (FAA)
Dr. K. Kerns (MITRE)	Mr. J. Fabry (FAATC)
Dr. K. Boff (USAF)	Dr. W. Johnson (Galaxy)
Dr. C. Barrett (DOE-Los Alamos)	Dr. R. Thackray (FAA-CAMI)
Dr. L. Hitchcock (FAATC)	Mr. W. Thomas (FAA-MEM ARTCC)
Dr. P. Kayten (FAA-AXR-3)	Dr. R. Smilie (USN)
Dr. R. Johnson (USAF)	
Dr. D. Hunter (US Army)	
	Mr. J. Wiley (FAATC)
	Dr. C. Drury (SUNY-Buffalo)

Figure 3. STPG Membership

The projects in the aircraft maintenance section of the National Plan are grouped into three research domains (Figure 4): (1) Personnel and Training Systems; (2) Advanced Technology Systems; and (3) Environmental and Organizational Systems.

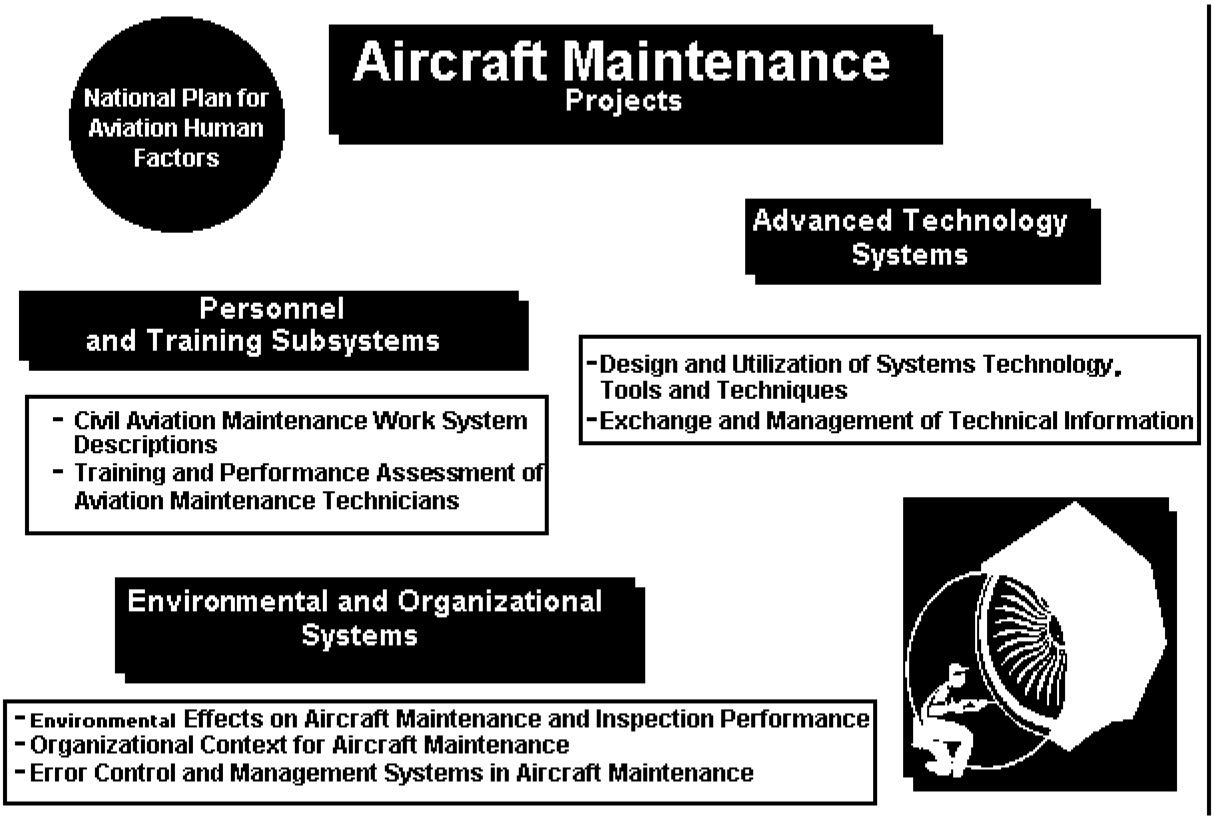


Figure 4

Each of the projects grouped under these domains address at least one of five primary human factors considerations for maintenance operations: training, the work environment, tools and technology, technical information exchange, and organizational culture (Figure 4).

The National Plan's detailed technical agenda is currently being used to guide FAA budget planning. We presently have work in progress and expected products in each of these areas.

The ATA's Human Factors Task Force presently has "Tiger Teams" reviewing the plans for each environment, and submitting comments and recommendations for additional priorities and tasks. We can expect to see continued interest and support for addressing human factors issues in the aircraft maintenance environment.

The National Plan is a "living document." As we gain more knowledge of human factors in the areas most lacking -- and aircraft maintenance remains one of those areas -- our priorities may change. It is hoped that the human factors organization put into place as a result of this effort will provide the structure needed to assure that needed research gets done, and that relevant, state-of-the-art information is transferred to those who need it.

This meeting, and the ones I am sure will follow, will help to support the goals of the National Plan. Recommendations resulting from these meetings will help guide revisions of the plan, as they helped shape the present one. I look forward to another productive two days, and thank you for the contribution you are making.

THE FAA HUMAN FACTORS PROGRAM IN AIRCRAFT MAINTENANCE AND INSPECTION

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

The FAA's Office of Aviation Medicine once again welcomes everyone to another in our series of meetings on human factors issues in aircraft maintenance and inspection. The topic for this meeting is "The Work Environment in Aviation Maintenance," chosen because a growing body of research demonstrates the extent to which variables in the work environment affect the health, safety, and productivity of industrial workers. Also, as you can readily see, we chose Atlanta as the location for this meeting. Atlanta places us close to a major aviation maintenance facility, that of Delta Air Lines, and to the offices of a key member of the FAA Human Factors Team, Galaxy Scientific Corporation. I note that we have excellent attendance from each of these organizations today.

The FAA Human Factors Program has existed now for about two years. As you undoubtedly know, a major impetus for this program was the Aloha Airlines accident. Prior to that event, little had been done to examine the importance of human factors in aviation maintenance. Considerable time had been spent in studying the problems of pilots and air traffic controllers but maintenance technicians had been mostly the forgotten member of the aviation team. Hopefully the work we are doing and the contributions that you in attendance are making are doing much to rectify this situation.

The objective of the FAA Human Factors Program is to develop products that will be useful both for industry and for FAA personnel. We would like to define those crucial human factors issues that affect the performance of aviation maintenance technicians. We would like then to be able to provide industry with background information and with specific recommendations. A primary product of this effort will be a handbook which I have mentioned in past meetings. It is our desire that this handbook be an all purpose reference text of value for many different users, both in industry and in Government. For example, this text should help someone planning maintenance work schedules. It should provide information on how many hours a person should work at specific tasks such as inspecting identical items like rivets. The handbook also should provide information on features of the work environment such as lighting, temperature, noise, and other environmental parameters. We expect this handbook to be broad in coverage and, as I noted, of use both for industry and for the FAA. For example, we would like to provide useful data to the FAA inspection force which is working with industry in the oversight of air carrier maintenance.

We have gotten a considerable amount of valuable information for the handbook in the course of these human factors conferences. We are looking for additional input from today's attendees.

As I have done at previous conferences, I would like to set the stage for today's meeting by reviewing briefly the functioning of our research program, as shown in Figure 1. The top three blocks show the input we receive from the aviation industry, from other Government agencies such as NASA and DoD, and from the private sector which includes professional and technical societies, academia and advocacy groups. All of these provide input into our program through the operation of conferences such as this, workshops, and through site visits. Many members of our research team have visited various air carrier maintenance sites and collected very useful information. All of this information comes to us in the FAA's Office of Aviation Medicine. We represent the focal point for the program. The research program directed by the Office of Aviation Medicine collects information and develops specific end products such as the handbook I was just discussing. We also, as shown in Figure 1, provide information to a variety of end users, ranging from academia to industry, which represent the full spectrum of groups concerned with aviation maintenance.

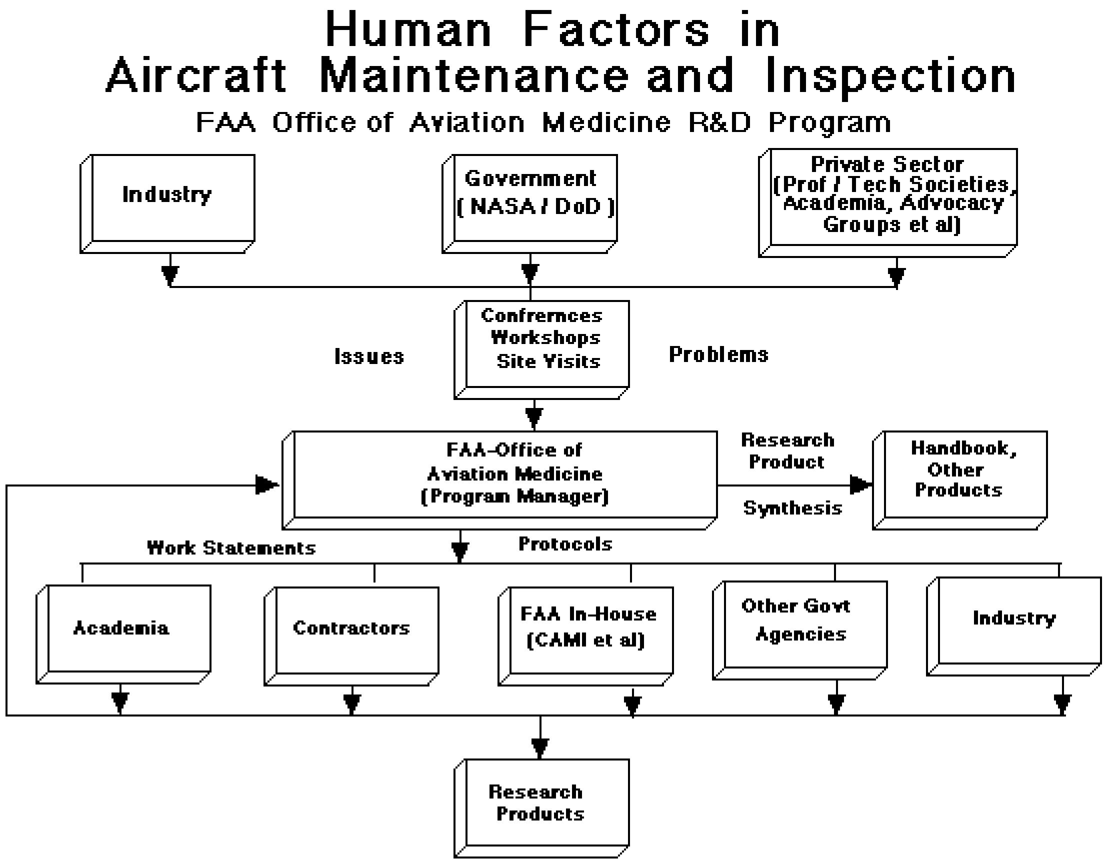


Figure 1

In preparation for today's meeting, I would like to have you consider some of the parameters underlying current maintenance operations, particularly those pertaining to maintenance costs. As you can see in Figure 2, maintenance costs for U.S. air carriers continue to rise. In the two-year period from 1987 through 1989, this cost increase approached $2 billion. Obviously, maintenance is not a cheap item. For the full U.S. air carrier industry, maintenance costs now exceed $8 billion per year.

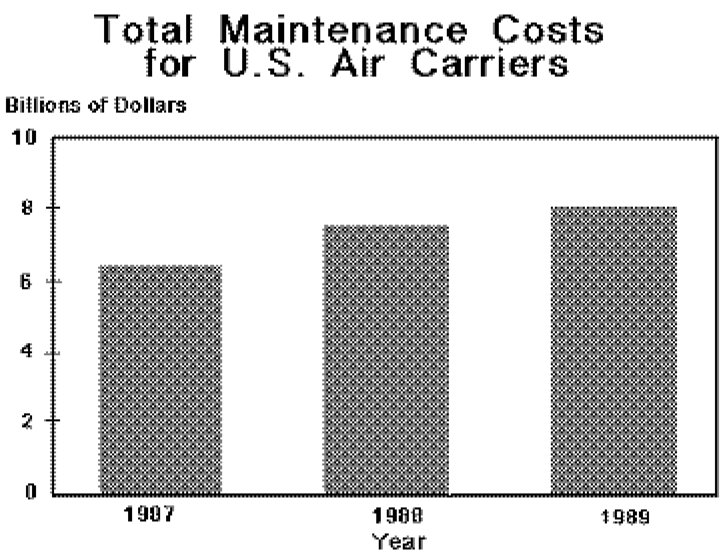


Figure 2

There are many factors contributing to rising maintenance costs. Among these is the fact that the industry is operating a large number of older airplanes such as 727's and 737's. These aircraft require a lot of maintenance. In addition, the FAA has been requiring some rather extensive modifications to some of these airplanes, all of which contributes to increasing maintenance costs. At the same time the industry has been acquiring new airplanes, producing a mix of old and new technology. The fact that both old and new airplanes are maintained by the same workforce also tends to increase maintenance costs.

An interesting feature is that, in the same two-year period from 1987 through 1989, maintenance costs increased as a percentage of total operating costs, as seen in Figure 3. This percentage increased from 11.2 in 1987 to 11.8 in 1989. This does not sound like much, only about one-half of one percent. However, the significance of this increase can be seen when one considers that the savings to industry, had these costs been held constant over the two years, would be about $165 million. This is a rather substantial number and, in fact, could have meant the difference between profit or loss for some air carriers.

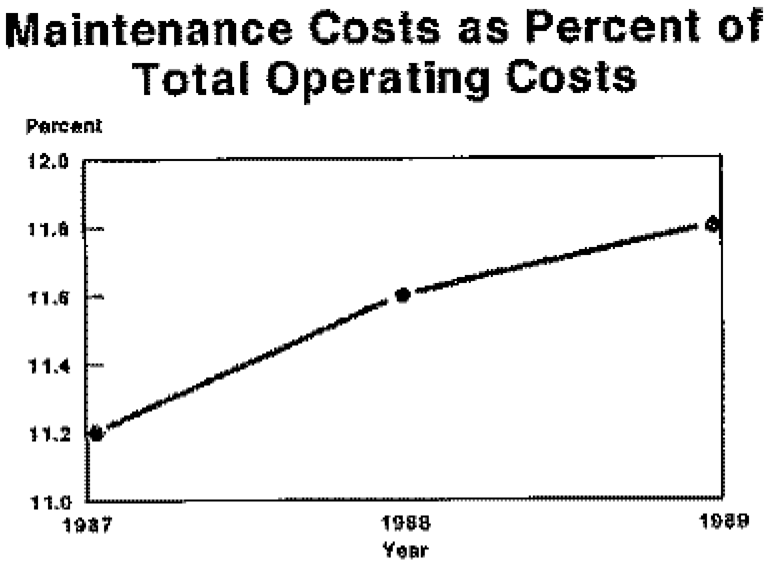


Figure 3

The fact that maintenance costs as a percent of total operating costs are increasing provides a powerful incentive to examine workforce productivity. If the performance of the maintenance workforce can be improved, productivity will improve correspondingly. While the primary interest of the FAA obviously is with safety, we are nonetheless concerned with industry productivity and would like to work with industry in this regard. In fact, it is difficult to separate safety and productivity. If one improves the safety of maintenance and flight operations, workforce productivity certainly will improve also. Many of the features of our research program that are targeting safety almost certainly will have a positive impact on productivity as well.

To deal with maintenance productivity we must understand the full maintenance process. Figure 4 presents an overview of the principal elements in this process. In particular, it shows four major factors which impact the performance of an aviation maintenance technician. These include the working environment, characteristics of the aircraft being worked on, the training of the technician, and the information and data sources available to him.

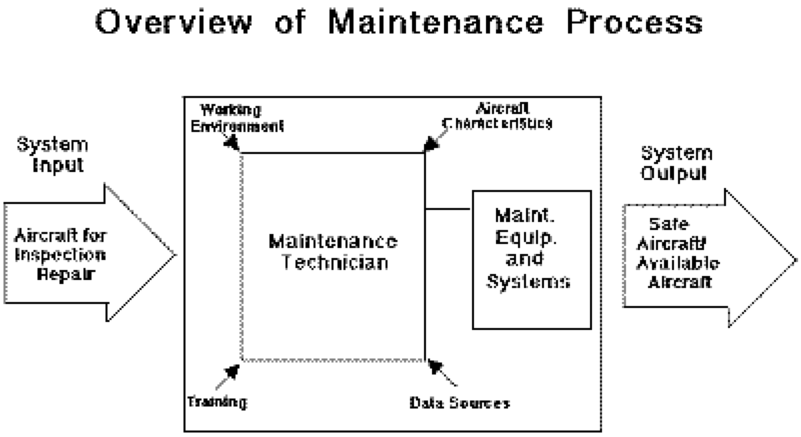


Figure 4

The theme of today's meeting is the working environment. You will see that we have a number of topics for discussion that we hope will be interesting, including some dealing with physical factors as well as those covering work factors. Again, we will cover issues affecting productivity such as job design and measurement. Also, we must not overlook the fact that the FAA, as well as the Congress of the United States, is involved in defining the characteristics of acceptable work environments. Congress is becoming much more active in examining the operations of the air carrier industry. At this time, this attention is directed mostly to areas other than maintenance, but I think we should expect that in the future Congress will give additional attention to maintenance activities.

I would like to note again that we require input from industry for our human factors program to be successful. Obtaining such information is a key goal. However, we also want to facilitate information exchange and communication among the people who are attending these meetings. I think, in fact, that we have been successful in that regard. Such information exchange and communication is almost a natural fall out from these meetings. From listening to presentations and the discussions afterward, the informal talks during breaks, and other discussions around the meeting, I believe that considerable informal exchange is taking place and that it is beneficial for everyone.

Finally, one important output from these meetings is found in the recommendations made both to industry and to the FAA. As I noted earlier, many of these recommendations to industry will be in the form of information to be presented in our human factors handbook. As we work toward this handbook, we will be requesting additional support and input from you people in the aviation maintenance community.

Again, I would like to welcome all of you to this fifth meeting and look forward to productive presentations and discussions over the next two days. Thank you.

CONCLUSIONS AND RECOMMENDATIONS

Managers responsible for maintenance of the U.S. air carrier fleet continuously strive for an efficient and error-free operation. Factors that might contribute to lessened workforce productivity or to error in aircraft maintenance and inspection must be understood and controlled. There are many such features including communications, equipment characteristics, training level of workers, management relations, and the environment in which the work takes place. This report addresses the last topic, the work environment. "Work environment" is defined broadly here and encompasses all factors, including the physical plant, the social environment, the organizational structure, and the many technical aspects that impact the performance of a workforce.

Features of the work site and ways in which work is structured can be quite important in determining the quality of worker output. A review by Miller and Swain (1987) discusses the ways in which proper design of the work setting can serve to reduce error rate. The authors note that whereas traditional industrial thinking puts the burden for human error on the worker and his or her presumed lack of competence, newer approaches examine the task demands, equipment, and work environment for characteristics that predispose a worker to errors.

The incentives for production quality and error control in air carrier maintenance are many. One certainly is cost. As noted during the meeting, the increase in air carrier maintenance costs in the two-year period from 1987 through 1989 approaches $2 billion. Of possibly greater importance than the dollar volume is the fact that during this period maintenance cost increased as a percentage of total operating costs from 11.2 to 11.8 in 1989. Had these costs remained at 11.2 percent, the savings to industry would have been about $165 million. This fact alone provides a powerful incentive to examine workforce productivity and, in turn, those factors that influence productivity. The work environment in which maintenance is conducted certainly is one such factor.

A second, and possibly even more important, incentive for examining the quality of workforce performance is flight safety. Many studies (review by Miller and Swain, 1987) have shown that work situations in which ergonomics are poor make errors more likely to occur. Such situations make demands on workers that are not compatible with their capabilities, limitations, experience, attitudes, and goals. The design of a maintenance workplace, just as the design of an aircraft flight deck, can make errors less likely or more likely.

Attendees at this meeting represent all segments within the air carrier industry, including airline operators, manufacturers, maintenance managers, union representatives, regulators, safety experts, industrial hygienists, and others. Formal presentations given during the two days covered a variety of topics related to different features of the broadly-defined work environment that affect the performance of aviation maintenance technicians. Recommendations for better understanding and management of the work environment were offered during formal presentations, during ensuing discussions, and during a final session directed specifically to conclusions and recommendations. The following recommendations represent a grouping and synthesis of broad topics considered important by attendees, with specific recommendations included within each topic.

Physical Parameters

The term "work environment" most readily brings to mind the physical features of the work setting such as lighting conditions, noise levels, ambient temperatures, vibration sources, and atmospheric composition. In air carrier maintenance, the three considered most important for worker proficiency are lighting, noise, and temperature.

While a perfect work environment would be desirable, the nature of aircraft maintenance means that certain features of the workplace will be less than optimum. Maintenance takes place, for the most part, in large hangar facilities that must hold aircraft, test stands, and maintenance equipment. Since aircraft must be moved in and out of a hangar from time to time, environmental control can never be perfect. In addition, some maintenance, particularly at line stations, must be conducted outside where technicians are at the mercy of the elements.

Maintenance managers recognize that the environmental conditions under which maintenance is conducted are not perfect and work on programs of continuing improvement. All airlines have individuals responsible for safety conditions. Larger air carriers maintain safety departments and participate with unions on safety committees. Discussions may include topics such as heating problems, use of proper job clothing, and any other matters designed to minimize problems with the physical environment. Nonetheless, the nature of the work and the environment mean that certain problems remain.

Lighting Conditions

Inasmuch as maintenance is conducted on maintenance benches, at test stands, on external surfaces of the aircraft, within the aircraft hull, and beneath aircraft wings means that lighting conditions vary dramatically. An FAA audit of major air carriers included a survey of lighting conditions and found a variety of lighting systems in use, including mercury vapor, metal halide, and high-pressure sodium lights. Although these lights differ in color rendition, the principal problem was with level of illumination. For work performed on upper and lateral surfaces of the aircraft, illumination levels were deemed adequate. These levels average to 66 foot candles (ft-c) during the day and 51 ft-c for night maintenance work. For work conducted below wings, inside the fuselage, and in cargo areas, illumination is poor and use of supplemental lighting systems was noted. However, these frequently were placed too far from the work being performed and were too few in number. The result was that illumination levels in shielded regions ranged, on occasion, from one to about 10-14 ft-c. In terms of recommended minimum illumination levels for aircraft repair and inspection tasks established by the Illuminating Engineering Society, these levels are not adequate. A minimum level of 75 ft-c is recommended for repair tasks.

Recommendation

1. The adequacy of illumination may well be the most important environmental issue affecting maintenance performance. This is particularly true for maintenance tasks which must be conducted within relatively inaccessible parts of the airplane. Further studies should be made to determine the significance of current illumination levels and to identify optimum lighting procedures for use within and under aircraft. Recommended solutions should be equally feasible for major air carriers and for the smaller regional/commuter airlines.

Noise

Noise levels during air carrier maintenance generally are quite acceptable. Average levels within hangar areas, measured by the FAA Audit Team noted above, were found to range typically from 70 to 75 dBA. This is acceptable for an industrial environment and does not require hearing protection. However, when riveting or other pneumatic tools were being used, levels about 90 dBA were recorded and levels in excess of 110 dBA can be produced. Exposure at this last level, without hearing protection, should not exceed 12 minutes in an eight-hour day.

Excessive noise is a concern for additional reasons at regional/commuter airlines. In the regional industry, geared engines with propellers are the mainstay of the fleet. These aircraft operate at a high decibel level and can increase the possibility for hearing impairment when aircraft taxi and run-up operations are conducted near the maintenance hangar.

Recommendation

1. Work in air carrier maintenance areas generally does not require hearing protection.

Noise as an environmental stressor does not typically impact maintenance proficiency. However, under those conditions, particularly in regional airline maintenance, where noise levels can exceed 85 dBA, care should be taken to ensure that appropriate hearing protection is provided and used. There are two reasons. First, proper protection will allow the work to be done more comfortably and possibly more accurately. Second, the technician will not have a history of being exposed to noise sources in excess of 85 dBA. Claims for hearing loss suffered in industrial operations represent a leading category of claims under workmen's compensation and a major cost item for industry.

Work Support Systems

The term "work support systems" refers principally to a variety of structures used by technicians to gain access to different parts of the airplane. These structures include the maintenance hangar itself and proceed through scaffolds, ladders, stools, and "cherry pickers." The underlying purpose of all of these systems is to allow direct access to aircraft components and, hopefully, to make the work easier and safer. Some structures are sophisticated and allow on-the-spot adjustments in height and lateral position. Some major airlines use massive scaffolding systems that move and essentially enclose a large aircraft, thereby allowing direct and safe access to parts such as the vertical stabilizer.

There are problems with existing work support systems. In some instances, a workstand will require a technician to work in an awkward position, thus tending to produce increased fatigue. The cherry pickers have the problem of inherent instability which becomes a safety concern and also increases the difficulty of detailed visual inspection. The application of torsional forces during maintenance also can be a problem when working from a platform of diminished stability.

Recommendation

1. The procurement of work support systems by air carriers, including majors and regional/commuters, would benefit from a set of human factors standards for these systems. The standards should address stability requirements, use of proper anti-skid work surfaces, the need for and recommended features of worker harnesses and restraints, and the inclusion of emergency warning and escape features. A careful review should be made of accident data supplied to the Department of Labor (USDOL) and the Occupational Safety and Health Administration (OSHA) as the standards are developed. The human factors standards should be reviewed and approved by representatives of the air carriers before being adopted as industry standards.

Workplace Variables

Changing Nature of Maintenance

Aircraft coming on-line with both major carriers and smaller airlines are different in many dimensions from those entering service 10 to 20 years ago. A major difference is in the growing use of composite materials. These materials use reinforcing fibers or filaments embedded in a resin matrix and offer both increased strength and lighter weight over the more common metal structures. While composites have been used in aviation for almost 20 years, newer aircraft such as the Boeing 757 and 767 and the AirBus A310, are expanding the use.

Inspection and repair procedures for composite materials differ from those used with metals. There is no single propagating crack as in metals. Instead, the damage is characterized by matrix cracking, fiber breakage, and delamination, all of which contribute to component failure. Inspection procedures and inspection equipment developed for metal failure modes must be changed significantly for use with composites.

Another change in maintenance practices arises from the broad use of digital electronics in aircraft systems. Digital electronics no longer are concentrated in avionics components such as the autopilot, navigation, and communications systems. In a discussion of the AirBus A320 aircraft, the observation was made that "One can say there is no more purely mechanical system on this aircraft. Mechanical forces are translated into electronic bits from the command to the actuator; there is no more lever or command which is not connected to a computer." Further, these digital systems were described as being so interconnected that troubleshooting must be accomplished on a system-wide basis rather than as a simple isolated task.

Features incorporated into aircraft such as the A320 are very important for maintenance practices and philosophies. The distinction between aviation mechanics and avionics technicians is becoming blurred. Aviation maintenance technicians (AMTs) now must extend their skills well into the field of avionics if they are to be able to do their job with greatest proficiency. Indeed, in the future mechanics and avionics technicians will tend more and more to do the same job. This has great implications for training, job design, and personnel management.

Recommendations

1. The occupational specialty of aviation maintenance technician must change as the requirements underlying maintenance and inspection of new and advanced aircraft change. As new job requirements evolve, those responsible for the training of maintenance technicians and those responsible for regulatory oversight of maintenance must work from a different script. To remain apace of these changes, the Federal Aviation Administration (FAA) should maintain a continuing review and update process for Parts 147 and 65 of the Federal Aviation Regulations (FARs). These parts cover the curricula for technical training schools and the certification of mechanics and repairmen, respectively.
2. Blending the skills of maintenance technicians and avionics technicians raises the skill requirement for the individual technician. This increase in requisite skill level may serve to lessen the supply of candidates. This fact, coming at a time when analyses of population dynamics shows the supply of technician candidates may be minimal in any event, could have serious and negative impact on the ability to staff air carrier maintenance operations. For this reason, the recommendation made at the conclusion of the Fourth Human Factors Meeting on "The Aviation Maintenance Technician" is reaffirmed. This recommendation states that "Some organizations such as the Professional Aviation Maintenance Association (PAMA) or the Future Aviation Professionals of America (FAPA) should undertake, with blessings from the FAA and financial support for the airline industry, a detailed manpower modeling study of the aviation maintenance technician occupation as it is likely to change over the next decade."

Work Schedules

The nature of airline operations, with the heaviest demand for aircraft during daylight hours, necessarily means that considerable aircraft maintenance must be done at night. The questions arises, will maintenance done by those on the night shift be of comparable quality to that done by day workers? Research findings tell us that night shift workers inevitably sleep less than those working during the day. This leads to a chronic sleep deprivation condition and one would predict an increase in fatigue, accidents, production defects, worker dissatisfaction, health issues, and other problems. However, measures of subjective fatigue show no differences between night workers and day workers. Laboratory performance tests, on the other hand, show that day shift workers perform better than night shift workers.

The above findings indicate that the performance of those working on the night shift may not match the performance of day workers. However, the difference may be slight and may not be noticed, either by management or by the workers themselves. Considering the number of quality checks routinely applied to maintenance operations, a slight decline in proficiency at night may be of no operational significance. However, management should be aware that it probably exists.

Recommendation

1. Research conducted on the efficiency of industrial shift work shows that differences do exist between the quality of day work vs. night work. However, no fixed guidelines are available for determining the best shift work arrangement. If problems seem to exist, the best solution is one in which management and workers examine the issue together, outline available options, and decide on the best course of action. In any event, any changes made in shift work and work schedules should be evaluated periodically. The simple fact of a change may produce temporary benefits, but a real evaluation will require some months.

Paperwork Requirements

The Federal Aviation Administration must rely on recordkeeping as an essential index of the adequacy of maintenance in commercial air carrier operations. This is true for the major carriers; it is equally true for air taxi operators. Records maintained by air carriers must be available and up to date. From the FAA perspective, proper recordkeeping must rank in importance with proper maintenance of the aircraft itself.

Aviation maintenance technicians view recordkeeping somewhat differently than does the FAA. While technicians recognize the need for and importance of documenting maintenance procedures, they question the burden imposed by paperwork and the serious amount of time spent in meeting paperwork require- ments. In one example described at the meeting, an aircraft ready for release for a 7:30 a.m. flight was delayed in its release until 10:30 a.m. by the requirement to complete paperwork prior to release. This is not efficient.

The simple volume of paperwork also constitutes a problem. In one instance described at the meeting, approximately 80 pages of paperwork were generated to accomplish two AD notes concerning the tailcone release on the DC- 9 and the DC-9-80 aircraft. The result was that technicians were unable to deal with the many instructions within these 80 pages and finally discarded them and proceeded with the work. When the work was completed, a non-routine card was written stating "Accomplished project per the maintenance manual." This defeats the purpose of generating the maintenance data.

Recommendations

1. The issue of the volume of paperwork required to support air carrier maintenance has been raised a number of times. This issue in all likelihood will never be resolved completely since the interests of the FAA on one hand and the aviation maintenance community on the other differ significantly. However, improvements can be made. Consideration should be given to introducing more flexibility into current procedures. Unless compelling reasons exist not to do so, mechanics might be authorized to release an aircraft on their own signature with a fixed deadline following this for completion of required paperwork. Airline operations would benefit.
2. The management of maintenance paperwork would benefit through increased standardization. The FAA should consider developing a standard set of paperwork requirements for each airplane. This would remove differences associated with paperwork identified by individual airlines and with the need to conform to the requirements of each individual FAA region.
3. Much of maintenance recordkeeping now is being processed through computers. While this increased automation carries many benefits, it does present problems. One is that maintenance technicians now must spend considerable time inputting information into the computer. A study of the technician/computer interface is recommended to develop procedures for minimizing the time required for data input.

Automation

A program of continuing improvement in maintenance requires increasing use of automation. Automation supports maintenance proficiency and leads to improved performance and availability of aircraft. Automation can bring significant economic benefits. The major air carriers are developing automated systems as rapidly as feasible. These systems cover everything from writing manuals, revising manuals, handling AD notes, specifying repair processes, and assessing the technology of new aircraft. Computer data bases now store and supply technical information required for all phases of aircraft maintenance. Computer-aided drawings in a three-dimensional format now can be incorporated into maintenance text.

Automation makes synchronized maintenance production more achievable. One presentation at this meeting described development of a "focused repair center" in which different engine parts are handled within one shop with all activities carefully coordinated. In this system, all tooling and equipment used for refurbishing components is under computer control. All completed components come together as required for reassembly. Studies show a dramatic reduction in maintenance costs through use of this type of automated repair center. Another benefit is a continuous flow rather than a segmented routing time, which results in reduced cycle time. Also, since one group of technicians is responsible for the entire process, a sense of ownership in the process is developed.

Recommendation

1. Increased automation in air carrier maintenance benefits everyone. Means should be explored, possibly through committees of the Air Transport Association (ATA), to ensure that the technology being developed at this time at major air carriers can flow freely and expeditiously to regional/commuter carriers. The ATA committee should also work to develop means whereby major carrier technology can be applied at the regional/commuter level without tremendous expense.

Worker Productivity

Work Teams

Considerable research has been done to determine those variables in industrial operations that affect both individual and organizational productivity. Progress has been made in defining organizational variables that do influence productivity. One of these is *team identification.* A presentation by Major General Albert G. Rogers, entitled "Organizational Factors in the Enhancement of Aviation Maintenance," addressed this topic at the Fourth Human Factors Meeting. Presentations at the present meeting elaborated on this theme.

Team identification is a form of decentralized management. Team members participate in the development of production goals, to the extent feasible, and make decisions concerning the best ways to achieve these goals. Goal interdependence means that the team has a clearly defined mission and individual team members feel that their individual goals and the group goals are consistent. There also is workload sharing. While everyone needs to pull his/her own weight, there must be a mechanism to ensure an equitable distribution of workload. Studies in the military and in industry indicate that the development of production teams and team identification does result in increased productivity.

Recommendation

1. Air carrier maintenance managers should review maintenance operations to determine the extent to which work teams exist now and ways in which this concept might be fostered.

To the extent that work teams can be defined and team identification established, maintenance productivity could be enhanced. Use of the team concept, however, involves delegation of certain authority to the team as well as a large measure of responsibility for its success.

Safety and Health in the Workplace

Safety and Health Initiatives

Recognition of the need for proper safety and health procedures in the workplace is very important. Congress did so in 1970 through passage of the Occupational Safety and Health Act (OSHAct). Just prior to the formation of OSHA, there was one fatality for each 6,000 people at work. By 1988, the rate of fatalities had fallen to one for each 19,000 workers. This is an impressive improvement but the record of U.S. industries in safety and health still is not perfect.

Violations of good safety and health practices do more than simply add additional expenses to industry and to the country. Workers who are injured or ill cannot perform and organizational productivity decreases. A maintenance work shift not fully staffed slows the tempo and can adversely affect flight operations and, in turn, company revenue. There are many reasons to work toward a safe and healthy workforce.

Major air carriers maintain industrial hygiene departments to oversee safety and health policies and practices. Regionals generally have smaller groups or individuals responsible for these matters. For all of these programs to be effective, however, employees must "buy into" industrial hygiene programs. Training and procedures designed to reduce the likelihood of injury or illness will not be used or followed if employees do not have proper safety attitudes. Management should maintain continuing educational programs to stress the need for proper safety and health practices. Employees should: (1) use protective equipment; (2) read information on chemical hazards; (3) ask questions when in doubt; and (4) keep informed on changing conditions.

Recommendation

1. Every airline, of whatever size, should have a standard operating policy which establishes a joint management/labor health and safety committee. This committee should meet on a regularly scheduled basis and have appropriate authority to review health and safety issues in the workplace and to mandate changes as necessary.

Reference

Miller, D.P. & Swain, A.D. Human error and human reliability. In G. Salvendy (Ed.), *Handbook of Human Factors*. New York: John Wiley & Sons, 1987.

Appendix A: Meeting Presentations

PHYSICAL STRESSORS IN THE WORKPLACE

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I very much appreciate the opportunity to speak with you this morning. More frequently I address audiences of health care providers such as occupational health nurses and physicians, but I relish the opportunity to talk with individuals like yourselves who face the physical hazards in the workplace we'll be discussing.

The topic of physical stressors is broad and extensive and we will only have time this morning to touch on some specific highlights and introduce new information. The stressors that we are specifically addressing are listed in Table 1.

Table 1

Physical Stressors

Mechanical Radiation

Acceleration Non-ionizing

Impact Ionizing

Vibration Thermal

Noise

Barometric Ergonomic

Lifting

Bending

Torque

Acceleration and Impact

In the aerospace environment, both of these stressors can have devastating effects on aircrew. We all are aware of sustained acceleration, usually referred to as "G." In today's aerospace environment aircraft are now capable of maintaining G force at levels in excess of what can be sustained by the pilot. Impact addresses sudden onset forces such as one would expect in a crash or ejection situation. Although both of these forces are appropriate in discussing the aerospace environment, we will set them aside as this meeting is addressing ground-based maintenance physical stressors.

Vibration

In operating vibrating tools such as impact drills, chippers, pneumatic tools and chain saws, employees frequently complain of hand numbness after the shift. With chronic exposure to these tools employees may develop white finger syndrome or Raynaud's phenomenon. This condition occurs following years of exposure to vibrating tools and will affect blood vessels, nerves, bones, joints, muscles and connective tissues in the hands and arms.

The employee can experience a sudden loss of fresh blood supply resulting in a sudden bleaching of the fingers. The hands become particularly sensitive to cold weather, become painful or numb, and it becomes difficult to grip large objects or to have the dexterity to handle small objects.

The condition, like so many other things, is dose dependent. That is, the number of times the tools are used and the power spectra or amount of vibration of the tool will determine how long the vibration can be tolerated before the onset of the disorder. The frequency of the vibration that is of most concern is found to be between 8 and 1000 Hz.

Over 20 years ago, scientists who were working to understand the effects of vibration on the human body designed a scheme to represent body segments as individual masses supported by springs and dampers. Such a representation can be found in Figure 1.

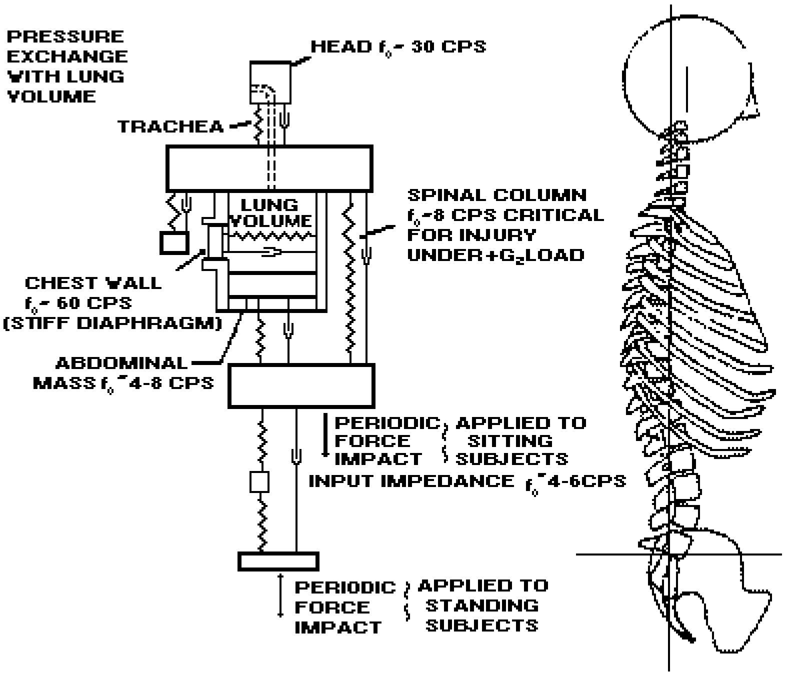

Figure 1 Models for describing and predicting vibration response. The left side of the figure shows the lumped parameter model; the right side of the figure shows the finite element upper torso model.

By dividing the body into segments, it has been possible to mathematically model the response of these segments to various vibrating frequencies under a variety of circumstances. Body parts have their own resonance frequency where they are most susceptible to vibration. For example, the resonance frequency for the abdominal mass is approximately 4 - 8 Hz, the head is most sensitive at approximately 30 Hz. A body part exposed to its resonance frequency is at greater susceptibility for injury.

With appropriate transducers, investigators can measure the vibration frequency of various vehicles such as automobiles, aircraft or machinery. By better understanding these frequencies, an estimation of their hazards can be made and preventive mechanisms brought to bear to dampen the frequency, alter its resonance, or protect the operator.

Adverse health effects from vibration are directly related to a time-intensity factor. As should appear obvious, an individual is able to tolerate a low-magnitude vibration for a longer period of time than would be the case in a high-magnitude vibration field.

The standards for exposure to severe vibration are illustrated in Figure 2. The graphs illustrate that one can tolerate lower magnitude vibrations for longer periods of time but is most sensitive to vibrations in the 6 - 9 Hz range. At higher vibration frequencies, the body becomes more tolerant within the realm of safety and health.

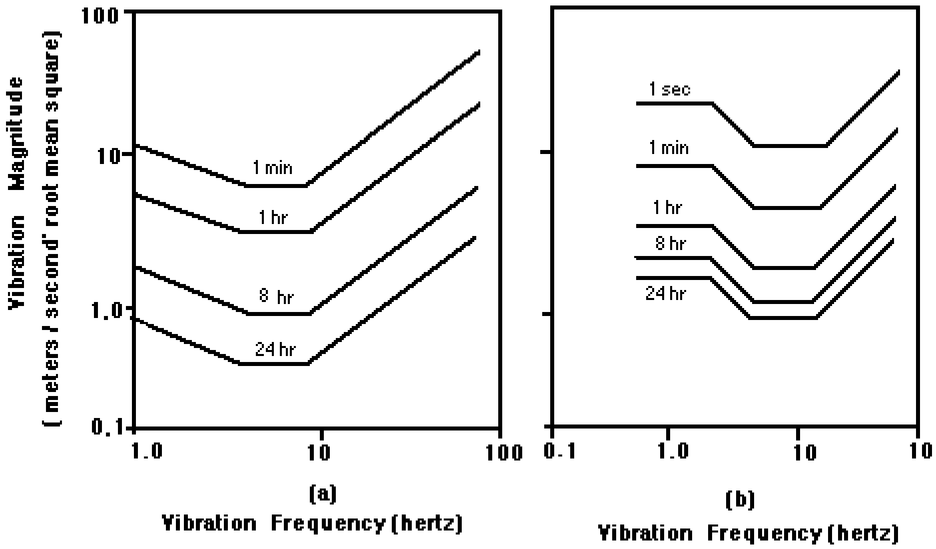

Figure 2 (a) Vibration exposure limits for safety and health defined in International Standard 2631 (1974); (b) Vibration conditions corresponding to a limiting Vibration Dose Value of 15 m/sec$^{1.75}$.

As we know from our daily activities, vibration can interfere with the ability to interpret the environment around us, particularly the visual environment. Whole body vibration increases both the reading time and reading error of a display. It is interesting to note that our interpretation of a display in a vibration field is worse if only the display vibrates, less severe if only the observer vibrates and least disruptive if both the observer and the display are in the vibration field. Further, once the observer has been exposed to vibration for an hour or longer, his ability to interpret the display is compromised for at least several hours post-exposure.

One form of vibration with relatively high magnitude but a very low frequency produces an unpleasant response in most of us -- we call this motion sickness. We tend to be most susceptible at frequencies below 0.3 Hz and, given a sufficient exposure duration such as eight hours, over half of us may experience the full spectrum of near-incapacitating motion sickness.

Noise

Arthur Schopenhauser stated, "Noise is the most impertinent of all forms of interruption. It is not only an interruption, but also a disruption of thought."

Noise not only may interrupt our concentration, but it may be physically damaging to our ears and contribute to the general stress levels that the body is experiencing. Our ear has the phenomenal capability of interpreting sound pressure over enormous range. This force range, from the softest sound to the loudest, can exceed 1012. To make it easier to express and understand this wide range, it has been expressed as a decibel (dB). If the reader is interested in the derivation of dB, it is recommended that an appropriate textbook be referenced.

In general, we find that the sound level around an average home is approximately 50 dB. A normal conversation will occur at about 55 dB, a woodworking shop in full operation will generate about 100 dB, and a jet plane on takeoff may reach 140 dB. This very loud noise of 140 dB has attained the pain threshold. Prolonged exposures of the human ear to noise in excess of 85 dB can result in permanent damage to hearing.

Noise interference with speech communication is illustrated in Figure 3. Here one sees that as the background noise level increases, communication becomes more and more difficult even when shouting.

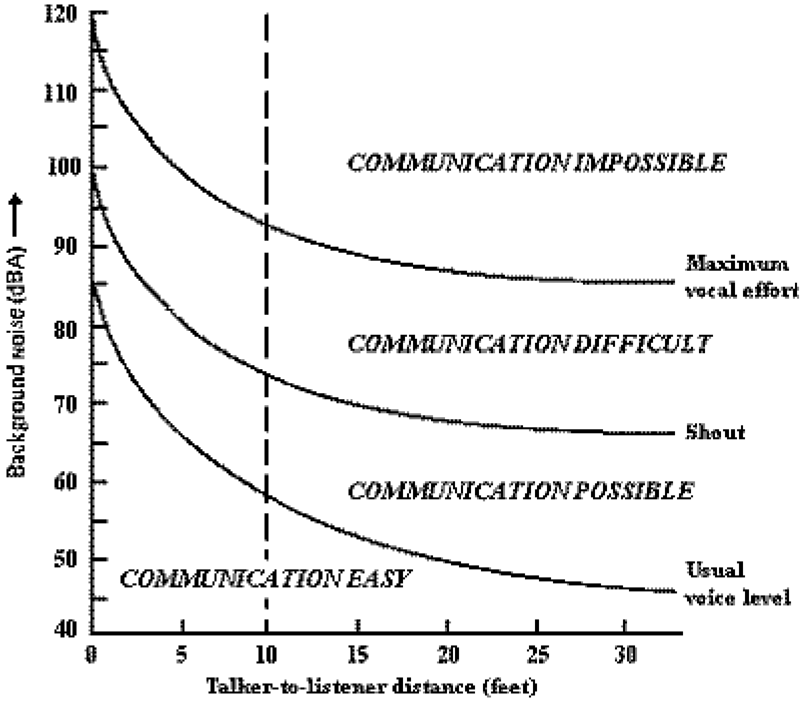

Figure 3 Noise interference with speech communication, at various distances.

To prevent noise induced hearing loss among employees and to assure adequate communications for both safety and production, a hearing conservation program is not only advisable, but frequently mandated by Federal regulations. The basic components of such a program are listed in Table 2.

Table 2:

Hearing Conservation Program (HCP)

Basic Components

1. Noise exposure monitoring
2. Engineering and administrative controls
3. Audiometric evaluation
4. Use of hearing protection devices
5. Education and motivation
6. Record keeping
7. Program evaluation

The most important component of a hearing conservation program is noise reduction. It is far better to reduce the environmental hazard of noise than to try to protect the worker. A number of engineering control concepts to reduce noise are presented in Table 3.

Table 3

Engineering Controls

- REDUCE NOISE AT SOURCE Muffler
- INTERRUPT NOISE PATH Acoustical Inclusion
- REDUCE REVERBERATION Absorbing Material
- REDUCE STRUCTURE-BORNE Vibration Mounts

VIBRATION and Lubrication

Barometric

In the aerospace environment, changes in altitude relate to changes in barometric pressure; the higher one ascends, the lower the barometric pressure. The hazards associated with barometric pressure changes such as air blocks and bends are not a subject for today's discussion as we are staying on "terra firma."

Electromagnetic

Two recent books written for a concerned public have sensationalized potentially adverse health effects of electromagnetic exposure. Paul Brodeur's *Currents of Death* published in 1989 employs the technique of selective references to alarm the public with regard to very low frequency radiation from power lines, power transformers, electrical appliances and the ubiquitous electric blanket. This book was joined in 1990 by Robert Becker's *Cross Currents: The Perils of Electropollution.* Two recent articles from the *American Journal of Epidemiology* are worthy of comment with regard to this issue. Savitz, et al., from the University of North Carolina studied childhood cancer with regard to exposure to 69 Hz magnetic fields. Over 200 children with cancer were compared to a like number of controls. Approximately 50 percent of the cohort homes were measured for magnetic field effect. Elevated risks were found for children living near highlines or buried electrical cables. These risks were limited to leukemias and lymphomas. The results of the investigation are considered suggestive but inconclusive. A second study was conducted by Severson and colleagues on the effects of exposure to power-frequency magnetic fields and acute nonlymphocytic leukemia. Over 100 patients were compared to a like number of controls. Magnetic fields were estimated from wiring configurations about the cohorts homes. In addition, actual measurements were taken in approximately 50 percent of the homes. There were no significant elevated risks identified.

The issue of extremely low frequency (ELF) electromagnetic radiation has garnered the attention of both Congress and the regulatory agencies. Additional research is ongoing. A peer review workshop sponsored by the Environmental Protection Agency (EPA), after much discussion, supported recommendations that there is currently inadequate data to suggest that ELF causes cancer. Although this review occurred in June 1990, only one month later, EPA analysts recommended that ELF be deemed a "probably" carcinogen. The issue of carcinogenesis as it relates both to environmental and occupational exposures remains undecided and thus warrants the careful attention of occupational and environmental health practitioners.

Thermal

The simplistic formula for calculating body heat is:

Body Heat = M + W ± C ± R - E

M=metabolism; W=work; C=convection; R=radiation and E=evaporation

In considering thermal loading, the first issue is metabolic heat generation as a result of the physical work. Typically this is expressed in kilocalories per minute or per hour. For the standard person, basal metabolism is assumed to be one kilocalorie per minute. Additional heat generation reflects any degree of work above that of the nominal basal state. For example, a mechanic using both hands working on a aircraft or piece of heavy equipment with handtools would have the following metabolic heat load:

Activity	Avg kcal/min
Standing	0.6
Two Arm Work	3.5
Basal Metabolism	1.0

Total 5.1 kcal/min or 306 kcal/hr

In 1986, the National Institute of Occupational Safety and Health (NIOSH) published its "Occupational Exposure to Hot Environments." This is a criteria document for a recommended standard. It should be pointed out that this remains a recommendation and not a regulatory standard. Considering our mechanic above who is generating 306 kcal/hour, 1200 BTU, or 349 Watts, we can review some work standards by applying the NIOSH recommendations. For environmental heat exposure (WBGT) we find that work would have to cease as a thermal exposure ceiling would be reached at a temperature of approximately 37°C or 98°F. Perhaps more significantly, the employee would enter a zone for a recommended alert limit if he were working sixty minutes each hour at an environmental temperature of 26°C or 78°F. These values are for an unacclimatized worker. For the individual acclimatized to heat stress, more leeway on thermal exposure would be permitted. Figure 4 illustrates the NIOSH recommended heat stress alert limits.

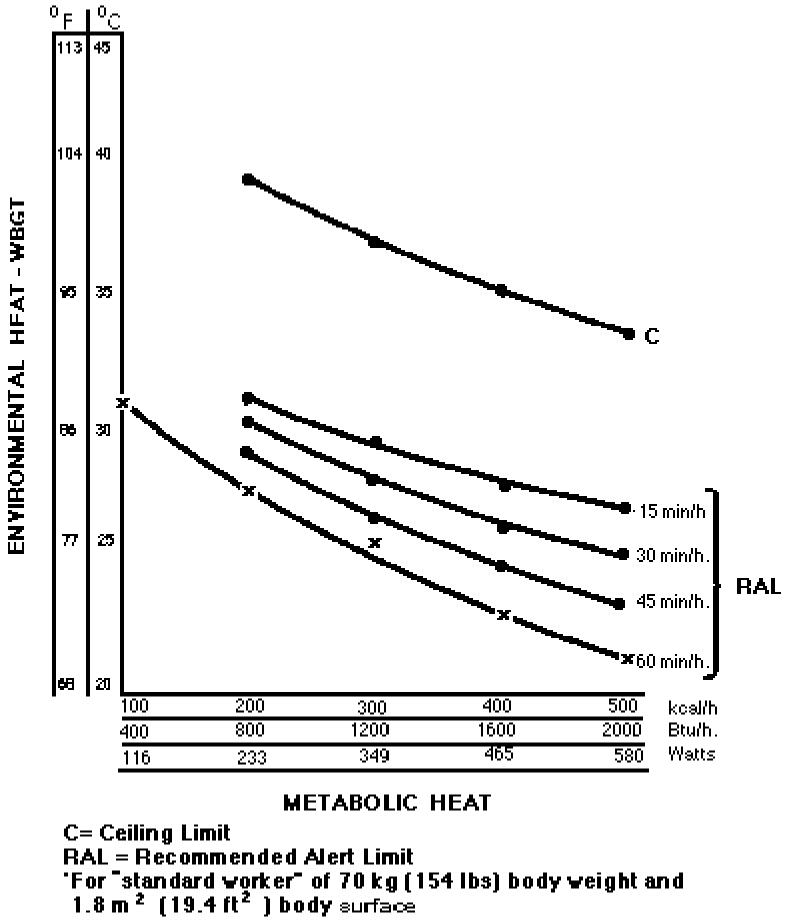

Figure 4: Recommended Heat-Stress Alert Limits Heat-Unacclimated Workers.

A point of confusion among health providers that I frequently find in discussing thermal stress is the concept of wind chill. Several years ago I heard this confusion contributed to by a national weather commentator as he unfortunately equilabrated the wind chill temperature with the actual thermal or environmental temperature. The wind chill temperature reflects the rate of cooling of the human body if exposed unprotected to a specific environmental temperature combined with wind at a specific velocity. This simply is a method to relate the degree of body cooling which might occur in such exposure.

For example, if an individual is exposed to a true environmental temperature of 35°F regardless of the wind velocity, neither tissues nor a bucket of water would freeze, although one may experience a very rapid loss of body heat. The wind chill temperature reflects the rate of body heat loss if one were exposed unprotected to a real environmental temperature of that magnitude with no wind blowing. Again taking our example of a 35°F real temperature and a 20 mph wind, the wind chill temperature would feel like it was near 0°F without wind. In other words, the exposed body would lose heat at approximately the same rate in the windy condition as would be the case at near zero and no wind. However, there would be no frostbite because the actual temperature remained above freezing even though the sensation was one of a much colder environment.

Ergonomics

The physical stressors which are related to mechanical force on body are normally defined under ergonomic considerations. Although this is a concern of major importance with aircraft maintenance and inspection, its discussion must await another time.

In the few minutes we have had together I have attempted to highlight some new developments with regard to stressors in the workplace. I focused primarily on vibration, noise radiation and heat. I welcome your questions.

INDUSTRIAL HYGIENE IN AIR CARRIER OPERATIONS

Brad Baker
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and
Al Schafer
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Introduction

At Mesaba Airlines, we are committed to a philosophy that hazard awareness in the maintenance environment helps employees achieve an increased level of job safety which, in turn, increases performance and reduces the propensity for job-related illness and injury.

Mechanics and maintenance department personnel are continually associated with an ever-changing work environment. From hazardous materials usage to hearing protection, everyday conditions warrant the incorporation of a program designed to inform persons of the steps to take in order to reduce the likelihood of long-term exposure to certain chemicals and dangers associated with the aviation maintenance environment.

To set up and effectively manage an Industrial Hygiene Program, certain objectives have to be met. These range from employer responsibilities and regulatory compliance to identification of potential hazards in the workplace and employee responsibilities.

Areas of involvement in industrial hygiene at Mesaba Airlines range from confined space entry and hearing protection to chemical awareness and respirator usage.

Hazard Communication, or "Right to Know"

The Hazard Communication Standard (CFR 1910.1200) clearly defines certain training requirements. Basically, the standard states that all employees have a right to know the chemical name and properties of the hazardous substances they are working with and how to handle them safely.

Right to Know = introduction to the Hazard Communication Standard, Material Safety Data Sheet (MSDS) overview, equipment awareness and correct procedures to use when handling chemicals.

Technological advancements in aviation have brought new chemical substances into the workplace which are necessary to maintain and repair our aircraft, engines, and accessories. Many of these are hazardous, and others have long-term systemic effects if used improperly.

We have found that Right to Know training has been well accepted within our organization. Any time information is made available dealing with personal health and well being, people tend to take notice. It was evident in the maintenance area as well. Rubber gloves, respirators, and goggles are used more frequently, and people are using more caution when handling and working with hazardous chemicals.

Our Right to Know training also incorporates an in-house chemical labeling program. This was accomplished after an in-depth inventory of on-hand hazardous materials was completed. Initially, this was a monumental task. All hazardous materials in the Maintenance, GSE, and Stores areas were identified and, if over five gallons, labeled by our program. By doing a chemical inventory. we could also match up MSDS against chemicals. This allowed us to see which MSDS were not on hand and request them from the distributor. Information for labels was obtained from the MSDS, a guide we established prior to labeling, and from the manufacturer.

Employer Responsibility

The employer's role in establishing the Industrial Hygiene Program must be that of providing a work environment that is free from health hazards and dangers associated with the aviation industry. If these hazards cannot be removed, they must be minimized through the use of protective equipment and the incorporation of procedures and policies designed to minimize the effects of hazard exposure over a prolonged period.

The company must also provide training designed to educate and inform employees in the aviation environment of the physical and health hazards. Equipment furnished by the employer must be of the type and design that will effectively reduce a potential hazard.

The employer must continually review their Industrial Hygiene Program and incorporate changes that keep abreast of the type of aircraft maintenance being performed. Training must be structured so that individuals can easily understand the goals and objective to be met. Procedures should be written with the major concern being the employees' health, not Federal compliance.

Confined Space Entry

Confined space entry for fuel cell repair had to be addressed as both a health concern and a safety concern. Fuel vapor concentration must be monitored when maintenance personnel are performing repairs in the cell area. The condition of the fuel cell atmosphere will also determine the equipment necessary for tank entry. Maintenance personnel assigned to fuel cell repair must be trained in the understanding and operation of the monitoring equipment; in the use and operation of an air-supplied respirator; and proper procedures for dealing with potential fuel tank rescue. Currently, the size of our fleet does not allow an individual to completely enter the tank, so a safety stand-by is not used.

This ties in with our respiratory protection program. All employees receive training which explains the limitations, capabilities, and operation of the respiratory equipment -- including correct fit. Training also covers the specific data on cell atmosphere; i.e., fire safe, health safe, the LEL, and percent of oxygen content in the fuel cell.

Hearing Protection

The problem of excessive noise is a major concern with most airline operations. In the regional industry, geared engines with propellers are the mainstay of the fleet. These aircraft tend to operate at a much higher decibel level, increasing the possibility for hearing impairment. This is compounded by aircraft taxi and run-up operations near the maintenance hangar.

There are two major approaches to preventing employee hearing loss: (1) engineering controls and

(2) hearing protection. Two basic engineering options are available when attempting to limit a noise problem. One is to reduce the level of the noise source or replace it with a quieter source; the other is to reduce the noise level with some type of acoustical absorption material. It is not practical to think of equipment replacement as an option to reduce noise. Absorption of noise can be accomplished by installing suppression materials. This, again, is not practical unless you are building a new facility or expanding an existing structure.

Hearing protection, on the other hand, is a more desirable option in the aviation industry. Selecting the correct type of protection requires a survey of the work area where such protection is to be used, ensuring comfortable fit and ease of cleaning, and attention to compatibility with other headgear. This is especially important in extreme temperature change climates.

Workers generally prefer to wear earplugs in areas where noise is an occasional problem, and earmuffs in ramp or gate operations where noise is continual. Both should be available for use in the workplace. Noise testing should be accomplished to establish a threshold value and time weighted average. These figures are then studied to determine if a Hearing Conservation Program should be incorporated. Data at Mesaba Airlines indicated that such a program was not necessary, but protection must be provided to reduce hearing loss. As Dr. Roy DeHart said earlier, hearing loss is a safety concern as well as a health concern.

Control Procedures

Procedures incorporated at Mesaba Airlines for ensuring employee safety and Federal compliance cover a wide area. Procedures and policies were incorporated into the General Maintenance Manual on correct fuel cell entry, as were precautions for ground operation of airborne weather radar. Written job responsibilities for key positions include maintaining a safe work environment and the mandatory use of safety equipment when doing assigned jobs.

Formal Hazard Communication Training was added to our New Mechanic Familiarization Course, and annual training is scheduled as necessary to comply with Federal regulations.

Making information available to employees is the best procedure for safety. An on-site index of all MSDS enables employees to reference the log prior to working with a new chemical substance.

For our operation, NDT X-ray inspection is accomplished by out-of-house vendors. They have the aircraft isolated when work is being done and use a safety standby who informs people of the "shooting."

Training has also been expanded to include operation and usage of confined space entry equipment and monitoring devices. This includes respirator training.

Job safety is stressed during all training classes, whether it be on an individual aircraft or hazardous substance handling. Instilling the attitude of working safe when a new employee begins work at Mesaba is a good "first brush" of industrial hygiene.

Employee Responsibilities

An employee must "buy into" the Industrial Hygiene Program. Training and procedures designed to reduce the likelihood of illness will not be used or adhered to if employees do not want to adopt a work safe attitude.

Training must be structured so that individuals can easily understand and read MSDS and warning labels. Procedures should be incorporated with the employee's health as the major concern rather than Federal compliance.

Employees must: (1) use the protective equipment; (2) read information on chemical hazards; (3) ask questions when in doubt; and (4) keep informed on changing conditions. The employees must also maintain the protective equipment assigned to them. The employees must use protective equipment properly when the maintenance action warrants.

Recommendations

Operators must develop an Industrial Hygiene Program that utilizes employee ownership in order to enjoy continued success. Operators should work extensively with vendors and suppliers to help bring into the workplace materials and chemicals that are less hazardous and more environmentally sound.

The Federal Aviation Administration (FAA) must work with manufacturers to expedite the testing and approval process that will allow safer materials to be developed and utilized throughout our industry. The FAA, along with occupational and environmental agencies, should share information to define regulatory boundaries in the aviation maintenance environment.

FACTORS AFFECTING SHIFT WORKERS

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The majority of you attending this meeting, I suspect, have done shift work or have people working for you who work at night. One of the hazards of this is that you end up an expert, think you know a great deal about shift work, and generate theories about shift work, many of which are quite false. The discussion today will center on things we know and some of the crude corollaries we have about shift work. While we should recognize that the practice of shift work remains more art than science, nonetheless shift work is an important issue to consider in the work place. There are some rational and professional approaches to this problem that should be considered.

I would also like to remind you that the National Transportation Safety Board (NTSB) has a "ten most wanted" list and that on that list is the study and possible revision of the hours of service of the various transportation industries. You in the airline industry know that they are interested in this topic with regard to flight deck operations. I want to warn you, however, that what may be appropriate in flight deck operations may be totally inappropriate at the shop level. This is important since some of the principles developed in studies of flight operations may not apply to you at all. One important difference that should be stressed is the distinction made in biomedical circles between chronic and acute effects. The Federal Aviation Administration (FAA) is appropriately concerned about the jet lag that affects pilots. This is mainly an acute effect. In aviation maintenance, we are concerned about the machinist or the industrial worker who has been working the night shift for five, ten, or possibly twenty years. This is a chronic exposure. What is the effect of this exposure?

Now let me remind you that some of the issues concerning time and the hours we work are man-made and do not flow from some natural order. For instance, the eight-hour day, the crux of our working schedule, came about because an English king wanted to be able to pray for eight hours a day. Night work was started by the Greek oracles who thought it lent a certain amount of mysticism to making predictions at night rather than during the day. So we see that religious purposes rather than work efficiencies played a major role in establishing our work practices. However, this does not mean that these practices are holy and cannot be changed.

There is an expression, dating to the 1930's, that says that "If we can master time, we will master technology." Today, this phrase is even more true, as you in the airline industry certainly understand. Now, let me mention some examples where time and, in particular, work schedules have not been mastered and disaster ensued. The truly serious phase of the Chernobyl accident began at 1:23 a.m. In fact, some have pointed out that there has not been a single nuclear disaster that has not been associated with the hours from midnight to 8:00 a.m. This certainly suggests a relationship.

Another example can be found in an instance in which two freight locomotives collided. The trains were in good shape and the crews were not using drugs. An investigation by the National Transportation Safety Board (NTSB) determined that the accident was related to the work schedule being followed by the operating crews.

A final example is provided by the death of a lineman working for a utility service in the State of Connecticut. Following a hurricane, roughly one million people were without power. To restore power, utility crews worked very unusual hours, as shown in Table 1. No one complained since service was coming back and workers were making considerable money as a result of the extended overtime. In this case, an experienced lineman after working six, nineteen-hour days in a row essentially committed suicide by a careless action. It is fair to say that accidents like this should be prevented.

Table 1

Restoration activity by a utility lineman following a hurricane:

Friday	17 hours at work
Saturday	19 hours
Sunday	19 hours - begin starting time of 0500 hrs
Monday	19 hours
Tuesday	19 hours
Wednesday	19 hours
Thursday	19 hours
Friday	1.5 hours followed by death via electrocution

Work in a rural area. Work times do <u>not</u> include commute times.

A study published in the *Harvard Business Review* in 1983 by a consultant named Emberman reinforces the importance of time for industrial operations. Emberman looked at 18 companies with which he had consulted that had a strike history and 18 companies that had not had strikes. He examined many variables to determine the differences between these two groups of companies. The three most important variables were "how quickly grievances were settled," "how well people on the night shift were treated," and "is there an abuse of overtime?" Concern over wages and pay was not even in the top five variables. An examination of the first three, as listed above, clearly shows the importance of the time dimension.

If we are interested in the time dimension and its effect on work and the worker, we must consider some definite features of workers' lives which are time-driven and which affect performance. These features fall into three classes of variables. These are (1) work schedules, (2) sleep schedules, and (3) social schedules. These three classes are interrelated and each is important in determining performance efficiency.

The Circadian Clock

You have probably heard the term "body clocks." Body clocks are real. In one study, body temperature was charted throughout the day. At the same time, subjective reports were received from workers concerning how alert they were. On a graph, these two functions practically sit on top of each other. This study showed that alertness and body temperature run on a 24- to 25-hour clock and show high correlation.

Findings of the study just described, plus many more, clearly show that people have an internal biological clock. This clock will run whether subjects are in a cave, in a mine, in a time isolation unit, or whatever. It is not a 24-hour clock; it takes a bit longer. However, we reset it every day. What makes it reset? The answer is simply that we live in a world which is 24 hours in nature; in which the world revolves around the Sun on a 24-hour basis; a world in which social events have been organized to match the 24-hour day and, in particular, the period of light. In short, man has a biological clock, which we term a circadian clock. This clock approximates the 24-hour day, running just a bit longer, and is adjusted daily by the routine features of life and our environment.

The circadian clock is important. Man, for a variety of reasons, has evolved as a diurnal animal. We are not naturally night time animals. Our cycles affecting such matters as alertness tend to peak during the day. Therefore, common sense and chronobiological theory would tell us that our work would be best when our work/rest cycles and our biological clock are in perfect synchrony.

There is a theory that holds that most of our behavior is determined by our chronobiology. Variables such as the social and work environment and one's health and well being simply moderate behavior. I would argue that this is somewhat misleading. In fact, social and environmental factors, as well as work schedule factors, are very important determinants of behavior.

Sleep Issues

Many studies have examined the effects of altered work schedules, including night shift work, on work performance. Two of these studies reviewed data for over 4,000 American industrial workers to assess the effect of shift work on a variety of personal variables. In each study, the percentage of workers divorced or separated was higher for the night shift. While one might argue that people who cannot adjust to marriage tend to go to the night shift, follow-up studies indicated this was not true. Results indicated that the biggest effect of changes in social and work schedules was on the sleep of workers. In fact, in my 30 or more years of research dealing with shift work and work schedules, the most robust variable in studies of industrial workers has been sleep. Sleep operates as a benchmark; it offers a way of telling what the impact of a work schedule is.

Other work in which I have been involved sought a better definition of the role of sleep in industrial work. Two studies covering several thousand industrial workers in the midwest examined patterns of sleep for workers on different schedules. The key finding was that those working different shifts approach the matter of sleep differently. Day workers sleep before they go to work and then go to work. Workers on the evening and night shift work and then go to sleep. This means that not only does the time of day you sleep vary depending on the schedule you are on but, also, the order of things in your life varies. Your strategy for life is definitely affected by the shift you work and the time when you sleep.

Work schedules also affect sleep length. In a study of workers conducted over a six-year period, researchers found that people who are on the day shift and people on the afternoon/evening shift sleep considerably longer than those on the night shift. Generally speaking, workers on the afternoon/evening shift sleep the most, those on the night shift sleep the least, and workers on the day shift are somewhere in between. It is particularly interesting that after six years of study, the differences were still there. There is no evidence that the average worker adapts, in terms of length of sleep, to different work schedules.

One explanation for the above findings might be that only people who sleep short or have sleep problems select the night shift. Results show this is not the case. Many studies affirm, as just noted, that afternoon/evening shift workers sleep the most and night shift workers sleep the least. On days off, however, all groups sleep longer and there is no significant difference between sleep amount for the three shift worker groups. Also, results show that workers do not make up lost sleep on days off. Workers on a permanent night shift lose about 2 1/2 hours sleep a week compared to other workers.

In summary, results of a number of investigations show that not only do workers on different shifts have different orders in which they sleep; not only do they sleep at different time of the day; but they sleep different amounts. These results are consistent through many studies.

Why do people working at night get less sleep? Chronobiological theory argues that people who are trying to sleep during the day can't sleep properly because their biological clocks are in disarray. One study investigated this by asking the question "To what extent are you dependent on an alarm clock?" Results showed that the majority of night shift workers were dependent on alarm clocks, or some other system, to wake up. These night shift workers were deciding when to go to sleep and when to awaken. The reduced amount of sleep they were getting was based on a decision and not a disturbed biological clock. Therefore, a large part of the problem is simply people making bad decisions.

Another study identified three groups of shift workers. These were (1) those working the day shift who wanted to work during the day, (2) those working the night shift but who preferred day work, and (3) those working the night shift of their own choice. Again, results showed that night shift workers sleep less than those working during the day. The interesting finding, however, was that those workers in the third group, the people who work at night out of preference, sleep even less. For whatever reason, workers who want to work at night are choosing a shorter sleep schedule. This may not be evident to you as a manager from their behavior because you may well consider them to be good workers. But, are they in fact good workers?

Studies investigating the effects of sleep disturbance on quality of performance must be carefully controlled. One investigation studied two groups of 12 workers each under very controlled laboratory conditions. One group of workers was on a day shift and another was on the night shift. All subjects were carefully matched and slept in the laboratory so that sleep duration could be carefully recorded. Measures of subjective fatigue were obtained. Interestingly, no differences were found in terms of the fatigue variable. These results suggest that night workers who are not getting enough sleep on a chronic basis go to bed not feeling any more tired than other workers and wake up thinking they are just as refreshed. On this basis, we would question whether the sleep loss is actually having any effect.

Performance was measured using a standardized laboratory test involving an addition test. On this test, day shift workers performed better than night shift workers. The interesting feature here is that day shift workers were better both before sleep and after sleep. These results match our view of sleep loss as a chronic problem. In this case, we have workers who felt they were alright but could not perform as well as other workers. From a management point of view, this means that simply asking an individual "How well are you doing?" will yield bad information.

A theoretical model of short-term sleep deprivation, developed at the Walter Reed Army Institute and depicted in Figure 1, predicts that individuals working one night shift will get an acute sleep loss. Working consecutive night shifts will produce a total acute sleep loss (TASL). This TASL has a carryover, just like a drug, in which you do not get rid of it all. So if you work consecutive nights, you have accumulated tazzle and a chronic sleep deprivation condition. We then conclude that this chronic sleep deprivation leads to accidents, production defects, worker dissatisfaction, health problems, sleep disorders, and other problems.

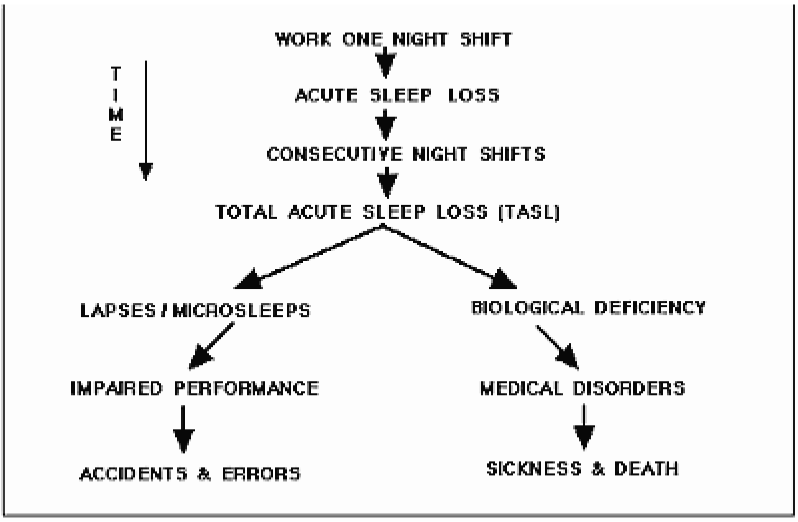

Figure 1

In studying the relationship between performance and sleep, we note that people often take "micro-sleeps" which last seconds, not minutes, and which produce brief periods of performance impairment of which the individual may well be unaware. So people perform well before having a micro-sleep; they have a micro-sleep; and they may or may not perform well afterward. This is the type of event that can happen to someone watching television where he takes a brief micro-sleep. The person has no recollection of falling asleep and only recognizes that he may not remember part of the show. Obviously, these micro-sleeps can degrade performance if they occur during a night shift.

Work Schedules

The research studies we have discussed, combined with my own experience in this field, lead me to several broad conclusions concerning the establishment of work schedules for industrial operations. Hopefully, these conclusions, or guidelines, may be of some help in establishing or reviewing work schedules for aviation maintenance.

In most cases, work schedules are fixed as if set in cement. They are allowed to harden and resist change from then on. You need an environment which says, "Work schedules aren't cement. They may have to be changed. No work schedule is sacred."

Another point is that work schedules might be considered very much like safety shoes. While the benefit of neither is particularly obvious on a day-to-day basis, in each case they can save your company money. My personal estimate, based on my experiences for 20 years but little by way of hard data, is that a company with the right shift work system can save about $100,000 a year per 100 workers in a production plant.

Another point, again drawing on the safety shoe analogy, is that one size does not fit all. There is no one unique work schedule that will fit all industrial situations. When people ask me about the best work schedule for them, they really are looking for the silver bullet. There is no such thing. Different situations require different solutions.

In seeking the best work schedule, you should realize that you can get advice concerning work schedules from almost anyone in the plant and almost any other professional you know. However, very few people know very much about the issues underlying work schedules and sound advice will be difficult to find. The best scheme may be simply to develop a work schedule, using the best information available, and try it, recognizing that no one schedule will fit every situation. The best work schedule for your situation will be a function of the kind of workers you have, the duties these workers have, the size of the workforce, and the demands for company services and products. Since these things change with time, your work schedules should be evaluated as times change. Work schedules that fit a young company, with workers in the 25 year age group range, should be reviewed periodically as the years go by and the workforce ages. Different schedules may be appropriate.

When the time comes to make a change in work schedules, some caution is in order. People feel comfortable with what they have. This is one of the forces that turns work schedules into concrete. Workers may be quite reluctant to give up long standing work schedules even after the benefits of change are quite apparent.

Work schedules require preventive maintenance. You cannot simply establish a work schedule and then forget it. Periodic attention is needed and changes, however small, should be made as circumstances dictate.

Naps

At this time, consideration is being given to changes in the rules regarding commercial flight crews that would allow these crews to take naps during a flight duty period. The theory is that at the end of a long flight crew members will perform better if they have rested prior to the final approach and landing. In Japan, 25 percent of the workplaces doing shift work have on the premises a sleep room where a worker can sleep. The idea, of course, is that they would rather have a worker doing a good job than be half asleep.

I am not suggesting that maintenance facilities establish a sleep room. It might well be good strategy for the FAA to consider having places where pilots can take naps on long flights. However, the data for industrial shift workers seems to indicate just the opposite. Here, probably the best strategy is to not have a nap at all.

A survey of 2,200 industrial workers inquired concerning problems in sleeping, staying asleep, or falling asleep. About 30 percent of the respondents said, "I have trouble sleeping." Night shift workers who napped both on work days and on days off indicated, at about twice the level of other workers, that they had problems sleeping. All those naps did not seem to help much.

Conclusions

The first conclusion that can be drawn from the many studies done on shift work in industry is that there are no universal "best ways" to do shift work. If you are looking for universal solutions, you will be disappointed. Different circumstances require different solutions.

There are no instant solutions to shift work problems. The best solutions arise in participatory programs in which management and labor sit down together to look at the problem, examine the options available, and decide on the best course.

Changes in work schedules should be evaluated. To make a change and then not determine objectively the extent to which it works, is asking for problems. I am sure you know of the "Hawthorne effect" which frequently occurs when new work practices are introduced. If workers want something to get better, it will get better for a while. So if a work schedule change is introduced, it may well improve work for a month or two or even four. The question is, will the change be better a year later?

Successful solutions for work schedules, which help productivity, reduce accidents, and improve health may be unique to a specific work place depending on the kind of work done there, the people who work there, and the kind of demands placed on their services. Again, there are no silver bullets. However, we know that work schedules do impact industrial performance. To the extent that production can improve and safety factors be increased, a careful review of work schedules, followed by appropriate changes, certainly is warranted.

WORK SUPPORT SYSTEMS

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The Technical Operations Division at Delta Air Lines is charged with the responsibility of keeping Delta's aircraft fleet in excellent flying condition, up to date, clean, and, above all, safe for the traveling public. Over 10,000 men and women in the Technical Operations Division, or about 16 percent of Delta's total personnel complement, work to meet this daily challenge. The operation of this Division is predicated upon restoration of an aircraft at a set number of hours as part of Delta's continuous airworthiness maintenance program. Our objective is to keep our airplanes maintained on a daily basis.

Many maintenance procedures are performed to support Delta's aircraft fleet. Some of the major operations are:

- The *trip check,* performed each time an aircraft travels to a maintenance station.
- The *layover check,* performed when an aircraft lays over for two hours or more at a maintenance station.
- A *service check,* performed after 100 - 300 hours of flight, depending on aircraft type.
- The *letter check,* performed, sometimes in stages, after 1,250 -1,550 hours of flight time or by date, depending again on aircraft type.
- The *heavy maintenance visit (HMV).* This is performed after 15,000 - 20,000 flight hours, or by calendar date, 48 months for the L-1011, for example.
- Scheduled *aging aircraft inspections* and *engine boroscope inspections.*

Each type of maintenance procedure, reading from the trip check, takes a corresponding increase in manpower and time for completion. A trip check will require from 15 - 20 minutes while a heavy maintenance visit will require up to 24 days, depending on the aircraft. We do corrective maintenance and preventive maintenance and make every effort to keep maintenance carry overs (MCO's) to a very minimum. MCO's are maintenance items which can be deferred safely for a short period of time with strict deadlines for repair.

The maintenance for Delta Air Lines is accomplished through facilities at 67 cities designated as maintenance stations within the Delta system. This gives Delta better than 50 percent maintenance coverage, in terms of cities served, which is the highest for all of the major domestic carriers. With this coverage, we are able to achieve an average of 1/2 MCO per aircraft, which we believe to be the lowest in the industry.

The year 1991 marks the 17th consecutive year in which Delta has been recognized by the U.S. Department of Transportation Air Consumer Reports as the major airline receiving the fewest number of passenger complaints for 100,000 passengers boarded. The excellent passenger service provided by Delta accounts for the majority of the passenger satisfaction, but it is the dispatch reliability which makes this accomplishment possible. Delta's aircraft fleet, now numbering 470 aircraft, has an average aircraft age of slightly less than 8.7 years and a dispatch reliability average of 99.023 percent. Technical Operations continues to strive to improve this performance. How can this be achieved?

Good management coupled with a well-defined maintenance program and a trained workforce are indispensable for performance improvement. No single element will do the job. A complex combination of all of these is necessary together with the inclusion of the most important element, the human factor. The people in this system make it work. In our case, its Delta's special spirit, the family spirit. The dedicated individuals working at Delta represent our greatest asset. Our management has a concern for these people and supports a commitment to excellence. Under this commitment, aircraft are repaired and returned to service without any compromise in the quality of maintenance performed or in allowing unsafe conditions for working personnel.

Use of Work Support Systems

One way in which the overall effectiveness of the workforce is supported is through the use of safe and efficient work support systems. Proper work support systems tend to enhance and aid each worker's performance. With safe and stable work systems, maintenance personnel are more productive. When they are comfortable and competent with this equipment, maintenance practices remain consistent. Sustaining the technical reliability of Delta's aircraft fleet is very dependent upon the repeatability of the quality of maintenance. The use of access equipment and other support systems, designed with considerations for human factors, represents our best chance for achieving consistent maintenance quality.

Maintenance Hangars

One of the most important work support systems is the maintenance hangar. This hangar provides an environment that protects both aircraft and workers from the weather. These structures are tailor-made for the sole purpose of caring for both. There are ten Delta maintenance hangars or hangar complexes in the U.S.: Cincinnati, Los Angeles, Tampa, Boston, Dallas, Seattle, Salt Lake City, Atlanta, Chicago, and Detroit. At these hangars, high service bays can accommodate several wide bodied aircraft and several narrow bodied aircraft simultaneously. This capability is very important during inclement weather as well as at night when the majority of maintenance is performed.

In the Delta Atlanta maintenance complex, 15 - 20 aircraft can be worked in a hangar over a day's period. Within these hangars, a variety of work support systems aid technicians in their activities. Fixed and mobile work platforms allow individuals performing the work, that is, the mechanics, inspectors, painters, and cleaners, to access an aircraft quickly, easily, and safely as they perform their assigned work tasks. Easy access allows a worker's energy to be spent in the actual accomplishment of the work task.

Service Vehicles

Service vehicles, including service trucks, are critical to the maintenance operation. These systems, when designed as a work platform, can be a considerable aid or a significant hindrance. If a service truck breaks down, it can impede the work area and make it difficult for the next aircraft to enter the hangar. The service truck must be removed, a task that can be complicated if the work platform should be jammed in an extended position. For this reason, it is very important that valves on the main lift cylinders and outriggers have a manual override capability. Our trucks also contain an engine overkill switch on the platform as a safety measure. We also, of course, use anti-skid floors on the van body of the work platforms.

Another important service vehicle is the deicing truck. We have many types of deicer vehicles. These units can produce specific mixtures of heated water and glycol antifreeze. In one system, the mechanic sits in a deicer lift bucket, wearing a body harness, where he sprays the deicer fluid on different aircraft surfaces. In these vehicles, there is always a sunroof in the truck cab to allow visual contact between the driver and the deicer operator. With this system, the operator in the bucket can indicate to the driver if he is coming too close to some part of the airplane.

Service Platforms

Service platforms, as noted earlier, are an essential item of maintenance equipment both inside and outside the hangar complex. Most service platforms are mobile and supported on the top of a truck. These platforms can be raised to a number of different heights and serve many purposes. A standard item is the 30 foot lift truck. This truck has swing down hydraulically operated outriggers for stability, safety chain rails, and extendable side slide-out floor panels. The platform can translate forward over the truck cab by four feet. This makes it a fairly simple matter to position the platform as desired simply by driving the truck to the proper place.

Another type of service platform is used for specific applications with the Boeing 727 aircraft. This is a 16 foot lift truck with a different type of stabilizers, safety rails, and an easy rear entry step assembly. The platform is mounted on a conventional truck chassis and allows for 16 foot lift capability. The front of the platform over the truck cab can be used for pulling under a 727 number two engine during servicing. Technicians can climb up from this position and service the engine directly.

For work at considerable height, we use an articulated boom lift, called the Condor 100, which features an up-and- over-reach capability. Outriggers are extended with the chassis suspended above the wheels. This gives us a 94 foot platform height. With a six-foot man onboard, work can be done at a height of 100 feet. The operator of the articulated boom works from a console displaced from the boom itself. He is thus out of harms way for any potential head injury from down movement of the basket. A relatively new item of platform-type equipment is the stick boom. This system uses no outriggers and has a capability of reaching as high as 85 feet. Interestingly, the stick boom can be driven while it's at its maximum height. This feature adds to its utility.

Our new paint and strip hangar at Atlanta, with three separate bays, uses telescoping assemblies to support detachable work platforms. Each of these platforms has water, steam, air, and electricity. The area can be filtered and the temperature raised by ten degrees in approximately 20 minutes. Normally, stripping an aircraft requires 14 - 15 hours. Using these new well supplied work platforms, we have been able to achieve two strips in less than eight hours.

Maintenance Docks

A most important item of support equipment is the maintenance dock, a large scaffold structure used to support technicians as they work. The tail dock for the 727, for example, is a portable stand used for maintenance access to the horizontal and vertical stabilizers. This unit is very safe and solid, with hand rails and kick panels to keep equipment from being accidentally kicked off the stand. The dock is extendable, locking, has roll-out floor panels, and provides a safety lanyard with attached cable for technicians. From this dock, technicians can work with an overhead crane to do removal of different aircraft parts.

Fixed maintenance docks also are used to good advantage. For example, we have a fixed tail dock that can accept a wide range of aircraft in either the normal on gear or in the jack position. This flexibility helps us to reduce bottlenecks resulting from space constraints and job scheduling. For safety of the technician, our fixed tail dock includes a fire escape. It also has a trash chute for the inevitable discardable material generated during maintenance work.

All fixed maintenance docks have features and facilities designed to make the work of maintenance personnel both safe and efficient. Fire extinguishers, lighting systems, air hoses, electricity, and slide-out floor panel extensions are found on most. Stands are constructed to provide fast docking and dedocking of aircraft with unobstructed access to overhead cranes. Some docks are built as multi-tiered scaffold systems.

The versatility of our maintenance docks is shown in one which allows infinite vertical adjustments of the fuselage and tail platforms. The height of each section can be moved independently to different levels to accommodate work demands. This is especially useful during painting operations. A cargo elevator also is available for lifting heavy items to various platform levels.

The two-tiered nose stand for the Boeing 727 aircraft also shows versatility. The upper section can be used during windshield maintenance and the lower for performing maintenance to the weather radar. A forward fuselage stand on the side allows maintenance of doors as well as access to the pitot system and the angle of attack probe. In general, access to all forward elements of the airplane is made straightforward through use of this maintenance dock.

Ladders

One of the simplest and also one of the most useful items of work support equipment is the ladder. We have a large inventory of ladders. Most are of the fixed aluminum type with side rollers for easy movement and wide anti-skid step treads. These ladders can be used to gain access to difficult work areas. For instance, a mechanic working on the discharge wicks on the tail of an L-1011 airplane will use a ladder which will support his work at approximately 42 feet above floor level. Other ladders are used in conjunction with work platforms and allow access to difficult areas of surfaces such as the horizontal stabilizer.

Some ladders are designed for specific maintenance tasks. For example, work in the wheel well of the L-1011 airplane requires a specially designed ladder which also incorporates a tool rest. This allows an individual to go fully within the wheel well during his work. The door to the wheel well would prevent access using a conventional ladder.

Summary

Many different items of support equipment are necessary to ensure that maintenance personnel work safely and efficiently. We appreciate the efforts of the Federal Aviation Administration (FAA) and the Occupational Safety and Health Administration (OSHA) to develop a better understanding of the human factors involved in the use of different kinds of equipment. We need human factors standards that will allow us to procure and use the best support equipment for our maintenance workers. Our workers are our most valuable resource. If maintenance is to continue to improve, these workers must have the best work support systems we can provide.

FAA INTERPRETATION OF MAINTENANCE AND INSPECTION PAPERWORK REQUIREMENTS

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Federal Aviation Administration

The responsibility for oversight of air carrier maintenance activities rests with the Aircraft Maintenance Division in the Office of Flight Standards of the Federal Aviation Administration (AFS-300). This Division is concerned both with maintenance for air carriers (FAR Part 121) and for air taxi operators and commercial operators (FAR Part 135). A major responsibility in all of our maintenance oversight is to review and approve maintenance recordkeeping. This is a responsibility we take quite seriously and will be the subject of this presentation.

One of my recent assignments has been to inspect the "aging aircraft" fleet. As you know, concern has grown in the past several years over the safety and special problems of older aircraft being used in commercial operations. In dealing with Part 121 and Part 135 operators of older aircraft, we found that the keeping of maintenance records was probably the biggest problem we had to police. Maintenance recordkeeping is an important matter for operators and requires considerable attention if operator responsibilities are to be met.

In my visits to commercial operators I have encountered a number of questions on different aspects of maintenance recordkeeping. In a recent trip to San Francisco, a group of Part 135 operators asked five questions that I think might be of interest for today's meeting. I would like to go over these questions briefly at this time and give you the essential answer to each. A handout accompanying this presentation lists these questions and gives specific places in the Federal Aviation Regulations and in the Inspector's Handbook where complete answers can be found.

Question: May an on-demand FAR 135 operator who uses contract maintenance facilities use the manufacturer's or certified repair station forms to record inspections and discrepancies found during that inspection?

The answer to this is "yes." However, if the operator uses such forms the practice has to represent a *maintenance policy, a procedure to be followed, and it must be in your maintenance manual. This practice also must be accepted by your Principal Maintenance Inspector (PMI).*

The reference to PMI's calls to attention one problem related to recordkeeping which might be noted here. I have found that about 60 to 75 percent of all commercial operators have had their PMI's changed over a two-year period. This does represent a problem. I might visit your facility, look at your manual, and say that you need changes. In reply, someone might say to me that the company has been working with this manual for the past three years and the PMI during that period did not call for changes. Lack of PMI continuity does cause some problems.

Question: If this same operator has a trained and qualified maintenance person on site during inspection and routine maintenance to determine the adequacy of the work done, what level of training, if any, must the mechanic and inspector have at that repair station?

The FAA does not specify a level of training for mechanics. The training simply has to be adequate for the carrier maintenance demands. When you go to your PMI and discuss training, he will give you assistance in developing your training manual so that you can have adequate maintenance training for all mechanics.

Question: May a certified repair station on the certificate holder's program return a FAR Part 135 aircraft to service?

Again, the answer is "yes." An operator is responsible for all maintenance performed on all aircraft owned and operated and may authorize a repair station to return an aircraft to service so long as the repair station is appropriately rated.

Question: Must a Part 135 certificate holder train manufacturers or certificated repair station personnel to authorize engine run-up and taxi operations?

The answer here is "yes." Procedures regarding the training of manufacturers or repair station personnel for run-up and taxi operations should be stated in the operator's maintenance manual.

Question: If a repair station is used for maintenance, may the operator use a photocopy of the records for the aircraft? In other words, who keeps the original for their recordkeeping system, the repair station or the aircraft operator?

The owner/operator must receive the originals and the repair station shall keep a copy for its records. One problem we have encountered in inspections and also have heard about from the field is that many operators are given carbon copies of aircraft maintenance records. This is not proper. Originals must go to the operator and/or owner. Repair stations should maintain copies of all maintenance records.

Recordkeeping Procedures

Recordkeeping concerning Airworthiness Directives (AD's) has been something of a problem in the field, particularly with respect to inspection of aging aircraft which might have a number of pertinent AD's. Many operators are affected by aging aircraft inspection requirements and the need to comply with the AD's associated with these aircraft. Figure 1 shows a suggested format which might be used in maintaining Airworthiness Directive compliance records. This format illustrates the kind of information sought by the FAA as it reviews an operator's records to determine AD compliance.

* Aircraft, Engine, Propeller, Rotor, or Appliance: Make_______Model______Ser. No.________N_______

AD Number and Amendment Number	Date Received	Subject	Compliance Due Date Hours/ Other	Method of Compliance	Airframe Total Time in Service at Compliance	Component Total Time in Service at Compliance	One-Time	Recurring	Next Comp. Due Date Hours/ Other	Authorized Signature Certificate Type & Number	Remarks

*Suggest providing a page for each category

Figure 1 Airworthiness Directive Compliance Record (Suggested Format)

Another recordkeeping problem concerns the documentation of major repairs and alterations. In this kind of repair work, what is "acceptable data?" What is "approved technical data?" How do you get such data? While such questions are asked, the FAA, in fact, does provide guidance concerning the source of the desired data. FAA-approved technical data to support major repairs and alterations can be obtained from a number of sources and channels, as follows:

- Type certificate data sheets
- Aircraft specifications
- Supplemental Type Certificates (STC)
- Airworthiness Directives (AD's)
- FAA field approval
- Manufacturer's engineering approved data
- FAA engineering (ACO) approved data
- Designated Engineering Representative (DER)
- Designated Alteration Station (DAS)

Figure 2 shows the workflow when an aircraft undergoes major repair and major alterations. This figure also shows the FAA Advisory Circulars which pertain to specific phases during the work cycle. Most of these Advisory Circulars can be found in the 43 series. Some of the key Advisory Circulars in this series include:

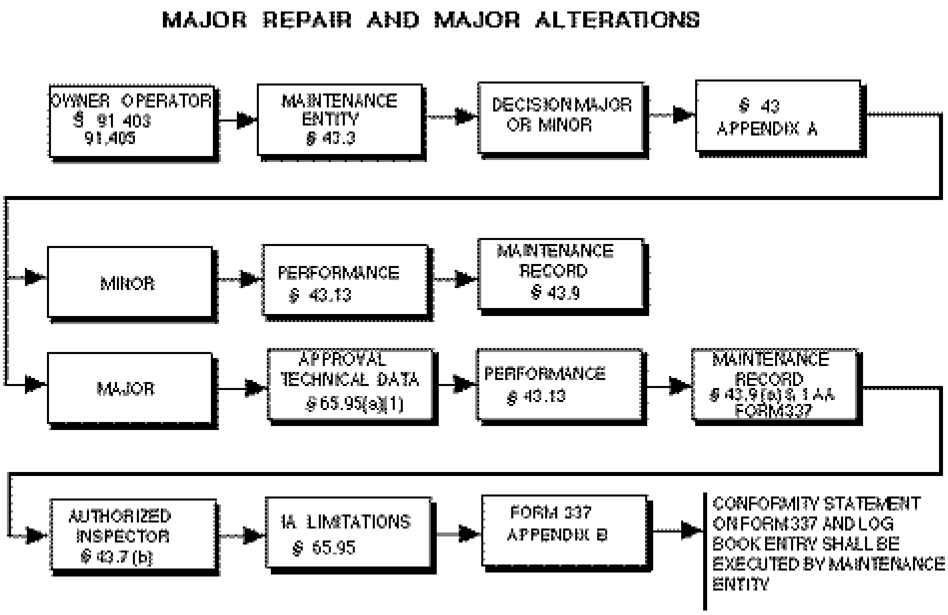

Figure 2

AC 43-9 Maintenance Records: General Aviation Aircraft.

AC 43-10 Mechanical Work Performed on U.S. and Canadian Registered Aircraft (1-26-76).

AC 43-16 General Aviation Airworthiness Alerts.

AC 43-17 Methods, techniques, and practices acceptable to the administrator governing the installation, removal or changes of identification data and identification plates.

AC 43.13-1 Acceptable methods, techniques and practices, aircraft inspection and repair.

AC 43.13-2 Acceptable methods, techniques, and practices, aircraft alterations.

When an FAA inspector visits to review the repairs and alterations made by an operator, he will principally check to ensure compliance in the paperwork. He wants to see if the recordkeeping process is in order. He may ask you for current status of an AD. This does not mean that an operator has to produce a piece of paper immediately, hand it to the inspector, and say "here it is." However, the operator does have to respond in a timely fashion. At times, our inspectors have requested current status of an operator's AD's and waited for five to six days for a reply. This is not responding in a timely fashion, according to the Administrator.

Maintaining up-to-date records for major repairs and alterations is particularly important. When an FAA inspector goes to an airplane which has had significant problems recently and asks for the paperwork to support the repairs, the paperwork should be there. This is not always the case. We stress, however, that this paper trail is a serious matter and documents the aircraft status and changes from the time it goes on line until it ultimately is resold. All maintenance work must be supported by records.

The Federal Aviation Administration must rely on recordkeeping as an essential index of the adequacy of maintenance in commercial air carrier operations. This is true for the major carriers; it is equally true for air taxi operators. Therefore, when an inspector checks an airplane he probably will ask first for the supporting maintenance documentation. If the records cannot be found there, the inspector will return to the operator where, hopefully, the records will be readily accessible through the quality control program. Generally, this is the case. However, there are instances that cause concern. We have, during some observations, found that a number of junior mechanics were assigned to work the night shift without proper supervision. This leads to poor learning experiences, improper recording of maintenance work, and inadequate traceability of the work. Recently, I noted that one operator was using small green tags and yellow tags to account for maintenance status rather than proper maintenance logs. This is not acceptable. I hope that discussions such as we are having at this meeting will contribute to proper and effective maintenance recordkeeping practices throughout the air carrier industry and that the FAA and the air carriers will work in harmony on this important matter.

The FAA is currently promoting rulemaking and associated guidance material in the area of recordkeeping as part of the Aviation Rulemaking Advisory Committee (ARAC) to further clarify this issue.

IMPACT OF MAINTENANCE AND INSPECTION PAPERWORK REQUIREMENTS OF AIR CARRIERS

Eugene ("Dutch") Drescher
International Association of
Machinists and Aerospace Workers

I have attended a number of these meetings and have found the presentations to be clear and concise. Today, I may change that somewhat by introducing a little controversy. Many other discussions have been about "what if's." I plan, instead, to talk about "what was," that is, the real events that have been happening in air carrier maintenance. Remember, one other member of the audience and I are the people who, only a couple of days ago, were in the maintenance hangars working on aircraft.

To begin, I would like to explore the theme "How paperwork is developed and how we can keep it so wonderful." To illustrate this theme, we can use the recent Airworthiness Directive (AD) to the tailcone of the DC-9 and the DC-9-80 airplanes. The tailcone is a simple system. There are four or five pulleys, a couple of cables, two handles, four locks, and no electronics. There is nothing magic about its operation. You pull the handle and the tailcone falls out. At least, that is the plan.

Attention was drawn to the tailcone release system as a result of a runway accident in Detroit a few months ago. I participated in the investigation of this accident. During the course of our investigation, we found that the tailcone, which was not released, could not be deployed from the interior position. We also learned that the interior handle was broken. As a result, passengers could not escape through the tail exit.

Now I would like to present a chronology of work growth dealing with a relatively simple problem. While we were still working on the accident investigation, we sent a message through Northwest Airlines to examine all DC-9 exterior and interior handles to be sure no handles were broken in our fleet. This was a simple, quick check and was done within three days after the accident.

The second paperwork dealing with the DC-9 tailcone was completed about a month later with input from the FAA, NTSB, the airlines, and Douglas Aircraft. This was the same system, the only difference being that now the paperwork had grown to approximately 20 pages. To accomplish the work described with this paperwork required between four and six hours now.

About two months after the accident, the actual AD was prepared. This first one, dealing with the DC-9, was about 20 pages. About five months later, the AD covering the DC-9-80 airplane was completed. When all was done, we ended up with approximately 80 pages to accomplish the two AD notes between the DC-9 and the DC-9-80. The result was a completely unworkable situation. We could not comply.

I learned of the problems with the two AD notes when an inspection foreman complained to me. He said the paperwork is no good and we can't follow it. Since the tailcone release is, after all, a relatively simple system, I felt he might be exaggerating. To look at this problem, another lead inspector, the foreman with the complaint, and I, representing over 100 years of aircraft experience and all with DC-9 backgrounds, studied the paperwork together and agreed that we could not understand it. At the moment, that's where we are. We are still trying to resolve the paperwork requirements. How does this happen?

First, we ourselves did not supply the proper paperwork at the start. There is a reason for this. When you want something taken care of immediately, you will skip steps. You will do what is required as quickly as you can.

The second part of the problem is that the FAA, the NTSB, Douglas, and Northwest kept changing the criteria for what the paperwork is supposed to do. This certainly compounded the problem.

Yet another reason is that untrained or inexperienced people are developing some of the paperwork. I do not mean all of the paperwork, but certainly some. Finally, the reason the paperwork grew to some 80 pages is that, as a new procedure was produced, the old one was never taken away. Also, instead of having two pieces of paper, one for the DC-9 and one for the DC-9-80, we kept piling revision on top of revision for both aircraft until we ended with 80 pages that are completely worthless.

Now let's move to the real world. Picture a mechanic in Montana who has a DC-9 coming through and whose computer spits out his work package. The computer presents him with 80 pages describing how he will comply with this DC-9 AD tonight. Is he going to do that? No. He will look at the 80 pages, discard them, and then proceed with the work. When finished he will write a non-routine card that says, "Accomplished project per the maintenance manual." One simple, quick sentence. And it's legal, we think.

How do we repair this? First, we should reduce the number of people involved in the development of paperwork. We should use fewer and more qualified people. Have one person, or perhaps five people, develop the paperwork for one item. I am not saying that five people should develop paperwork for all items at our airline. However, for one certain area, only a small group should be responsible.

Next, we should use the same paperwork for all aircraft. I would like to see all DC-9's, all over the world, use the same paperwork for maintenance. In this day when everyone is talking globalization, we still have the situation where one group says that their procedure is better than your procedure. What would be wrong with the airlines, working with the Air Transport Association, getting together and adopting one set of paperwork for a DC-9, one for a DC-10, and one for a 747. That way we could go from airline to airline and presumably find everyone doing the same work. This would mean that all aircraft would be maintained the same way.

If one set of paperwork existed, the FAA might be responsible for its contents rather than having a shared arrangement as at present. One form of maintenance involves "tacit approval." This is an open and liberal form of approval under which the FAA defers to the airline. About four years ago, the tailcone on the DC-9 was a Required Inspection Item (RII). Someone in our company evidently decided that, since the tailcones always work, they should be removed as an RII inspection item. Therefore, a few years ago, we did remove this RII. Then the inevitable happened. When the accident occurred, the tailcone didn't work. Now it is back to being an RII inspection item. This is not entirely the airline's problem. Since the FAA approves the maintenance, the problem is shared between the airline and the FAA. A single set of paperwork requirements for all airlines would remove the issue where a single airline assumes at least a shared responsibility for changes in maintenance procedures.

That's it on DC-9's. Little airplane, little problem.

Now I would like to move to the 747. Here we have a little problem on a big airplane. Since our airline had reconfigured the cabin on a 747, the FAA required a conformity check of escape slide use. About two months ago, we blew five escape slides on a 747 as a demonstration. Everything worked perfectly. The next morning, by 6:00 o'clock the airplane was essentially put together again. We were told that operations needed the aircraft for a 7:30 a.m. flight. This was no problem. It took us about an hour and the airplane was ready to go. Then we found that indeed we did have a problem. Before the airplane could be released, we needed to complete the paperwork and do the inputting into the computer. It was done about four hours later. An airplane that was ready to go on time was released for flight at 10:30 in the morning.

The problem here is that the FAA requires paperwork to be done before an aircraft is released for flight. This makes sense and I cannot argue against it. However, the problem arises with the fact that paperwork now is computer-based. Computers have become central to all of our operations, including paperwork. While maintenance cannot operate without a computer, the computer is not the mechanic's friend. Mechanics and inspectors are the ones who must input information into the computer, i.e., the part numbers, what we did, when we did it, and so on. The FAA, Management, Engineering, Routing, and everyone loves the computer because it is a source of information. It is resource information that allows them to see when an airplane was in town, how long the work required, what was done, and anything one needs to know. If you notice, though, I did not mention mechanics or inspectors in the group loving the computer. We are the ones who must input the information.

How can we fix this? Is there some way to streamline the information input process and also to release an airplane before the computer work is completed? I believe we should differentiate between paperwork and computer work. Paperwork to me is the mechanic signing a piece of paper. You sign the paperwork off, you sign the logbook off, and you put the logbook on the airplane. As far as I am concerned, the airplane should be ready to fly then. Following this, there should be a nominal period of time, in the order of several hours, to complete the computer work. With such a procedure, flight delays would be reduced, safety would remain intact, and the computer labors would be done.

The plan I have just described would have an additional benefit. Using these procedures should reduce the number of violations the FAA charges simply because there would be less time pressure on the mechanic working at the computer terminal. Knowing that his work is not holding up the release of an airplane, he might proceed with his labors at a more rational pace. There certainly would be fewer inputting errors and prescribed procedures could be followed more closely.

Now I would like to talk a little more about the paperwork burden for the 747 airplane. This time I will describe a large problem on a large airplane. We have a program, for our aging aircraft fleet, under which we try to "zero-time" an older airplane. We change skins; we change airframe structural parts; we complete anything deferred over the years; in short, we try to bring the airplane as close to zero-time as possible.

The last time an aging aircraft was brought in for this zero-time process, the computer-generated paperwork to specify work procedures ran for over eight hours on our high-speed printer. After eight hours, the printing wasn't complete but it was close. During this time, we used five boxes of printer paper. After this pile of paper was completed, it went through a review. One inspector, two foremen, one mechanic, and a work control clerk worked for three days to go through this paperwork pile and remove the duplicate items. In the meantime the airplane waits for the work to begin. How does this happen?

The principal reason for the abundance of paperwork just described is that we have people in Production Planning who do not know maintenance. The production planner may know something about airplanes, certainly he's ridden on them, but he does not know maintenance. As a result, he uses his light pen to highlight every step in the computer because he doesn't know. Thus, the package that is sent to the mechanics, the foremen, and inspectors on the floor is not tailored to the process and to their needs. The production planner apparently thinks that these people know what they're doing, therefore they can figure out what all the paperwork means. They can, but it takes time -- lots of time.

The problem with computer-generated work requirements for maintenance is relatively easy to fix. Use people at the computer who know aircraft and who know maintenance. Use a few qualified people to take care of a specific job. Don't give every job to everyone. Also, as we work to improve this, recognize that the responsibility for the current situation is shared by the FAA and the carriers. All of this paperwork is FAA-approved. Therefore, any solution must be developed by the FAA and the air carriers working together.

Now I would like to mention briefly one or two workplace variables, again focusing on paperwork issues. A simple task will serve as an example for the first. To change a wheel on a Fokker airplane requires nine pages in the maintenance manual to tell the mechanic how to do it. Do you think a mechanic is going to read that maintenance manual every time he wants to change a wheel on a Fokker -- read nine pages? No, I doubt if he will even read it the first time. You cannot give any experienced mechanic this much paperwork because he simply will not use it. He will throw it away and write out something that works. The complexity of the job and the volume of supporting paperwork must match. Simple, straightforward maintenance jobs do not require nine pages of explanation.

Another workplace variable concerns the nature of our paperwork. At our carrier, we have two primary kinds of paperwork. While this may sound strange, it is true. If one work item is supported by two paperwork sources, one would think one source would be primary and the other would be secondary. In our case, we have two primary sources of paperwork. First, we have the CYTEX cards, the computer-generated cards, which is a primary source. These cards describe the work and tell how inspections are to be done. The cards represent the FAA-approved work procedures unless the CYTEX cards tell us to go to the airplane maintenance manual. Then the maintenance manual becomes primary. However, in many instances the maintenance manual and the CYTEX cards read differently. Both are primary and both are FAA-approved. How did this happen? Again, we can trace it to the computer and the data inputting process. Clerks are hired to type the maintenance manual into a computer. In the course of this, decisions are made that "and's" or "or's" or certain punctuation marks are not needed. Frequently, if a number was used earlier in a sentence, the input clerk decides not to use that number again. Soon, we have two different kinds of paperwork. This, of course, leads to problems.

Another factor that affects the workplace is the geographic regional structure of the FAA. Large air carriers operate throughout the world; yet, we operate under nine different sets of rules within the United States. This entirely defeats our concept of globalization. While in theory FAA rules are nationwide, regional interpretations make this a different matter.

If, for whatever reason, a member of our maintenance workforce is cited by the FAA and the citation occurs at Minneapolis, it generally can be resolved. I talk to the FAA; I know the Principal Maintenance Inspector; he knows our paperwork, all of which is FAA-approved. If the matter is not settled then, I go to the FAA Des Plaines office or FAA lawyers from Des Plaines come to Minneapolis. Then we sit and resolve the issue. This is the way the system is supposed to work.

If one of our mechanics happens to be cited while working in Dallas, for example, as has happened, we have quite a different problem. Then the matter is handled through the Dallas office, the Dallas inspectors, and the Dallas lawyers. In one instance, I went to Dallas to meet with the FAA inspector, who told me that our way was not the way Delta does it nor the way American does it. I did not see this as any particular problem since our maintenance manual is FAA approved and we had been following it. This approach was unsuccessful and the matter finally had to be resolved in court, costing a lot of money and taking about three years to be resolved.

Resolution of this problem will be difficult since the FAA regional structure is firmly entrenched. However, it would seem that a better approach would be, in our example, for the FAA inspector in Dallas to do the investigation and then to send the paperwork to Minneapolis, where the FAA office holding our certificate could handle the paperwork. Then we would be dealing with one entity, using both standardized procedures and language.

Finally, I leave you with this thought. There are many people who say that we in the airline industry do not analyze our mistakes. We do. We study our mistakes carefully and go over them closely. I know this happens. If we didn't study our mistakes so closely, we couldn't repeat them so perfectly. Thank you.

AUTOMATION AND EFFECTS ON HUMAN FACTORS

Raymond P. Goldsby
Manager, Maintenance Resource Development
United Airlines

Automation is well underway in maintenance operations at United Airlines. Today, I will discuss what automation means to our airline, the directions we are taking, and the progress we have made.

First, why would we want to automate? There are a number of external drivers pushing us in this direction. There is consistent regulatory pressure from the Federal Aviation Administration and other agencies to improve control and recordkeeping within maintenance. There also is competitive pressure from every other airline to improve maintenance performance. Airline viability depends on productive maintenance as well as productive flight operations. Then there are the repair and operational requirements of new aircraft introduced into our fleet. These aircraft bring tighter tolerances and more complex geometries, advanced materials, and use onboard computers and satellite communications. These new technologies affect the level of knowledge we must have, the recordkeeping we need to do, and the amount of information we maintain in our data bases. Also, the technology itself is redefining the way our industry operates. Committees of the Air Transport Association are working on this and are defining standards for electronic text, graphics, retrieval, and networking.

We also have internal drivers or reasons why we want to automate. We have a BEST Maintenance process at United which is just beginning. It is directed toward cycle time reductions, total quality management, and continuous improvement in maintenance. As our BEST Maintenance process grows, we are looking toward significant economic benefits. We should increase the performance and availability of aircraft. One of the real advantages of cycle time reduction is to put more product in service. Along with this should come improvements in inventory, reductions in outside vendor costs, greater employee efficiencies, and maintenance of our safety and legal margins.

A final reason for automation can be found in our industry growth. Every major airline is facing heavy growth spikes. Just a few years ago, United was operating 250 to 300 airplanes. Now, United, along with American and Delta, is looking at greatly increased operations. At the present, we are running about 475 to 479 airplanes in service. We are adding line maintenance stations and planning a second major maintenance base. In the process of branching out, we will have more places outside the United States and will, of necessity, deal with people who are not as well experienced as our San Francisco personnel. These are some of our internal drivers.

The external and internal drivers are guiding a number of major automation programs at United. These include engineering, operational aircraft, engines, airframe and components materials management, interactive training, development of knowledge-based systems, and systems design in maintenance. In all of these, automation facilitates change. This is where automation interfaces with human factors. Automation should make human factors different and produce a better and more improved working world for our aircraft maintenance technicians. First, as so well illustrated in the examples by Mr. Drescher, you can't automate the status quo. If you take the maintenance manual and put it under the glass of the computer, without doing anything else, the system will not work very well. It may well take you four hours to release an aircraft with the paperwork monster that you've built if you really have not engineered your automation process.

Automation forces teamwork to occur. As I noted, you cannot simply automate the status quo. You have to simplify and clarify. Then you have to organize all of the information or the process before you can automate. This requires teamwork. You must have automation and design personnel. You have to have subject matter experts. You have to have project management people, programmers, and so on, to conduct an automation project. The project doesn't just happen. It is not generated by one person or with one set of rules or technology.

Engineering and Technical Services

Engineering and Technical Services at United is a major operation impacted by automation. Engineering has the responsibility for providing technical information and documentation to mechanics and support personnel. This includes everything from writing manuals, revising manuals, handling all AD notes, specifying repair processes, and continues right to the point of assessing the technology of our new aircraft. In our new world, automation will underlie all of these processes.

The development of the DC-10 maintenance manual serves as an example. In the traditional way of preparing maintenance documentation, you use a bucket, a large brush with white out material, a pair of scissors, some glue or paste, and you do a lot of cut and paste work to assemble the manual. When finished, as in the case of the DC-10, there are about 20,000 pages of material in the completed manual.

The industry, both on the manufacturer's side and on the airline's side, is beginning to automate the manual production process. We're beginning to change from thinking in 8-1/2" X 11" to some form such as 640 X 480 pixels, or whatever screen resolution we need. We are going to stop thinking about tables of contents and looking up information into a new process that involves navigation and search engines, information tags, and other devices to make information more usable.

The status of our automation efforts in Engineering and Technical Services is shown in Figure 1. In this figure, automation is ranked on a scale of one to ten, with one being the least progress and ten being the most. You can see that we've done quite a bit on on-board engine performance monitoring, computer-controlled machine instructions, and computer-aided tool design and wiring diagram maintenance. The other areas are those that we plan ultimately to automate fully but are at some beginning stage at the present.

WHAT DO WE HAVE

Functionality	**Rank (1 to 10)**
Maintenance program administration	2
Authoring & publishing technical documents	4
Document distribution	2
Time-limited engine parts control	7
On-board engine performance monitoring	9
Authoring work card documents	4
Engineering analysis assistance	4
Repair process specification	5
Computer-controlled machine instructions	9
Computer-aided tool design & wiring diagram maintenance	9
Aircraft weight & balance control	6

Figure 1 Engineering and Technical Services

At the present, we are upgrading our existing capabilities with new systems, particularly concerning computer-aided tool design and enhanced wiring diagram maintenance. We also are establishing an electronic data base for technical information under which we will have network work stations for tracking service bulletins and AD notes. We also are moving into electronic publishing using Standard Generalized Mark-Up Language (SGML) for engine repair specifications, airframe job cards, and minimum equipment lists. Here we are working with Boeing to integrate our projects and set document standards.

Figure 2 shows what our document delivery system is beginning to look like. We now have 450 Macintosh computers, with 250 of them networked. Hopefully, the rest will be networked by

October of this year. Then, we can have our Component Department, our engine personnel, the tool and inventory control system, and the fleets all working together, with information passing back and forth in electronic form. Then, of course, we should be able to deliver that information to the mechanics.

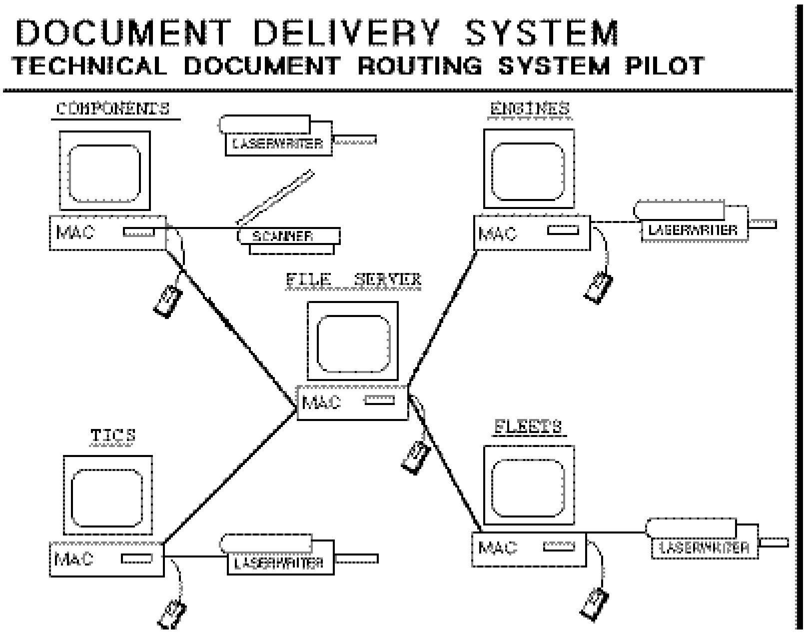

Figure 2

We also are working with computer-aided drawings in a three dimensional format that can be incorporated with the maintenance text. Hopefully, when all of this is complete, we will have a system that distributes such information throughout United, at first using CD-ROM systems. We look at CD-ROM as an interim step. Eventually, all data will be on-line and interactive. This will be something more than a data base. It will be more of a continually updated collection of information in the form of a living electronic document. With such a system, a mechanic should be able to locate information the way he thinks about it. For instance, if looking for a fuel pump, he will not think of ATA Chapter 28-20 for fuel distribution and then wait for the machine to arrive at that index point. If our system has been tagged properly, he will simply click on "pump," then click on "fuel," and then look through all of the possibilities, the part numbers, the maintenance manual information, the wiring diagrams, etc., until he extracts exactly the performance support information that he requires for his job.

We have begun to work with manufacturers such as Boeing and with our primary vendors to determine the structure of our automation effort. Figure 3 shows the Boeing automated system that is helping us. In this system, the operator can put information, both text and graphics, into the computer. It then goes to an integrated text and illustration computer, from which output can be obtained in various forms such as hard copy, microfilm, optical disk, and tape media. In the future, we should be able to exchange information in systems such as this via either satellite link or by telephone line.

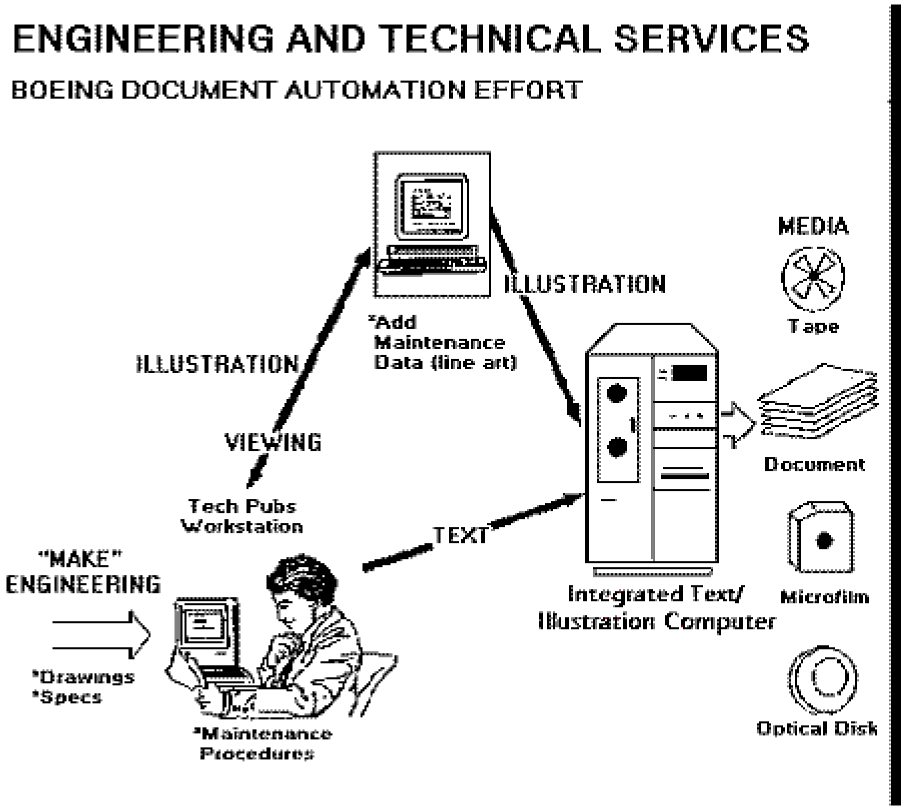

Figure 3

Operational Aircraft

The focal point of our business, of course, is to provide airworthy aircraft at the departure gates at the scheduled time. This is a significant assignment because, at this time, United is operating 465 aircraft resulting in 1,980 flights per day. To support these flights, we have 29 domestic, nine Pacific, and two European line maintenance stations, with a total employment of 3,700 line mechanics. Seventy percent of flight-crew-identified defects in domestic operations are transmitted through ACARS. Our maintenance control center receives about 1,200 calls a day. The result of all this is that 75 percent of our line workload is non routine. And, because our fleet size is increasing, both our scheduled and non routine workloads will increase.

Our functionality in automation to support our operational aircraft requirements is shown in Figure 4. We have made good progress in enroute workload forecasting, overnight and check workload forecasting, control of monitored items, and performance reporting. We want to go a lot further with automation here but, if we consider earlier times, progress has been made. In the 1970's, many different documents were required for us to run an aircraft through the dispatch program. Automation has helped us considerably here today.

WHAT DO WE HAVE

Functionality	Rank (1 to 10)
New station/fleet integration	7
Fault identification & reporting	6
Enroute workload forecasting	8
Overnight/check workload forecasting	9
Station/system level planning	8
Task, personnel & part requirements	5
Control of monitored items	8
Chronic aircraft monitoring	5
Chronic unit monitoring	3
Work accomplishment recording/reporting	6
Performance reporting	8
Reliability analysis tool	3
On-request special reporting	2
Communication with operating fleet	5

Figure 4 Operational Aircraft

Engines

Probably one area where we have done more work than anywhere else is in the engine area. Here we have the advantage that this work is reasonably contained within an engine shop environment centrally located at our San Francisco facility. The mission of Engine Maintenance is to provide serviceable aircraft engines, auxiliary power units, and engine components. This activity supports nearly 1,800 United engines and APUs and performs nearly 800 engine overhauls per year. Almost 2,500 mechanics and inspectors are employed in engine maintenance. Each year, expenses are about $500 million, with a $750 million inventory maintained. This is a big business.

Automation provides major support for our engine work. We have ongoing systems now that support our work in part identification, tool tracking, and material requirements planning. This kind of automated support is critical for the success of this engine maintenance facility. For further support, we are developing automated systems in the areas of configuration control, data input technology, production planning, performance reporting, and others. Ultimately, all aspects of engine maintenance should have significant automation support.

Automated Document and Repair Selection

Currently we are using, as shown in Figure 5, a print and distribute paperwork-type job planning card (JPC) system. Although this system is helped through the use of automatic high speed printers, it still is not optimal. We would like to reach the point where an inspector identifies a discrepancy and, through increased automation, a customized job planning card will appear, either on the screen or be locally printed.

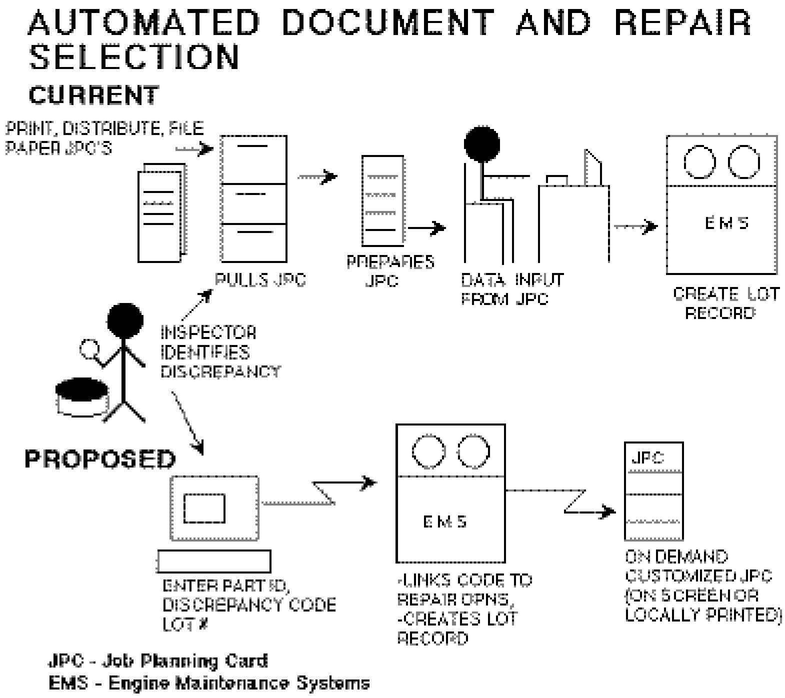

Figure 5

One of our proudest accomplishments in engine maintenance has been the development of focused repair centers. In a typical shop environment, an engine component will be torn down and different parts will go to various places. Work is done on each part and then, if all goes well, the parts come back together in one place, are reassembled, and move out the door. This process requires a lot of time, a lot of routing, a lot of tracking, and a lot of training of different people for different parts and procedures. Nobody has any real ownership for the entire repair process. Many different departments work on it.

We are now working on a focused repair center in which blades, vanes, and cases are handled on dedicated repair lines. Each of these parts goes completely through the repair process, from the disassembled engine down to the final checking of the coding, and then is returned to the engine for final assembly without all the routing. Everything is done in the one shop. We hope that synchronized production is going to be the way of the future so that we have focused repair centers for just about everything in our shop. This would shorten cycle times and would mean all shops hopefully would be producing at the same tempo.

Some of the tooling and equipment to be found in these focused repair centers will be computer-controlled automatic grinding and lathing units, robotic welders, flame-spray robotics, and other automated systems. Before we proceed fully in this direction, however, we should look to see if the effort will be worth it. Figure 6 shows performance improvement achieved by our nozzle guide vane focused repair center to date. As we look at these improvements, we must remember that the front end of this change costs a lot of money. A big investment is required to obtain this kind of improvement. Nonetheless, the improvement is there. Cycle time went from 130 to 23 days; labor dollars per vane from $57 to $33; rejection rate from 50 percent to five percent; miles routed from six to .0.01; number of inspections from 12 to three; and so on. Note the final item, where inventory cost was reduced from $5.4 million to $1.9 million. This is where you start paying for your up front costs in establishing the focused repair center.

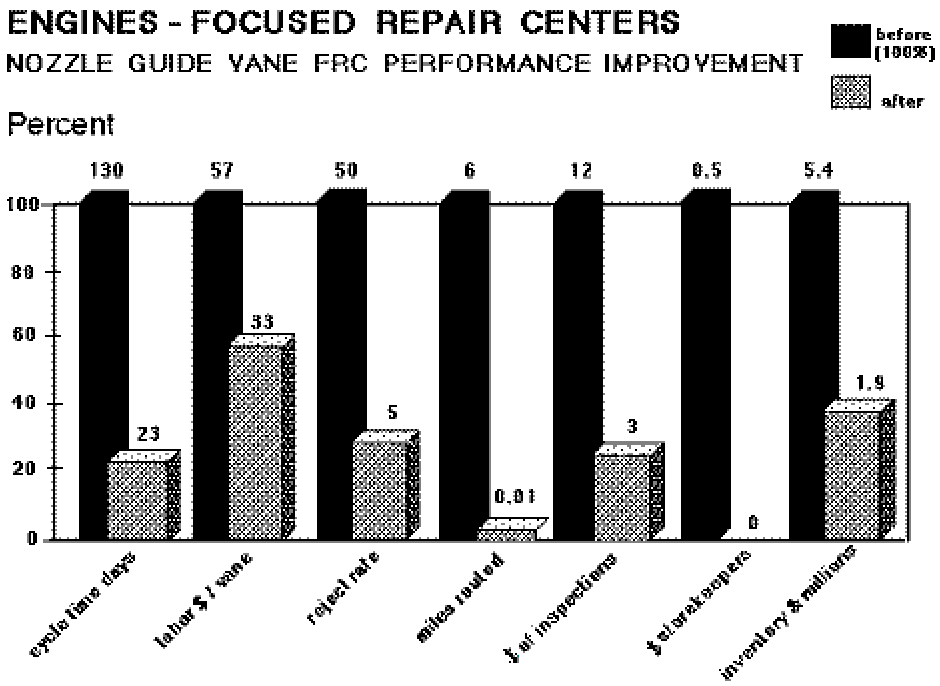

Figure 6

What does the focused repair center buy you? You establish teams and develop a sense of ownership in the process. You have continuous flow rather than a segmented routing time, which results in reduced cycle time. Statistical part process control gives you better quality. Higher technology equipment results in higher productivity. In all, the focused repair centers bring increased employee involvement and continuous improvement in the process.

Airframe and Components

The largest element here is airframe maintenance, where we perform heavy checks and implement fleet modifications. We are now running 18 maintenance docks employing 4,800 mechanics. This is up from 1,150 mechanics in 1983, a sizable increase. One of the results of this expansion, of course, is that now nearly 70 percent of our mechanics have less than two years of experience. One reason for this low experience level is that mechanics tend to come into airframe maintenance docks as their start-up position because that is where the vacancies are. After about 15 months of experience here, mechanics tend to go to shops or back to other line locations. About 90 percent of our mechanics are hired for the San Francisco maintenance base. After the 15 months, due probably to the high cost of living in the San Francisco region, many of these mechanics want to head back to some Eastern location. As a result, as you have seen, airframe maintenance has many new mechanics.

Component maintenance has 28 back shops at multiple locations, employs about 1,400 mechanics, and produces approximately 1.6 million component units every year. Hopefully, we are building and automating a more coordinated effort between the airframe shops, the component maintenance shops, and technical services that provides the information and documentation. Figure 7 illustrates this coordination effort. To further this coordination, we are working on a program called the Aircraft Visit Management System (AVMS), which is a major effort to automate many aspects including job card distribution, recording and distribution of non routine maintenance, compiling of non routine scheduling, planning, and other features.

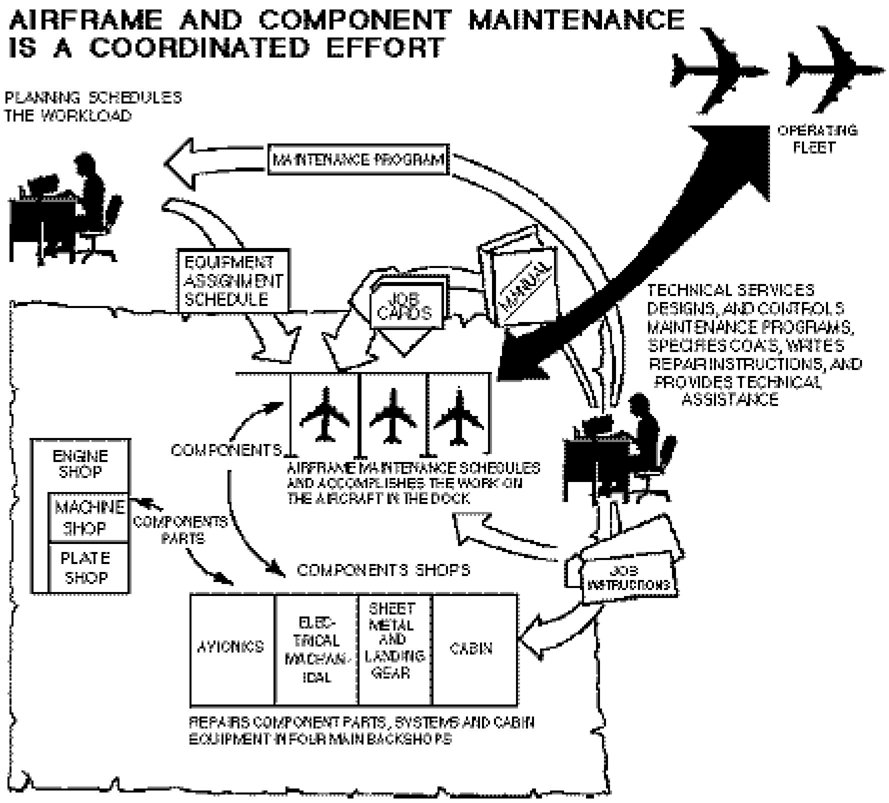

Figure 7

In our automation, airframe technology is proceeding a bit faster than components technology, although we have major efforts to automate both operations. Hopefully, we can proceed on both sides to a point where we have eliminated much paperwork and have most of the data contained in an electronic environment. Some day, we hope to sign off an aircraft in an electronic environment. The AVMS is a step in this direction. Under this system, we are using bar codes on badges, on job cards, and on non routine tasks that we need to track. Employees will "wand" their entry for going on and off jobs, and the progress of jobs themselves will be followed through bar coding. Large schedule boards, with all the associated paperwork, should be disappearing.

Material Management

United Airlines has a $1.1 billion inventory to control, excluding spare engines, which represent another $165 million. Our stores catalog contains 170,000 individual line or stock items. We now have some automatic storage, retrieval, and delivery systems at San Francisco and O'Hare that save significant work. However, the work remains impressive. There are close to one million computer transactions each month and 30,000 purchases. As you can see, material management is a big business. Automation will do much for us here.

Interactive Training

Interactive training, to me, is probably one of the most exciting areas we have. Here, we attempt to implement emerging training technologies and methods that will produce task oriented interactive training and, subsequently, improved operational performance. With interactive training, I appreciate the rapidity with which one can pay back up front investment costs through reduced classroom training time and improved retention. Efforts in this field range from development of high level computer-based instructor-led or student-controlled programs all the way to performance support systems embedded in the maintenance data network. Because our senior workforce is leaving us, we must have an educational and support system that brings new mechanics on-line rapidly and ensures effective performance. We hope to reduce training development cycle time, training delivery cycle time, and produce enhanced training which is cost effective.

The traditional training, which we have come to accept, involves an instructor working with a number of inexpensive tools such as overhead transparencies, paper, chalk, and possibly a few audiovisual aids. This approach works reasonably well. When we move to interactive training materials and computer-based systems we incur significantly higher costs. The initial development is pricey. The development requires considerable time by subject matter experts and other technical personnel. What we want to do is consider interactive training as a business, just like any other business, and develop it as such. In our interactive training group, we are beginning to work directly with the maintenance training people. For interactive training, maintenance training represents our customers, with the real customer being the mechanics.

One program underway now is for the 737-200/300 auxiliary power unit (APU). In this program, one can start, run, and go through all procedures for APU start and shut down just using the computer. In effect, we are bringing the airplane right into the classroom in the standard IBM environment. In this course, a student now can go through the course, test out of the course, and work with an instructor at the airplane for about 15 minutes to achieve desired proficiency. This compares with the usual course of working with an instructor at the airplane for about an hour to achieve that same proficiency level.

In another effort, we hope to develop performance support systems that will let us deliver training "just in time," which really is the way to do it. Mechanics would receive information needed to complete the task at hand when they need that information or, if they've done the task before, to refresh themselves. Delivery of the task information would be under the control of the person using it. He could use as much or as little of the task information as needed.

We also are beginning to pursue knowledge-based systems (KBS). Such systems offer the promise of solving problems previously beyond automation. Here, we will attempt to automate human expertise and thereby increase the quality and speed of decision. Such automation also will protect against the loss of individual expertise. At this time, we have one individual working full time on knowledge-based systems. We see potential applications to issues such as fault isolation, diagnostics, repair selection, and configuration management.

Conclusions

Automation is happening very rapidly. At times, we feel it is happening too rapidly. There may be too many opportunities for the normal justification process. By the time you go through what we call the "normal" justification process, some of the advantage of new technology and automation may have escaped you. The useful life may dwindle just in the process of trying to justify it. For this reason, in some instances at United we have proceeded on faith and intuition into areas of automation before completing the full justification process. The potential advantages of new automated technologies are so considerable we feel this is warranted.

We must continue to improve our automation systems. At the present, we have 75 mainframe information systems with about 5,000 programs. We have two automated storage/retrieval systems and two focused repair centers, with a third coming on line soon. We also are working with Boeing in conjunction with development of the Boeing 777 airplane, which will have completely electronic support from the maintenance data base right through distribution of maintenance job cards. We are moving toward an electronic world that will be more efficient, more effective, and certainly better for our maintenance workforce. I think, if anything else, good and proper automation, done effectively in the proper framework, creates teamwork and fosters the spirit of continuous improvement in our maintenance operations.

IMPACT OF NEW GENERATION AIRCRAFT ON THE MAINTENANCE ENVIRONMENT AND WORK PROCEDURES

Daniel Desormiere
Engineering and Maintenance Division
Air Inter

Air Inter Aircraft Maintenance Organization

Air Inter, an affiliate member of the Air France Group, is operating a 60 aircraft fleet. The carrier, which was one of the five A320 launch airlines, began A320 operation in June 1988. More than 50,000 hours have been flown to date with the company's 19 A320s, and the fleet will increase to 28 aircraft by the end of 1991.

Air Inter is a short-haul operator in France (350 commercial flights a day). The carrier's main competitor is not another airline, but the French Railroad Company and especially the High Speed Network (TGV) which began operation in 1981 and which is to be extended to Air Inter's main traffic routes within ten years.

As the Railroad System in France has a reputation for being on time, punctuality has always been, after safety of course, the top item of Air Inter's policy of service quality. The Company's maintenance organization philosophy stems from this challenging situation.

Air Inter's maintenance workforce (1300 employees) is focused on maintenance functions upon which operational performance is dependent; i.e., fleet availability, flight dispatch reliability and punctuality, and all-weather landing. These functions are technical follow-up of aircraft and engineering, line maintenance and troubleshooting, minor maintenance (up to C check), avionics maintenance, and the support and logistics functions required to back-up the above-mentioned technical functions. These functions represent about 50 percent of the daily tasks and constitute Operational Maintenance.

The decisive criterion for the other maintenance functions, which constitute Industrial Maintenance, is attaining the required quality of service at the lowest cost. The criterion usually results in subcontracting.

The maintenance activity is conducted through a product-oriented organization, where a sub-division is dedicated to each of the four aircraft types Air Inter maintains. An aircraft-dedicated subdivision is headed by the Chief Aircraft Engineer; it includes an engineering staff whom the quality inspectors report to, and a production side with foremen, lead mechanics and mechanics.

Mechanics dedicated to an aircraft are polyvalent on airframe and non- electronic systems. Troubleshooting on avionics is performed by avionics technicians, polyvalent on conventional aircraft and dedicated to the aircraft on the A320.

Responsibility in the Maintenance Division is decentralized as low as possible and the flight crew has been clearly identified as the Division's actual customer. Thus a close functional link has been established between the Maintenance Division staff and its counterpart on the Operations side to handle the technical discrepancies better and control operational reliability.

Although the general aircraft subdivision diagram remains the rule for new generation aircraft maintenance organization, the new technologies introduced on the A320 have changed the environment in which the maintenance is conducted, and thus generated some changes in the work procedures.

The Change in the Work Procedures

The more widespread use of composites on the airframe has resulted in a change of the mechanics' behavior and has focused their attention on a new kind of structural defect which has to be looked for during turnaround checks. In addition to the routine search for cracks, corrosion or impact damage on metallic parts of the airframe, mechanics must now look for such defects as a little hole or a paint scratch on the composite portions. These signs can reveal real internal damage which mechanics must be trained to detect and first evaluate by a tapping test.

The main change of course is due to the generalization of digital electronics in the aircraft systems. Avionics are no longer concentrated in some specific systems like the autopilot, navigation or communication systems, for example. One can say there is no more purely mechanical system on this aircraft. Mechanical forces are translated into electronic bits from the command to the actuator; there is no more lever or command which is not connected to a computer.

Furthermore, systems are so interconnected that any troubleshooting task must be conceived with a wide system approach and no longer like a simple isolated task; one of the connected systems can be disrupted by another system malfunction through an indirect connection that has never been encountered on previous conventional aircraft.

For maintenance purposes, the A320 is fitted with a Centralized Fault Data System (CFDS) which concentrates all information on the aircraft's status.

This system has generated a new three level maintenance concept. It had been anticipated that:

- 80 percent of the failures should be isolated without requiring any further search or thinking (Level 1)
- 15 percent of the failures require more search and thinking (Level 2)
- Five percent of the failures are so sophisticated or stealthy that they require more search and thinking in cooperation with the manufacturer (Level 3)

For the time being, an overall 75 percent figure has been reached for Level 1 failures with a top 95 percent recorded on some systems.

The flight crew and the technicians use the same on-board Multipurpose Centralized Data System (MCDS); a third keyboard has been installed in the cockpit of Air Inter's A320, so the maintenance technicians can work on the system while the flight crew is still in position during a turnaround.

With the Aircraft Communication Addressing and Reporting System (ACARS), fault messages and engine data are automatically transmitted to the ground in real time; fault messages are also printed on the Post-Flight-Report, which the flight crew gets 10 seconds after engine shutdown.

Aircraft system maintenance is thus considerably facilitated by this comprehensive amount of information, and troubleshooting actions can be anticipated as warnings are transmitted to the ground before the aircraft comes to a stop.

Air Inter New Generation Aircraft Maintenance Philosophy

Our philosophy is based on two topics:

- First, the A320 generates a lot of information which can considerably facilitate aircraft maintenance provided technicians know how to take advantage of all the system possibilities. This means that maintenance technicians must be well familiarized with the use of information systems so that they consider them as usual mechanics' tools.
- Second, the cooperation with the flight crew has been reinforced and the flight crew is considered an essential partner for maintenance. Maintenance technicians are educated to deal with crews easily; and conversely flight crews must be familiar with the maintenance organization requirements and this is included in their technical instruction.

A New Training Program

As we first found the technological step from the A300 to the A320 very impressive, we carefully prepared the training program well in advance and we finally defined an 11-week comprehensive program, which was about three times longer than the training program for any conventional aircraft. (See Figure 1).

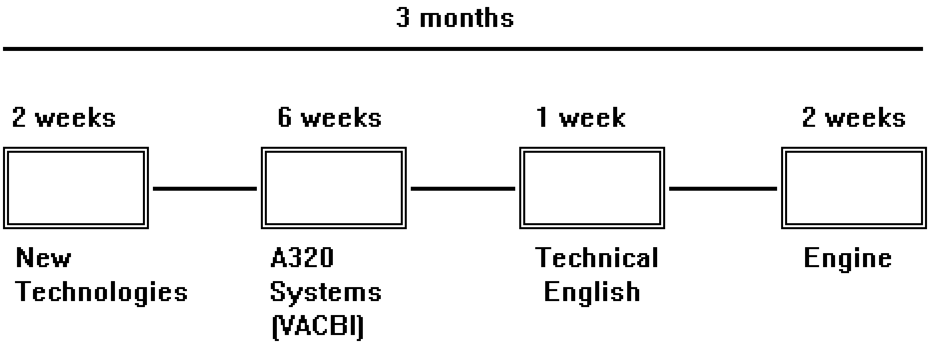

Figure 1

The first step was to give people additional general training on such notions as microprocessors, composite materials, two-man crew concept, and familiarization with the different on-board systems. This preliminary training was done with conventional means.

Then we used VACBI, the CBT Aeroformation System, to perform a six-week A320 System Course where every session was preceded by a briefing done by an instructor and followed by a debriefing.

Furthermore, although there is a French version of VACBI, some parts cannot be translated, such as the CFDS chapter. Therefore, we include a short course of technical English in the program. The last step was a training session at the engine manufacturer's facility.

Today, with two years' experience behind us, the diagram has become the following: (See Figure 2).

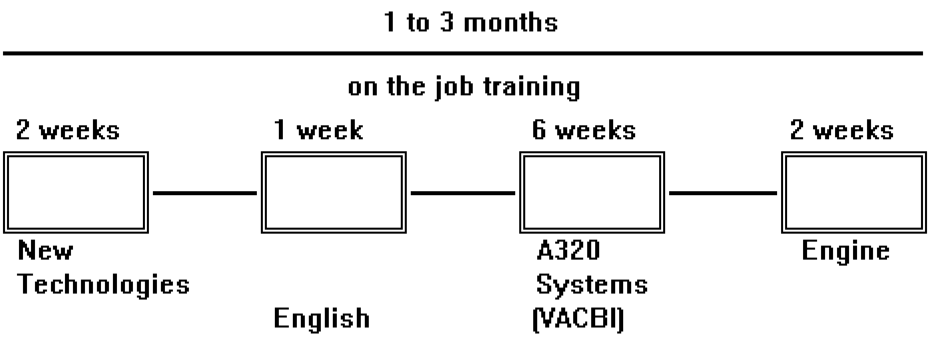

Figure 2

We now find it better to schedule the English step earlier in the process and add one to three months on-the-job training ahead of the VACBI sessions.

This on-the-job training (OJT) phase allows the mechanics to become familiar with the new A320 terminology and the comprehensive information management system to use the technical documentation so that the VACBI phase is more worthwhile. During this intermediate period, the mechanics will also perform simple, routine maintenance tasks, like daily preflight checks, wheel and brake removals.

Toward One Person Qualified for the Entire Aircraft

The usual work-sharing between mechanics and avionics technicians we have successfully been practicing for 15 years on conventional aircraft does not suit the A320 due to systems integration, where a straightforward ATA chapter distribution is no longer significant.

However, we first took a conservative approach and we did not change our work-sharing where avionics people are dedicated to ATA Chapters 22, 23, 31 and 34. At the same time, we also decided to integrate avionics people in mechanical teams and experiment this kind of configuration for at least two years before making a final decision.

Furthermore, it clearly appears that with the CFDS A320 line avionics, troubleshooting does not require such skilled technicians as conventional aircraft.

It has become obvious that because of an overlapping of activity, mechanics and line avionics technicians tend to do the same job and that we have to manage a new social problem. We have learned how to train mechanics so they can do their job on the aircraft properly; we must now find out how we can train avionics technicians so we can extend their skill beyond their usual ATA chapter-dedicated field. This problem, which is being discussed in a working party, will be solved before the end of the year.

The New Recruiting Policy

Because of a skill shortage, we had to start an *ab initio* program three years ago. We then implemented a new recruiting procedure in which we raise the general level, selecting trainees holding the French Baccalaureat (the equivalent of the US high school diploma) to attend a one-year course on aviation maintenance technology, in cooperation with a private institute. At the end of the year they are granted the Aeronautical Maintenance Diploma which is a national diploma created in 1988.

They then spend one year alternating courses (25 percent of the time) and on-the-job training. During that second year, they follow the typical A320 training program; at the end of the second year they are confirmed as qualified A320 mechanics. This is now 80 percent of our external recruitment; the remainder is coming from the Armed Forces or other airlines.

In selecting people, we show as much interest in human qualities as in professional skills, for we need people who can communicate and be able to work successfully in teams. Thus we have a 50 percent reject rate when we finally select people who have already been qualified from a technical standpoint. But we definitely prefer well-educated people to well-trained ones, for it is a long-term investment.

Cooperation With The Flight Crew

Although our organization has been conceived to ease technical information exchange with the flight crews, much of our punctuality relies on the quality of the individual contacts which take place on the apron between flight crews and line technicians.

This is particularly true when the two pilots and a ground technician share the same on-board Multipurpose Centralized Data System unit during a turnaround to get a common consensus on the decision to make; they just work like a three-man team and they must be able to communicate easily. Of course, the final authority is always the aircraft captain, as far as the Minimum Equipment List is concerned. But the individual attitude in a technical discussion, which is sometimes very close to a negotiation, is decisive.

We definitely made this cooperation between flight crews and maintenance personnel a cornerstone of our organization. We asked the first joint crew and maintenance A320 task force which prepared the aircraft operation for Air Inter to work as a joint team with trust and mutual respect.

In the beginning, crews and maintenance engineers attended the same Aeroformation sessions and even had to stay in the same hotel, so they could know each other and become friends. Today, the new A320 crews have a two-day session with our people to meet them personally and become familiar with our facilities and work procedures. One can say there is a real "A320" spirit, which we also want to extend to the A330 in the future.

The New Social Challenge

After our first three-year experience on the A320, we now have a clear idea of what the maintenance requirements are for new generation aircraft, both in terms of professional skills and human qualities. The technological and cultural transformation we initiated in 1988 to get the right people in the right place is leading up to 1993 when we take delivery of our first A330.

On the other hand, such a move has generated more expectations that we now have to cope with. The salaries have already been revised so as to take the higher skill required into consideration. The problem is raised today in terms of self-recognition, self-achievement, promotion and mutual respect.

We want to maintain human-sized units, where we can apply our usual management methods, like Q+A employee/upper management sessions, maintenance teams, and crew meetings.

We have also been experimenting with quality circles for three years and we intend to implement a global quality policy within the next three years. This is our new management and social challenge.

However, this year we have a matter of pride we can share with everyone concerned with maintenance and operations. For the second time in three years, we have been granted the A320 Operational Excellence Award by Airbus Industrie. I can say that our objective is very clear for the coming year: Remain the top scheduled operator!

JOB DESIGN AND PRODUCTIVITY

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Purdue University

Proper job design can have a real effect on workforce productivity. While this fact has been recognized for some time, considerable research is still required to determine the optimum structure of jobs for particular occupational settings. The research I have done is directed toward the examination of different work structures and their impact on outcomes such as productivity, work quality, employee satisfaction, errors, customer service, training requirements, and so on.

Today's presentation will address three broad objectives. First, I will review different approaches to job design and the outcomes they influence. Second, I will review the dimensions of work as they relate to the effectiveness of work groups, as opposed to individual workers. Finally, to the extent that research findings allow, I will discuss the relevance of work design for the jobs in aviation maintenance.

Much about job design and its effects is not realized. Many productivity and personnel problems are a direct result of the design of jobs. As an example of one effect, one study I did found that, at a major industrial firm, differences in the way jobs are designed account for 80 percent of the statistical variance in compensation. That is, how jobs are designed and assembled can have a strong influence on how much you will have to pay people to do them. In another study at an insurance company in which team performance was assessed, well designed teamwork resulted in a 20 percent increase in the number of insurance applications processed. In short, many people mistakenly view job design as technologically determined, and thus do not consider job design as a source of problems or opportunities.

Job designs are really inventions. How we invent them depends in large measure on values. These job design values are influenced in large measure by the societal values of the time. Thus there is an historical element as we consider different approaches to job design.

There are four separate schools of thought in job design. These are the *mechanistic approach*, the *motivational approach*, the *biological approach*, and the *perceptual motor approach*. Each of these approaches is based on a different set of values, as we will discuss later. Each approach also is associated with differential benefits and costs. Inasmuch as there are conflicts among the four approaches, trade-offs frequently are required. However, knowing the four approaches to job design and the outcome that can be influenced by each, one can approach job design in a way tending to maximize benefits and minimize costs.

Job design relates to a host of outcomes, although productivity comes to mind most frequently as the outcome variable of interest (Table 1). The following listing shows different outcomes that can be affected by job design. The manner in which a job is designed may depend in part on the particular outcome of interest.

Table 1

Outcomes From Job Design

Productivity	Mental Ability Requirements
Quality	Physical Ability Requirements
Employee Satisfaction	Job Involvement
Employee Work Motivation	Absenteeism
Ease of Staffing	Aches and Pains
Error Rates	Injuries
Accident Rates	Boredom
Mental Fatigue	Turnover
Physical Fatigue	Compensation Rates
Stress	

The first approach to job design I would like to discuss is called the *mechanistic approach*. This approach comes from classical industrial engineering and is basically scientific management, with heavy involvement of time and motion studies. Names such as Gilbreth and Taylor are associated with this classic approach which came into vogue in the first quarter of the 20th century. At that time the workforce consisted of immigrants with little education and often not speaking the English language. The industrial scene was made up of a lot of people and very little equipment. For this reason, it made sense to break jobs down into their smallest pieces and have each person perform a very small increment. Jobs were highly specialized and generally very simple. Jobs could be performed repetitively. The intent of this design approach was to increase the efficiency with which one could staff those jobs, train for those jobs, and offer low compensation for the work. To some extent this approach to job design is still used today, best represented in the assembly line in the automobile industry but, as well, used in other industries. I believe the mechanistic approach to job design is probably the most innate and the one we first think of when we design jobs (Table 2).

Table 2

Interdisciplinary Approaches to Job Design

APPROACH (Discipline Base)	Recommendations	Purposes
MECHANISTIC (Classical Industrial Engineering)	0 specialization 0 simplification 0 repetition	- training - staffing - compensation
MOTIVATIONAL (Organizational Psychology)	0 variety 0 autonomy 0 significance 0 participation 0 growth 0 achievement	+ satisfaction + motivation + involvement + attendance + performance
BIOLOGICAL (Physiology, Biomechanics, Ergonomics)	0 strength 0 posture 0 environmental stressors	- physical demands - fatigue - medical incidents
PERCEPTUAL-MOTOR (Experimental Psychology, Human Factors)	0 lighting 0 information processing 0 user friendly equipment	- errors - accidents - mental fatigue - stress

The second approach to job design, the one most commonly taught in business schools and probably more "modern" if you will, is the *motivational approach.* This approach derives primarily from organizational psychology. The real thrust here is how to design jobs that are psychologically meaningful, challenging, motivating, and interesting. In designing these jobs, we tend to give advice such as "provide variety and autonomy. People should think what they're doing is important and significant. They should participate in decisions, have opportunities for feelings of achievement and growth, etc." This particular approach to job design often is called job enrichment or job enlargement and is a common innovation in companies today. Its intended purpose is to increase the motivational, satisfying aspects of work.

The next approach to job design is called the *biological approach* and deals principally with the physiological aspects of work. Here we draw on expertise from the fields of work physiology, biomechanics, and ergonomics. This expertise results in a set of job design recommendations oriented primarily toward the physical capabilities and limitations of people. Since other presentations today have dealt with topics in work physiology, oriented toward aviation maintenance, I will not address this approach to job design further.

The last approach to job design is the *perceptual/motor approach,* which derives primarily from experimental psychology and human factors engineering. The goal here is to not exceed a worker's attention and concentration capabilities. We try to monitor the lighting, the control/display design, the information processing requirements, and other task-oriented variables to be sure that they are entirely consistent with the worker's capabilities. Just as the Aloha incident was a key stimulus for studies of aviation maintenance and older aircraft, so the Three Mile Island nuclear power plant episode served as a stimulus for consideration of human factors job design requirements.

The different approaches to job design are not necessarily all oriented in the same direction. The optimum job design may require trade-offs among these approaches. The mechanistic approach, as noted, relates to efficiency and affects matters such as training requirements, staffing needs, etc. The motivational approach relates strongly to job satisfaction. The biological approach is concerned with issues such as comfort, health, lack of medical incidents, and so on. The perceptual/motor approach relates strongly to its intended outcomes, specifically issues of safety, reduction of errors, and provision of user-friendly equipment.

The various job design approaches can produce outcomes that are unintended, with negative benefits at times. For example, the motivational approach may have negative effects on efficiency. So if you design a job to be more motivational, you often get a job where training is more difficult and the chance for errors/accidents has increased. Likewise, the mechanistic approach may have a negative relationship with job satisfaction. It is no surprise to me that the automobile industry has had serious employee relations problems through its history. The nature of the work, where a worker is tied to an assembly line performing the same actions repetitively, is a frustrating way to spend the work day.

Avoiding the negative effects possible in specific job design approaches requires trade-offs. We find that the primary job design trade-offs are the mental requirements of the job. If you design jobs to be more mentally demanding, in other words more motivating, you tend to achieve increased satisfaction and lower absenteeism. On the other hand, if you simplify jobs, that is, if you reduce mental ability requirements as in the mechanistic and perceptual/motor approaches, you tend to reduce training time, achieve high utilization levels, and produce low error rates. The basic trade-offs depend on one's underlying value structure. To obtain the positive advantages of two or more approaches to job design can be complex and certainly requires insight into the costs associated with each approach.

What I have heard concerning job design in aviation maintenance in the course of presentations at this meeting would lead me to believe that maintenance jobs are well designed in the motivational approach and have at least some positive attributes. There is variety and autonomy, with considerable skills usage. Probably the paperwork requirements reduce some of the motivating value of the job, however. The paperwork burden apparently serves to reduce job freedom and somewhat stifles feelings of achievement and autonomy. Mechanistically speaking, maintenance jobs probably are not well designed. They are not simplified jobs and my guess is that they are not highly repetitive, at least not in the short term. The information I have obtained here would lead me to believe that the aviation maintenance job has high training requirements, high skill requirements, is well paid, is usually satisfying and motivating, although sometimes frustrating. There is a good chance for errors and an inordinate paperwork burden to ensure that every step is documented and that errors can be caught.

What innovations can one consider with respect to job design? Probably the most common job design innovation is to make jobs more motivational. As I said earlier, the most popular approach to job design today is the engineering/mechanistic approach. The most common innovation in job design in the last 20 to 30 years has been to make these jobs more motivating. We call this job enrichment or job enlargement. When this is done, you generally achieve the benefits you expect such as increased motivation and satisfaction. You also incur a set of costs. You may have increased training requirements as well as higher skill requirements which make staffing more difficult and set higher compensation levels. I think we have seen some examples of this in the aviation maintenance industry. Daniel Desormiere mentioned that at Air Inter one person qualified for the entire aircraft. This is an innovative job design change which I would argue enhances the motivational value of the job by decreasing its mechanistic characteristics but which brings a predictable set of costs.

Recommendations and Challenges

The impact of job design within an industrial organization can be considerable and can represent a complex issue for management. However, the body of research dealing with the topic of job design does support a number of recommendations and conclusions, as follows:

1. Job design can be a source of potential improvement on many outcomes. Worker productivity, error rate, and worker satisfaction are three outcomes that come to mind most frequently. However, as noted earlier, there are many other outcomes.

2. Job design can be a source of many problems if its importance is unrecognized. Many cases of poor quality work or disenchanted workers can be traced to the design of the job rather than the capabilities of the worker.

3. An interdisciplinary perspective on job design is required to make optimal decisions. One may require expertise from the fields of engineering, psychology, human factors, ergonomics, and others, all at the same time to recognize potential cost decisions and to maximize potential pay-off of job design.

4. Potential design conflicts and trade-offs must be anticipated and identified. Although each of the different approaches to job design carry both benefits and costs, one can design jobs to realize the full measure of benefits without incurring significant costs.

5. Potential individual differences must be considered. Incumbents and other job experts should be involved. Some employees like more challenging work. Others like such work less. Some employees can tolerate repetitive work more than others. Some can tolerate physically demanding work more than others. In order to best structure the job for the potential population of workers, input from current job incumbents can be invaluable.

6. Experimentation and evaluation are necessary, including long-term evaluation. Although general rules prevail, each problem in job design has its own uniqueness. In order to ensure long-term success, a continuing program of evaluation is required.

Job Design for Work Teams

Current attention is shifting from issues of the individual worker and is focusing on work groups as a basic unit in manufacturing. The entire work team is considered a unit. Measures for enhancing team effectiveness are of concern. Research now centers on ways to design work teams to maximize effectiveness. Criteria for "what is an effective team?" usually are work productivity and employee satisfaction.

Dealing with the work team as a unit is an extremely popular workplace intervention at this time. Many industrial organizations are experimenting now in the use of work groups. In fact, manipulating work groups may be the number one innovation in terms of work design today.

The fact that work groups can be established and group goals defined does not mean that the group concept will work. Without proper definition and management, there can be many negative outcomes. Work groups can have low productivity norms or restrictions on how much work they intend to get done. Groups also can make poor decisions. In addition, group related work can result in conflicts among members and conflicts between groups. It is possible to develop work groups that produce more problems than benefits.

Current thinking on work group design is that it is basically a derivative of the motivational approach to job design. Thus, some conflicts may be created with the mechanistic approach. A well structured group may enhance employee satisfaction, which is a motivational outcome, yet still not achieve the desired efficiency in work. Much research needs to be conducted in order to develop rules to achieve the best of the motivational and mechanistic approaches.

Some recent research that I have been doing for the insurance industry is attempting to gain a better understanding of the dimensions of group that most affect work outcome. In this study, employees responsible for running an insurance company, not insurance agents, were divided into regional work teams. Eighty such work teams were formed. Through an extensive review of the research literature, some 19 dimensions for constructing group work teams were identified. We then measured outcomes presumed to be related to these design variables. The design dimensions then were validated against three measures of outcome, or effectiveness: productivity, employee satisfaction, and management judgments of effectiveness. Productivity measures then were separated into five productivity indices. An example would be a measure such as "insurance policies processed." Then, using the 19 design dimensions identified earlier, teams were ranked from top to bottom. It was found that productivity differences between the top one-third teams and the bottom one-third teams, as ranked in terms of design dimensions, were generally in the order of 20 percent. Teams assembled using better principles of team design showed, on certain productivity measures, a 20 percent improvement in performance.

With the above indication that good principles of work group design are effective in improving productivity, it is worthwhile to look more closely at these dimensions. The 19 design dimensions we worked with fall into six basic groups. These are (1) job design, (2) performance management, (3) reward systems, (4) selection and staffing, (5) training, and (6) employee relations. The following sections discuss briefly the variables included within each of these groups.

Job Design

The first, and possibly most important variable under job design is *self management.* By self management, we mean that a team should have considerable responsibility concerning its activities including such matters as making decisions about scheduling, about employee assignments, and even participating in the selection of new members. The responsibility of the manager is to provide resources necessary to make the team run. Another dimension here is that of *participation.* All members should participate. There should not be a pecking order within the group. Everyone shares and everyone is considered equal. Work also should be designed to provide *task variety.* There also should be *task significance* in which each member feels that his contribution is important. *Task identify* states that the team should be responsible for an entire piece of work. Work should not be separated among different teams. Finally, there should be *task interdependence.* Jobs should be designed so that employee interaction is required.

Performance Management

A basic tenet underlying performance management is that of *goal interdependence.* Teams should have a clearly defined mission and individual team members should feel that their individual goals and the group goals are consistent. Also, there should be *workload sharing.* While everyone needs to pull his own weight, there should be a mechanism to ensure an equitable distribution of workload.

Reward Systems

Team structure should provide for *interdependent feedback and rewards.* There should be a mechanism to identify individual performance as well as an individual's contribution to team performance. If the only output measure available is that of the total team, there is no way of defining objectively the contribution of specific individuals to team performance. In that case, some employees may not do their share of the work. If everyone's performance is assessed and related to team productivity, everyone then feels that they have a common responsibility and a common fate.

Selection and Staffing

Several considerations are important in the hiring of team employees. One is *membership heterogeneity*. There should be some diversity in terms of skills, with this diversity provided in such a manner that different skills complement one another. Everyone need not have the same skills, but the full team should provide the entire spectrum of skills needed to accomplish the variety of tasks presented to the team. In the matter of *group size,* a team should be just big enough to do the task, no larger. Teams that are too large tend to have many negative outcomes. Finally, employees should be hired who express a *preference for group work.* Some people prefer to work in groups and others do not. In particular, if one is attempting to establish self managing teams, employees are needed who are interested in the increased responsibilities accompanying team work.

Training

Technical training is of obvious importance for team members. However, *team training* also is quite important. There must be training concerning working as part of the team, participating in group decision making, developing interpersonal skills, and other facets of team cooperation. There also should be *job assignment flexibility*. Team members should be able to fill in for each other. Frequently it is desirable to have a formal program of job rotation and job switching to ensure that the necessary job flexibility exists.

Employee Relations

Many recommendations can be made with respect to employee relations. Obviously, anything that can be done to foster *team spirit* will make for a better team. Teams should have a "can do" attitude. There also should be *social support* and *managerial support* from the organization and from any other groups associated with the organization and its goals. *Communication* and *cooperation,* both within the work group and between work groups, is a given. One problem frequently encountered is that as one team becomes tighter, the more the world becomes "our team" vs. "your team." Such friction needs to be managed.

Conclusions

Developing clearly defined work teams within an industrial organization is a popular work innovation that should not be ignored. Unlike the traditional individual job design in which one can make jobs more motivating or more efficient but generally not both, design for team performance seems to have the potential for offering both. With proper design of teamwork, both the goals of productivity and employee satisfaction might be achieved. However, care in the design of work groups must be taken. It is possible to design such groups in a manner that leads to decreasing productivity and satisfaction. But the potential is such that I believe this work innovation should be pursued. Much can be learned and much can be accomplished through carefully conducted applications of work group design.

There is a final caveat. What works in one organization may not work precisely in the same manner in another organization. Each organization has its own differences which can affect success. However, the potential in well constructed group work teams is high. You should consider this approach quite carefully. Thank you.

MEASUREMENT OF WORKFORCE PRODUCTIVITY

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Workforce productivity is an important issue and a complex one, perhaps more complex than generally recognized. The term "productivity" can have many meanings and the concept itself can have many uses. Economists define productivity one way; psychologists another. Managers and engineers may have yet a third definition of productivity. One way to come to grips with this diversity is to recognize that the form of the productivity measure is the same, or should be the same, across disciplines but the content varies depending on one's discipline or point of view.

I would like to begin the discussion of productivity with the economist's view. In economic terms, productivity is an efficiency measure. Productivity is simply the ratio of output to input. The problem is determining the measures to be used for input and output, which is essentially a value judgement. What are you interested in? What is important to you and what kind of productivity do you want to measure? The point is there is no single productivity measure. There are lots of productivity measures.

Choice of a particular productivity measure depends on how you plan to use the measure. A productivity measure can be used for monitoring or controlling the workforce. It can also be used for planning purposes. For a maintenance organization, however, I would expect that productivity measures might be more useful as a basis for evaluating changes made in work procedures or in the work environment. Finally, productivity measures can be used for motivational purposes at the individual, group, or national level. For example, following World War II, Japan used comparisons of U.S. and Japanese productivity rates to stimulate greater productivity.

Now, let's take a look at some important characteristics of productivity measures. First, they vary in levels of aggregation. When designing productivity measures, it is essential to specify the level of aggregation of interest. For example, productivity measures at the national level are used for various kinds of Government planning, and to address national economic problems.

The next step down in the hierarchy of disaggregation brings us to the industry level. Here one can compare productivity across industries. An example might be a comparison of the transportation industry vs. the health industry. Such comparisons can be made within a nation or between different countries. For instance, rail transportation can be compared in different parts of the United States or a comparison can be made between train service in France and the United States.

Organizations also can be compared in terms of productivity. A popular comparison is Governmental organizations vs. private sector organizations. Then, we come to the kinds of productivity comparisons that are of greater concern to the audience -- group productivity measures, such as the performance of different maintenance groups; and individual measures, which describe productivity of specific individuals within the workforce. However, in practice, productivity measures typically are restricted to the group level and higher.

Another critical aspect of productivity measurement is the components included in the measure. The following two equations illustrate how the components can be altered to describe different types of productivity:

$$\text{Total Factor Productivity} = \frac{\text{products/services}}{\text{capital+labor+resources}}$$

$$\text{Partial Factor Productivity} = \frac{\text{products/services}}{\text{labor hours}}$$

Total productivity, as shown, compares the products and/or services delivered to the cost of capital plus labor plus resources. In particular, it is a reminder that total productivity is a function of more than the productivity of the labor force. For example, discussions at this meeting have described the development of focused repair centers, which presumably better utilize maintenance labor. Although labor productivity has improved, total productivity cannot be said to have improved until the capital costs of establishing such a repair center are taken into account.

The use of partial factor productivity measures, as shown above, represents an attempt to isolate the direct contribution of labor costs to productivity. Even with this simpler equation, however, the analysis of the causes and effects of labor productivity can be less than straightforward. For instance, a change in job design might result in improved labor productivity. The improvement could be due to the motivation resulting from enriched jobs, or be a direct result of more efficient design of the task itself. In either case, labor productivity increases may not be mirrored by total factor productivity if capital investment is required.

When using productivity measures, it is important to recognize that such measures are comparative rather than absolute. There is no absolute measure for productivity. As a comparative measure, however, productivity can be quite useful. In maintenance, productivity measures can be used to compare the output of a work unit before and after some change is made. Does the change affect important productivity measures? Another use is to make comparisons with the competition. If your productivity is up ten percent, you might consider this to be quite good. If you discover the productivity of the competition is up 30 percent, the 10 percent improvement takes on a different meaning. Productivity measures can be very useful in tracking organizational performance over significant periods of time.

Another important distinction in productivity measurement is that of efficiency vs. effectiveness. Efficiency is output over input. In the maintenance environment, the proposal for changing to an electronic system for handling paperwork should improve efficiency, at least labor efficiency. Effectiveness describes the extent to which an organization or unit is actually reaching its goals. In the automobile industry at this time, there are manufacturers who are very efficient at making cars but have trouble selling them. Their efficiency is high but their effectiveness index is considerably lower. An organization can be very efficient, but still not be effective in terms of achieving the goals of the organization. Obviously, one would like to be both efficient and effective. In the real world, fortunately, these measures usually are related, although the correlation certainly is not perfect. But both concepts are important, and it is dangerous to muddle the distinction between them.

With that, we conclude our brief overview of how the economists approach productivity measurement. Psychologists deal with productivity somewhat differently. In a recent article (Guzzo, 1988) which reviewed a broad range of psychological research on productivity, three general categories of productivity measurement were found. The first is output, which is simply the number of items produced or, for a maintenance crew, the number of airplanes serviced. In either case, there is a tangible output, which is the numerator of the productivity ratio.

A second productivity measure that has received a fair amount of attention is withdrawal, which refers to personnel turnover, absences, and tardiness. Withdrawal measure influence primarily costs, or the denominator of the productivity ratio. Many withdrawal events, even a simple one such as an internal transfer, result in costs for the organization and affect the productivity equation.

The third measure of productivity is "disruption," a measure rarely used but one which can be quite sensitive, particularly in certain industries. Included here are accidents, sabotage, and other non-predictable events which have considerable impact on productivity. This is a measure that is difficult to take into account in organizational planning.

Most of the psychological research on productivity has been done with individuals. While there is growing attention to team performance, the bulk of the information available deals with individual productivity. In such studies, using the productivity measures just described, researchers have found that psychological interventions of various types can lead to significant improvements in productivity, .

In planning research into productivity, a key decision is the determination of which job components to include in the productivity measure. Then, the components need to be weighted or scaled in terms of importance, which may require research into the relative importance of components.

A study by Pritchard and others (1989), investigated the performance of U.S. Air Force maintenance crews and attempted to assess the effect of three intervention procedures on crew productivity. The three interventions were (1) group-based feedback, (2) goal setting, and (3) incentives. Performance was measured at the group level, since the research team concluded that the maintenance task was so complex that it could not be measured well at the individual level.

Pritchard and his associates decided to use effectiveness, rather than efficiency, as the measure of productivity. Thus, the performance measures were directed toward the needs and goals of the organization rather than individual efficiency rates.

The maintenance crews, with the aid of the research team, identified the products they desired as team output and the type of indicators to use as measures of output. They then developed "contingencies" for each of these products, such as the criticality of the percent return rate for repaired items to effectiveness of this organization. The organization itself also translated percent return rate into an organizational effectiveness measure. Data from these judgments are presented in

Figure 1, which shows that judged effectiveness is not a linear function of the percent of return rate. Changes in percent return rate were judged to be more critical in the 6 - 14 percent range.

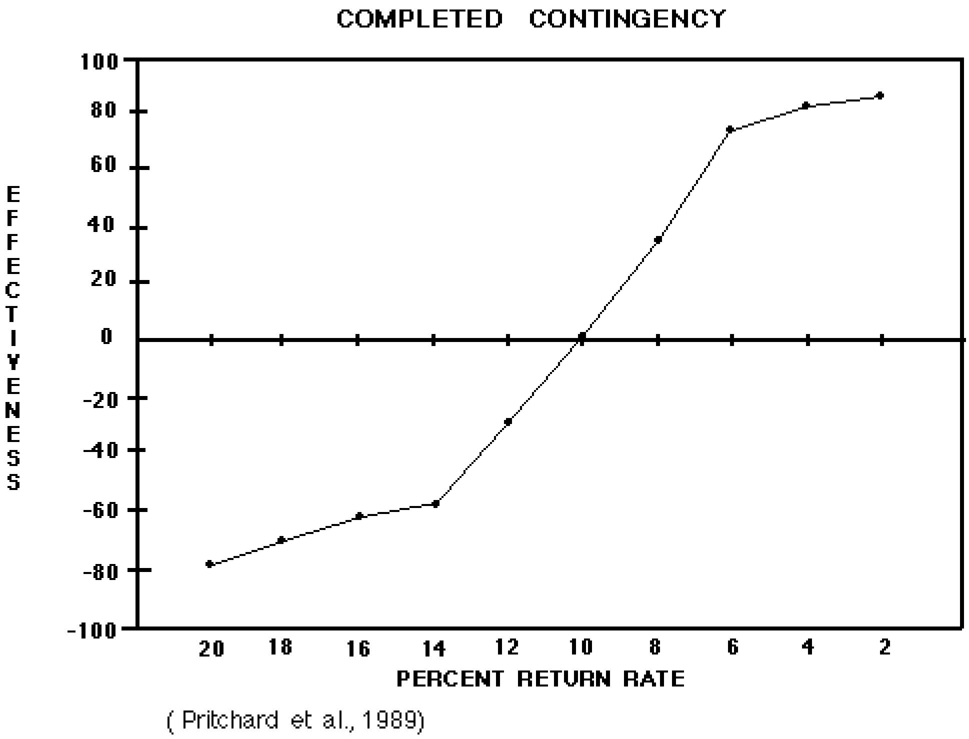
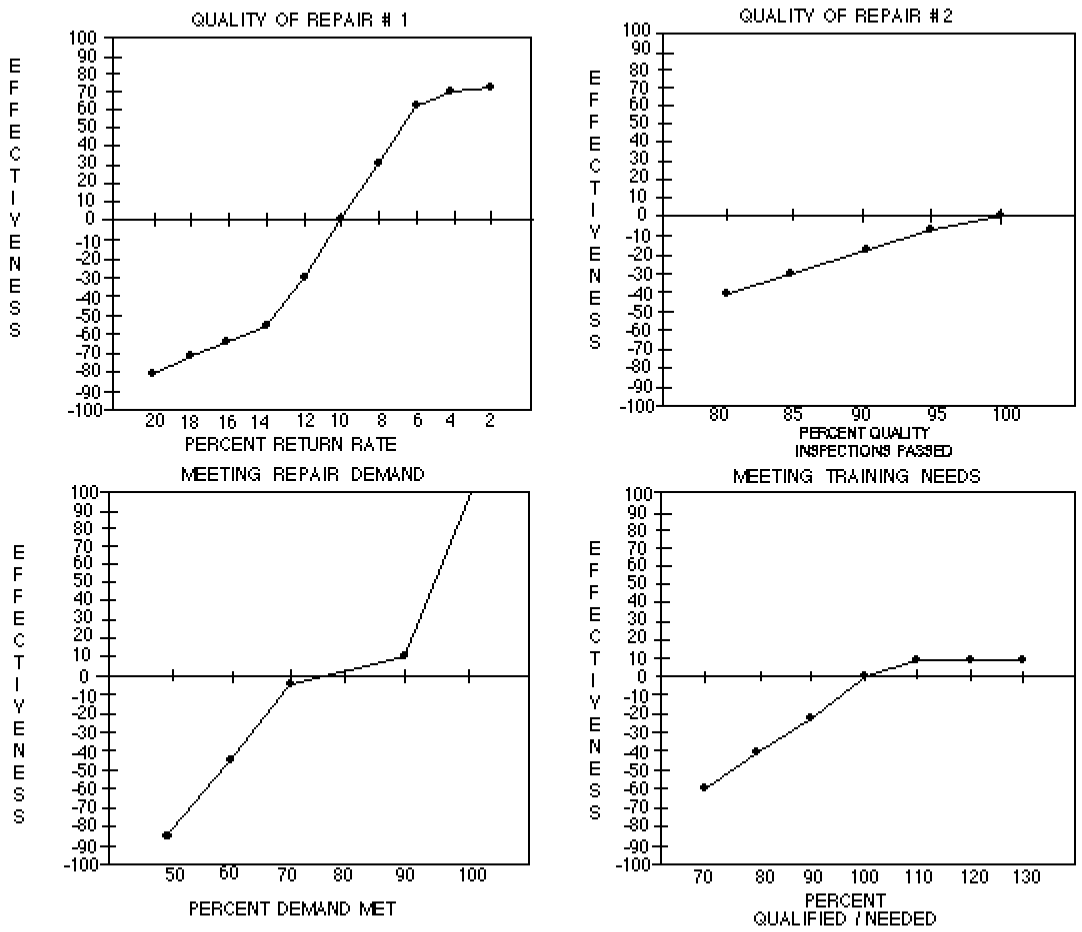


Figure 1

Figures 2 through 5 illustrate the impact of performance on effectiveness for various components of productivity. For instance, Figure 3 indicates that *quality inspections passed* produced a linear function, but is not one of the stronger contributors to effectiveness. On the other hand, the data in Figure 4 show that *percent repair demand met* makes a greater contribution to effectiveness, and the relationship is not linear.



Figures 2-5

The objective of this work was to develop a composite score for group effectiveness that reflected the organization's judgment of the importance of each of these components, and provide a means for summing across the components that took non-linearity into account. Granted, this was not a simple process, but it did represent an attempt to focus attention on the components of the maintenance jobs that were seen as most critical for organizational effectiveness.

Now I would like to describe some of the results obtained from this study of the effects of three interventions on the effectiveness of Air Force maintenance crews. Figure 6 shows the impact of the interventions over a number of months. The first part of the curve is the baseline period and shows the effectiveness of the group before implementation of any changes. The first change, made at month nine, was the introduction of performance feedback. Employees were given feedback information concerning their performance on critical components of the job, such as those shown in Figures 2-5 As you can see, this feedback resulted in a striking improvement in overall effectiveness. At about the 15th month, goal setting was introduced. This produced a small improvement. Finally, incentives were introduced. Incentives, at this stage of the study, had little impact on effectiveness.

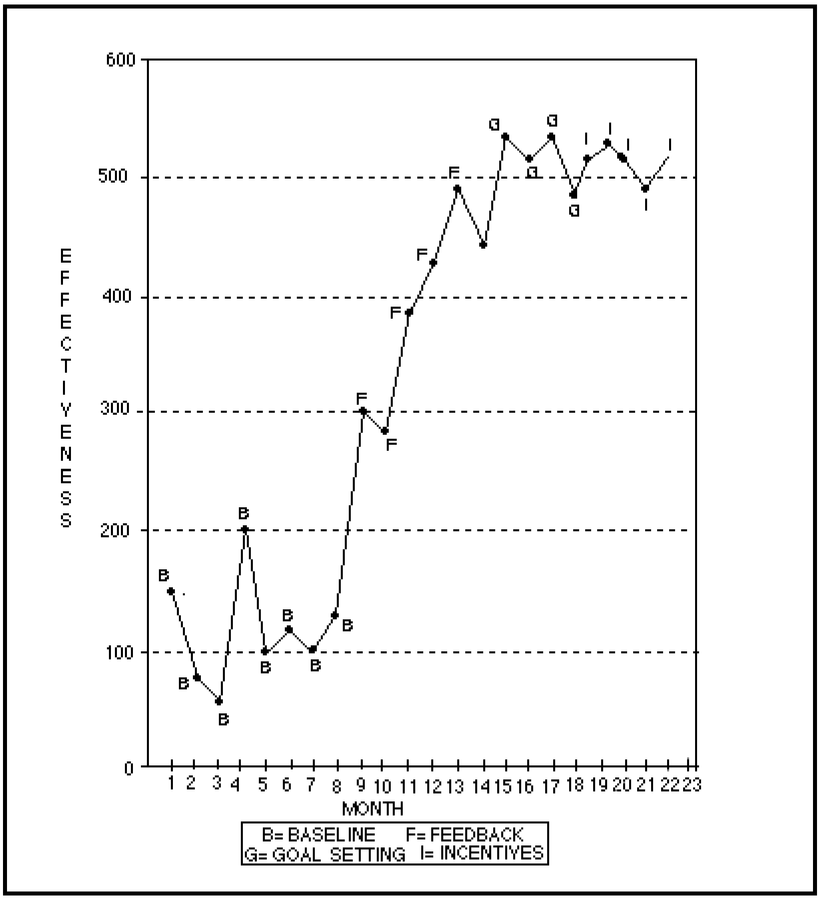


Figure 6 Productivity of all five sections combined

The results shown in Figure 6 demonstrate that psychological interventions can be quite useful and important in producing changes in group effectiveness. What one cannot conclude, however, is that incentives do not work, since the study did not use a balanced design. Had incentives been introduced first, they likely would have resulted in a sizable performance increase. In any event, the results of this study are generally consistent with the findings in the psychological literature that performance feedback is one of the most potent interventions available for increasing productivity.

Many studies have shown that psychological interventions of various kinds can lead to performance improvement. Table 1 presents the results of a review (Katzell & Guzzo, 1983) of a number of studies using the three classes of productivity measurement described earlier. For each type of productivity measure, a large percentage of the studies showed that psychological interventions led to productivity improvements. Undoubtedly, there is bias in these results, as positive findings are more likely to be reported. However, the results do offer strong evidence that psychological interventions can make a difference.

Table 1

Variations in Program Effects

3 TYPES OF CRITERIA	% OF MEASURES	% SHOWING IMPROVEMENT
Output	57	86
Withdrawal	34	75
Disruption	9	77

Source: Katzell & Guzzo, 1983

What are these interventions? Table 2 lists 11 interventions, or changes, that one might introduce in an organization to improve productivity. This listing is based on a review of studies published during a ten-year period (Guzzo, 1988). The interventions are quite varied, ranging from selection of personnel to organizational development.

Table 2

Eleven Types of Intervention

Realistic Previews
Selection
Training
Goal Setting
Management by Objectives
Financial Incentives
Feedback
Participation
Work Rescheduling
Work Redesign
Organizational Development

The interventions listed also vary in terms of robustness or effectiveness. Table 3 presents a summary of the review findings for each intervention in terms of measured positive effect on productivity. Some interventions have robust effects on productivity; for others the results vary and depend on the way the intervention is implemented. A third group yields either uncertain or negligible improvement. Again, we see that interventions such as performance feedback, specialized training, and employee selection, among others, can produce significant improvement in productivity.

Table 3

Summery of Review Findings

Effects on Productivity

ROBUST	DEPENDS ON HOW IMPLEMENTED	NEGLIGIBLE OR UNCERTAIN
Feedback	Realistic previews	MBO (Negligible)
Training	Financial incentives	Participation (Unclear)
Selection	Work rescheduling	OD (Unclear)
Goal Setting		
Work Redesign		

Source: Guzzo, 1988

Financial incentives are frequently included in productivity improvement efforts. This review found that some studies showed dramatic and positive results, while other study findings were negative. These results suggest that financial incentives offer opportunities for improvement but care must be taken in implementing them.

And now, to quickly sum up. There is no one productivity measure. Productivity has many meanings, and there are multiple paths to productivity improvement. Productivity measurement itself is a vital part of productivity improvement efforts, and the choice of measure should be suited to one's purpose. Feedback of performance results, as illustrated by the study of maintenance crews, can have powerful effects. The reviews of psychological research studies provide strong confirmation that a variety of psychological interventions can influence components of the efficiency ratio. Productivity measurement is a complex matter, not to be entered lightly, but the multiple paths to productivity improvement offer opportunities that should not be ignored.

Thank you for your attention.

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LEGISLATIVE TRENDS

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Guessing what Congress will actually do is like predicting what a two-year old will do during any thirty minutes. Certain things are predictable if a close time table is not included. We know that a two-year old will, in any twenty-four hours, eat, sleep, be happy, be cantankerous and soil its pants. In any twelve months Congress will meet, hold hearings, authorize spending in excess of revenue, raise money for reelection, hold hearings, court the press, hold hearings, go on a tax paid fact finding tour, hold hearings, go home to schmooze the voters, hold hearings, pass politically motivated laws and hold hearings. Paying very close attention to the hearings might indicate a legislative trend. A legislative axiom is that once the majority party introduces a bill, chances are good that some version of it will be passed; if not in the current session, in a later one. Washington, DC watchers know that even defeat of a bill will not lay it to rest. Like the Phoenix, legislation rises from its ashes to take on new life with increased vigor.

When watching Washington the eyes must not become fixed on Capitol Hill. The Departments, with their innumerable Agencies, are empowered to regulate and enforce. For health and safety the Departments of Labor (DOL), Health and Human Services (HHS), Transportation (DOT) and Energy (DOE) are important, along with independent agencies such as the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), the Consumer Products Safety Commission (CPSC) and the National Institutes of Health (NIH).

A discussion of legislation must start with Congress. When thinking of occupational health and safety the OSHAct is a good beginning. The Act is now more than twenty years old and has become a much more positive force than most would have predicted. The statistics that I will recite are not solely because of OSHA activity, but I am convinced that the Agency has been influential in improving safety on the job. Another word about the statistics. They are from the National Safety Council, not OSHA. For 1970, the year the OSHAct was passed and signed by President Nixon, the National Safety Council reported 10,100 occupational fatalities. In 1988 there were 6,000. An impressive reduction. That is not the complete story. In 1970 there were 77,700,000 people gainfully employed in the United States. In 1988 there were 114,000,000. Just prior to the formation of OSHA there was one fatality for each 6,000 people at work. In 1988 the rate of fatalities had fallen to one for each 19,000 workers. This is even more impressive. Safety on the job had been improving for decades before OSHA and has continued to improve since OSHA and at an even more brisk pace. While OSHA cannot claim all of the credit, we can agree that it has called attention to health and safety in the work place. The improvement has been significant, but conditions are not satisfactory.

For many reasons, several members of the U.S. House of Representatives have decided that because conditions are not satisfactory, Congress must fix OSHA. The Congressional fixers are not in agreement about exactly what needs to be fixed. Investigations have confirmed that injuries, illnesses and deaths continue to occur among the 120,000,000 workers in the 6,000,000 work places. By a leap of logic these incidents are the fault of OSHA and therefore Congressional action is necessary.

Even though the OSHAct is a labor bill, it has been a serious disappoint- ment to organized labor. Union leadership in Washington has been frustrated because OSHA, with 2500 employees and $300,000,000, has never been its pawn. OSHA has become increasingly professional, listening to all, but refusing to be dictated to by anyone. What the unions have been unable to get through OSHA regulation they have tried to get via Congressional action. Consequently in almost every session of Congress since the bill was passed, there have been bills introduced to correct some defect. Fortunately wiser heads prevail and until last year no changes were legislated. Last year Congress raised the penalty levels for both civil and criminal violations. Budget riders have been used to exclude employers with fewer than ten employees from scheduled OSHA inspections. Also, most farms are exempt, as are employees of Congress.

Don't relax. The current session of Congress has its share of bills for consideration. The two most important are the Construction OSHA bill and the Right to Act bill. The construction industry safety record is poor. For the past decade OSHA has directed about 50 percent of its resources to construction. Injuries and catastrophes continue to occur. OSHA has made administrative changes that hopefully will do a better job. The Congressional solution is to form a Construction OSHA similar to the Mine Safety and Health Administration. How this will change conditions in the construction industry is not clear; however, it is clear that more money will be spent, more inspections made with bigger penalties proposed along with criminal prosecutions by the Department of Justice. It can be argued that since OSHA brought more attention to general industry maybe a Construction OSHA will do the same for this segment of employees and employers. The logic can be extended to cover the petro-chemical, pharmaceutical, aerospace or any other industry group. This supports a basic misconception as to why a work place is either safe or not. Regulations, inspections and enforcement by Governmental agencies, are not what makes a place of employment safe or unsafe. The Government is not the responsible party, it is the employer. A work place will be safe only when management and workers decide that safety is as important as production, quality and cost. Government agencies can call attention and can inspect a small percentage of the work places for compliance with a few regulations and issue citations with proposed penalties, but successful progress in safety requires voluntary effort with a desire for excellence.

The unions are pushing very hard for a "Right to Act" law. Very simply, the "Right to Act" law will authorize employees (read unions) to stop an operation when in their eyes it is unsafe. When considering the right to shut down operations it must be remembered that good business practice and the Occupational Safety and Health Act make the employer responsible for conditions in the work place. The employer is the one cited and penalized for violations, not the employee. Employees can and have blatantly violated regulations in the presence of compliance officers, to cause the employer to be cited and penalized. If employees want to have the authority to shut down operations they must also be willing to suffer penalties for wrongful action. The State of Minnesota has a "Right to Act" law with provision for disciplinary action, including firing, for unwarranted action. It appears to be a satisfactory law.

Some members of Congress seem to believe that most employers intentionally harm employees and therefore should be treated as criminals. Congressional actions in the past support this concept. The revisions to the Occupational Safety and Health Act made last year and provisions in the recent Environmental Protection Agency statutes have included severe criminal penalties.

Agency regulatory actions reflect the pressures applied to administrators by constituent groups. A review of the annual regulatory agenda of OSHA will reveal current and past pressures along with what the Agency wants to do. Some of the items on the agenda have been there for years, for example the OSHA cancer policy. In the late 1970's there was pressure for OSHA to adopt a cancer policy. This proved to be a very controversial question that has been pushed to the back burner, hopefully to be forgotten. If it were to be removed from the regulatory agenda it would attract the attention of someone and questions would be asked. A regulation of a chemical, such as cadmium, may be under active consideration but still take many years to promulgate. Cadmium 1,3, butadiene and 4,4'methylenedianiline are under active consideration, but are not on a fast track. OSHA is spending resources on seat belt and smoking regulations along with harmonization of the Hazard Communication Standard with the European Economic Community regulators' thinking.

Criminal prosecution changes enacted by Congress have created some serious problems for OSHA. The current administration has declared that enforcement will be in accordance with the law but that OSHA does not intend to use the "big stick" in every compliance inspection.

The Environmental Protection Agency (EPA) picture is also a mixture of Congressional action, regulatory activity by EPA, and an enforcement strategy complicated by environmental action in the various states. The important laws currently before Congress are the reauthorization of the Clean Water Act and the Resource Conservation and Recovery Act. This is the first year that Congress must consider the reauthorization of the Clean Water Act. This has some controversial aspects that have resulted in debate in and out of Congress. Beltway wisdom says that Congress will not act on reauthorization this session. This does not mean the demise of the Clean Water authority for EPA. The budget for next year will continue to fund Clean Water while Congress ponders what the reauthorization should include. Almost everyone is affected by the Clean Water Act and the details are so numerous, it behooves any and all who have a concern to make certain that their message gets to the staff of the members of Congress who are on the appropriate committees.

The Resources Conservation and Recovery Act (RCRA), is also up for reauthorization and action is not likely this session. Remember that RCRA deals with the transport and disposal of hazardous and solid wastes. It is not expected that Congressional action, when it occurs, will change much in this Act.

Legislative consideration of environmental laws and regulations must include what is going on in the fifty states. Keeping up with these is a major task. Because of the complexity, a number of newsletters and services are available to help those concerned stay apprised of the events and activities. Court decisions must also be followed. As an example, a U.S. Court of Appeals ruling recently declared unconstitutional an Alabama law that prohibited transport of waste from certain states into Alabama. The case has been appealed to the U.S. Supreme Court. In the meantime Alabama cannot prevent transport of hazardous waste into the state. Chemical Waste Management and its customers are probably happy, temporarily.

The direction legislation and enforcement has taken in the past few years has made environmental professionals nervous to the point of changing careers. The laws and regulations are numerous, complex and carry criminal provisions. Compliance to avoid prosecution has become a primary motivation. Plant managers and environmental professionals can go to jail. It has happened. At the Aberdeen Proving Grounds two mid-level military officers were convicted of improper storage and disposal of hazardous waste. The defendants knew that the actions were improper and were to avoid EPA regulations. Their defense was that they thought the military was exempt. It is not. Excellence in pollution prevention is beyond the pale for many. Line managers who may not be closely attuned to environmental protection may want nothing more than minimal compliance.

Minimal compliance is not good environmental protection or good occupational health and safety policy for the individual plant or the country. The OSHA Voluntary Program, a plan to recognize excellence, has demonstrated that excellence in occupational health and safety achieves:

1. reduced incidents of illness and injury
2. decreased absenteeism
3. lower compensation and health care costs
4. better morale
5. increased production
6. improved quality
7. elimination of scheduled OSHA inspections
8. augmented profits.

Excellence in occupational health and safety does not require OSHA nor does excellence in environmental concerns require EPA. However, EPA and OSHA will continue to exist. Both have regulations that encourage end-of-pipe solutions. Professionals have always been concerned with regulatory compliance coupled with a drive to achieve pollution prevention and a safe work place. This is a desire for excellence beyond compliance, while the Government continues to emphasize end-of-pipe solutions with heavy penalties for out-of-compliance details. Frustration results. Frustration for safety, health and environmental professionals, and particularly for the latter. Frustration for line managers because environmental details obscure environmental policy. Frustration for regulators and enforcers because there is no (or there appears to be no) spirit of cooperation in trying to achieve the admirable goals of protecting the environment.

The Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA) are about the same age. Perhaps because OSHA never had any friends it was forced to grow up and act in a responsible manner and develop a rapport with employers across the country. The Agency is far from perfect but much progress has been made. It may not be loved, but it is respected as it goes into its twenty-first year.

My impression of EPA is that it remains, at best, an obnoxious, rebellious teenager who has always gotten its way and is not about to change its conduct now. Its parent, Congress, grants its whims and encourages a hostile attitude toward business and the public. Consequently there is a continual confrontational situation made worse by numerous, complex, detail-ridden laws and regulations under a cloud of criminal prosecution.

The topic was "trends in legislation." In summary, Congress wants to fix OSHA by amending the Act. This is not new but the unions are pushing hard for more influence in how businesses are run. They want a Right to Act provision, meaning the right to declare a process unsafe and shut it down. They would like to see a Construction OSHA and no doubt in the future other industry specific OSHAs. The prospects for any of these getting out of the House is remote and the Senate will not act prior to the House. Nothing this session.

It does not appear that Congress will reauthorize either the Clean Water Act or the Resource Conservation and Recovery Act; however, both will continue to exist through a budget provision.

On the regulatory side nothing new should come from OSHA this calendar year. "New" means something that was not in process four years ago. The new initiatives in OSHA are seat belts and smoking, neither of which have strong supporters other than the former Secretary of Labor, possibly because neither is fundamentally an occupational health or safety issue. Neither is enforceable against the violator. There are seat belt laws in almost all states and in many cities that apply to all drivers. OSHA does not need to try to augment these. If there is a need for seat belt protection for fork lift trucks or other industrial vehicles then that should be addressed, not the salesmen driving cars.

Washington watching is important to assure that our elected officials and civil servants act in our best interest which is the best interest of the country. We want a safe place to work and an environment that is healthful, enjoyable and wholesome. We cannot have either that is risk free. We must make sure that our knowledge and wisdom are incorporated into the laws and regulations. I'll see you in Washington. Thank you.

STANDARDS/REGULATIONS AFFECTING AIR CARRIER OPERATIONS

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The Occupational Safety and Health Administration (OSHA) always accepts opportunities to address groups, such as this, where the group members are sincerely interested in what they can do to provide a safer and more healthful workplace. The topic of safety and health in the workplace is broad and warrants extensive discussion. Therefore, to structure my presentation I was asked to address four specific topics of interest. These are:

1. OSHA activities in hazard communication as they deal with aviation maintenance employees.
2. OSHA guidelines concerning issues in ergonomics or human factors engineering.
3. Current thinking by OSHA for future regulatory activities, i.e., standards that might be in the wings.
4. Information concerning different avenues of assistance available to you from OSHA, i.e., publications and other means of providing information and assistance.

Before I discuss the above topics, I would like to review briefly the matter of FAA vs. OSHA jurisdiction. The Federal Aviation Administration, in short summary, is responsible for aviation safety. The Occupational Safety and Health Administration is responsible for ensuring a safe and healthful working place for men and women working in the United States. One paragraph in the OSHA Act says that, to the extent that another Federal agency has not exercised statutory authority to regulate safety and health, OSHA's regulations will apply. This section of the Act also requires

OSHA to work with other Federal agencies to ensure that there is no overlap of jurisdiction. To this end, we work with many agencies, including the FAA. However, there always are overlaps or possibilities for overlaps in safety and health jurisdiction.

A case involving Northwest Airlines was adjudicated before the OSHA Review Commission in the late 1970's. In this case, it was determined that if there is a reference to safety or health in an aircraft/airline maintenance manual that deals with a certain situation, then FAA has exercised its statutory authority and OSHA would be pre-empted for jurisdiction.

How does OSHA deal with the aircraft maintenance industry? To the best of my knowledge, OSHA has only made inspections within the aircraft maintenance industry when there has been a fatality of an employee, in which case we are mandated by regulations to make an investigation, or when we have received a complaint from an employee or an employee representative. We do not make general scheduled inspections in air carrier maintenance operations whereas in other industries, such as manufacturing or construction, we will conduct targeted OSHA inspections.

Now for our first principal topic, that of hazard communication. The OSHA Hazard Communication Standard requires that manufacturers and vendors of chemicals provide certain information to users principally through material safety data sheets (MSDS) sent with each initial shipment. The MSDS tells how we can safety handle the chemical and store it as well as the particular hazards to employees. Each employer, the end user of a particular chemical or substance, is required to have material safety data sheets available to employees. The employer is required to have labels on stationary containers so that employees can readily identify the substances with which they are working. The employer also is required to have a written Hazard Communication Program, a part of which will be training for his/her employees.

The Hazard Communication Standard is considered by many to be the single most pervasive regulation in OSHA's history. Although there are certain exceptions, such as pesticides regulated by the Environmental Protection Agency (EPA), drugs regulated by the Food and Drug Administration (FDA), distilled spirits, etc., most chemicals fall under this regulation. In the air carrier maintenance area, the Hazard Communication Standard says that you have an obligation to assure that your employees are aware of the hazards of chemicals they are handling. You also are required to train your employees in this regard. However, to the extent that aircraft maintenance manuals required by the FAA deal with these topics, then there may be an FAA jurisdiction. It is my understanding, though, that FAA has considered adopting some or even all of the OSHA safety and health standards for certain segments of the industry which it regulates but, thus far, has not done so. Therefore, it would seem that hazard communication for maintenance employees is regulated by the OSHA standard.

The second topic for today concerns ergonomics. A matter of recent concern in ergonomics has been the cumulative trauma disorders, or CTDs, found in certain industries. Cumulative trauma disorders are defined as health problems arising from repeated biomechanical stress due to ergonomic hazards. Terms such as repetitive motion injuries, occupational overuse syndrome, and repetitive strain injuries are essentially synonymous. CTDs are a class of musculoskeletal disorders involving damage to the tendons, tendon sheaths, synovial lubrication of the tendon sheaths and related bones, muscles and nerves of the hands, wrists, arms, shoulders, back, neck, etc. A frequently occurring occupationally-induced disorder in this class is carpal tunnel syndrome, or CTS. This problem has been occurring in the workplace for years and was noted as early as the 1920's in Manhattan clothing manufacturing facilities where women worked in sewing operations using repetitive motions for many hours. In many instances, these women developed numbness in their hands and in their wrists. This was the forerunner of what we today call carpal tunnel syndrome.

The aviation industry has been concerned with ergonomics, or human factors engineering, since the 1940's and early 1950's, when the industry began to design aircraft with a greater concern for human factors issues in the flying of aircraft. Dials, controls, and switches were made more easily reachable and viewable by the pilot. While the focus in ergonomics in aviation traditionally has been on the flight crew rather than on the maintenance team, the topic itself is not new.

The Occupational Safety and Health Administration has been dealing in the arena of ergonomics for only about the last six or seven years. The impetus, of course, was the considerable number of occupational illnesses or injuries noted. Since OSHA found little management attention being given to this problem in many instances, it felt strong enforcement action was necessary and issued several citations and penalties of high dollar value where significant employer negligence was indicated. OSHA was attempting to force management to recognize the criticality of human factors or ergonomics and the need for these disciplines to be used to ensure that proper workplace safety is considered in the design of operations, work stations and of work facilities.

Ergonomic issues are important in aviation maintenance. Many maintenance activities deal with repetitive motion. They involve lifting, repetitive movement of the upper torso, etc. Over a period of time, this can produce unfortunate injuries.

For those concerned with human factors issues in maintenance, I would suggest that you request from your local OSHA office an OSHA booklet entitled *Ergonomics Program Management Guidelines for Meat Packing Plants* (OSHA 3123). While this booklet was prepared for the meat packing industry, I would estimate that 80 percent of its guidance would apply to any manufacturer, maintenance operator, or anyone else dealing with repetitive motion or back injury problems. This booklet offers excellent guidelines. It also stresses commitment by top management, a very important issue, development of a written ergonomic program, and employee involvement.

Employee involvement in an ergonomics program is quite important. Your employees may well be the first to tell you of the ergonomics problems in the workplace. Another source of information concerning ergonomic hazards is through workplace injury and illness records. Workmens' compensation claims, first reports of injury, and other data you collect may show that in your operation you are experiencing the same problems found in manufacturing firms, that is, approximately 50 percent of all lost work day illnesses are resulting from cumulative trauma disorders. If this is the case, a checklist should be used to go through certain operations that might be causing these problems. An ergonomic expert can be used to review these repetitive motions and identify the problems that exist. In all likelihood, these will be a result of bad body mechanics such as continued bending at the waist, continued lifting below the knuckles or over the shoulders, and twisting at the waist. Lifting or moving objects of excessive weight also can cause serious back problems. Finally, prolonged sitting at any task should be looked at carefully. This is particularly true if the sitting involves poor posture and repetitive motions. With such jobs, regular rest periods are a necessity. All of this, of course, is dealt with in the OSHA booklet that I just recommended.

Our next topic concerns OSHA's thinking about future safety and health standards. In recent years, a public debate has been going on as to whether OSHA standards should be specification based or performance based. Many OSHA standards currently under 29 CFR 1910 are specification based. They specify exactly how certain machinery and equipment should be guarded or exactly how electrical machinery should be grounded.

Performance-based standards describe the end objective of what level or type of safety or health is to be achieved and provide only general guidelines as to how to achieve that objective. Exactly how an employer achieves that end goal is left to him. We think this flexibility is desirable in many instances.

Since OSHA is considering, and I emphasize "considering," a standard to deal with ergonomic hazards, I would suggest that a performance-based standard would be one we would consider. When you look at the variety of tasks that pose ergonomic hazards, one can understand that it would be nearly impossible for OSHA to specify exactly how all equipment and materials should be handled, lifted, etc. So, with ergonomic problems, OSHA might propose a performance-based standard.

Now I would like to note a few standards OSHA currently is considering. Of interest to you and aircraft maintenance operations in fixed locations, OSHA is reviewing walking and working surface standards. Standards dealing with these issues have been in place since 1971, but many of the stairway, work surface, and access standards are changing. The American National Standards Institute (ANSI) and other organizations have advanced new standards for industry and OSHA is considering these.

OSHA also is reviewing personal fall protection standards, an issue of interest to aviation maintenance since much of the exterior work on aircraft such as the Boeing 747 or other large aircraft is carried on at considerable height. The new standards might well affect the kind of protection required for employees performing such work. Of course, as we at OSHA look at advancing or redefining these standards, we need to consider your comments and, to the extent that you have opportunities to comment, I certainly suggest that you do so.

Another standard under review by OSHA pertains to use of personal protective equipment. OSHA standards concerning use of hard hats, safety glasses, safety shoes, and many other protective devices have changed little since 1971. We are considering modifications to these standards and are working more closely with those organizations which deal directly with personal protection issues.

Entry into confined spaces is a matter of concern and we hope to have a standard on this topic in the near future. We in OSHA have seen too many men and women die from entry into confined spaces with toxic or oxygen-deficient atmospheres. In many cases the death was a result not only of the lack of a safe breathing apparatus, but of inadequate rescue procedures being put in place by the employer.

Other proposed standards now under consideration deal with vehicles and vehicle safety. The training of industrial truck operators is one. To date, OSHA standards have simply said that such operators must be trained without providing any specifics concerning the training or performance goals. Another standard under consideration deals with operation of off road vehicles or highway vehicles not otherwise regulated by the Department of Transportation. To the extent that Federal agencies such as the FAA do not pre-empt OSHA jurisdiction, a future OSHA standard might require employees to wear seatbelts at all times and to receive driver training for operation of all vehicles.

One of the more controversial standards under consideration at this time is a "no smoking" policy for the workplace. OSHA is considering EPA and CDC studies on smoking that show that passive smoking can cause cancer under typical workplace environments, and the agency may deal with the problem via standard promulgation.

We also are studying the subject of blood borne infectious diseases. Subject to Office of Management and Budget (OMB) approval, OSHA may well promulgate a standard on blood borne hazards. This will not be restricted to the medical community. Many workers in American industry are exposed to blood borne pathogens, such as the hepatitis B and AIDS viruses, and a future OSHA standard may deal with such exposures. (As of December 6, 1991 such an OSHA standard was published in the *Federal Register*).

On the topic of toxic substances, I should note OSHA's involvement with methods of compliance. OSHA has had a hierarchy of compliance methodology for exposure to toxic substances for years. Traditionally, OSHA has considered the most desirable approach being one of "engineering-out" the toxic substance from the work environment. In other words, confine the toxic substance away from employees. Next, in terms of favored approach, is to control the exposure administratively. If toxic substances cannot be kept apart from employees, then exposure still might be controlled simply by rotating employees in and out of an exposure area through the work day so that they would have less than a full day's exposure. The least desirable approach, at least from a long-term view, has been use of personal protective equipment such as respirators. All employees will tell you that full time respirator usage is not pleasant, but may be the only practical means of protection.

Another matter under current consideration is that of medical surveillance programs for employees. In the event of exposure to any number of the hundreds of substances that OSHA regulates, how do employers determine if employees are suffering serious physical harm from such exposures? OSHA is considering a regulation that would specify, for most or all of these substances, the procedures whereby an employer would assess or monitor employees' health.

As new regulations and standards come into being, one should consider the impact of non compliance. In November of 1990, Congress amended the Occupational Safety and Health Act to enhance penalties for violations of standards. While this action was not requested by OSHA, it is nonetheless a fact of life and we must live with it.

OSHA penalties had not been modified by Congressional action since the Act was promulgated in 1970. Between 1970 and 1990, U. S. inflation probably had taken a threefold increase. Congress felt therefore that penalties needed to be raised. OSHA penalties for violations now have been increased, or at least the maximums have been increased, by sevenfold. Serious violations of the OSHA Act, previously at a maximum of $1,000 per violation, now are at $7,000. Repeated and willful violations, previously at $10,000 maximum per occurrence are now at $70,000 maximum per occurrence. Maximum failure to abate penalties, that is, where an employer fails to abate a citation for a number of days beyond the prescribed date of the citation, carry a daily penalty increase from $1,000 per day previously, to $7,000 per day. While these new penalties are not something we brag about, they are there and we want employers to be aware of the existence of these new civil penalties.

Our final topic covers the types of services OSHA can provide to interested employers. OSHA has about 80 area offices nationwide including, I believe, one in most of the capital cities of the 50 states. Any employer should feel free to contact any one of these offices where personnel will be glad to help you and provide whatever information they can. You also can visit the office and review documents that might pertain to your operations. Some of these are available on a one copy per person basis. Please avail yourself of these services.

I would also suggest that you obtain a copy of a document published in the *Federal Register* on January 26, 1989, entitled *Safety and Health Program Management Guidelines.* This document provides a good summary of how to implement a safety and health program. If you have any concerns about your safety and health program management, I would suggest that you obtain a copy of these guidelines. I would also suggest that, to the extent feasible, you remain abreast of possible changes to the OSHA statute that might occur and provide input to Congress regarding these changes as you feel appropriate. We, like Congress, want to hear from you. If there is strong enough input concerning the effect of new and proposed standards, OSHA must be responsive to this input.

Employers also should know about another available resource. Twenty-two states plus two territories have their own state-run OSHA programs. While they are state programs, they are funded up to 50 percent by the Federal OSHA. Most of these state agencies enforce the same standards under 29 CFR 1910 and 1926, for construction, for example, as does Federal OSHA. In many instances, to the extent that the FAA would not have jurisdiction over your particular maintenance operation, these state OSHA programs would.

In conclusion, I would like to emphasize that the development of proper safety and health programs simply is good business. We have found through the years that when employers become fully committed to workplace safety, not only do their lost work day statistics improve but the cost of injuries and illnesses is reduced. For those interested in the bottom line, the profit, safety and health programs pay. Minimizing injuries and illnesses in the workplace, OSHA feels, will clearly enhance corporate profits.

COMPOSITES IN THE WORKPLACE - SOME LESSONS LEARNED

James Mayr, M.D., MBA
Kurten Medical Group

The use of composite materials in the aerospace industry is growing as the industry develops experience with these materials and as their many advantages are recognized. While there are different kinds of composite materials, those used in the aerospace industry generally are reinforcing fibers or filaments embedded in a resin matrix. The properties of composites are impressive. For example, composite parts for aircraft are 20 to 30 percent lighter than conventional metal parts.

The application of composite material technology to aerospace structures is not new. Carbon and aramid fiber materials have been designed and used for about 20 years. However, use still is not extensive. The Boeing 737, for example, incorporates composite materials for about three percent of its total structural weight. On later production aircraft, such as the Boeing 757 and 767 and the AirBus A-310, greater use is being made (Anglin, 1987).

Experience with composite materials in maintenance operations necessarily will lag behind that for manufacturing. Some period of aircraft service will be necessary before maintenance requirements will develop fully. As requirements grow, maintenance procedures will change since the failure and repair processes for composites are quite different than those for metal structures. Workers will be using revised procedures while working with new materials having different physical properties. The health risks of working with the different fibers and chemicals are not as well understood as those for metal work.

I would like to describe at this time an experience that Boeing had several years ago when it introduced composite materials into the manufacturing process for certain aircraft parts. The lessons learned by Boeing and by all of us associated with this manufacturing experience might be of value for those of you in maintenance who will come into increasing contact with composite structures in the coming years.

The Boeing Experience

The Boeing Fabrication Division, located at Auburn, Washington, in recent years has been used for a variety of activities to support aircraft production. One of these is the manufacture of interior aircraft furnishings. The building used for this manufacturing is one of a number of wooden structures built in the early 1940's as part of America's effort to build up supplies for a war against Japan in the Northern Pacific. After the war, these buildings were declared surplus and Boeing acquired many of them. The buildings in many respects were large barns. They were not air conditioned for summer work.

One activity at the Fabrication Division was the manufacture of interior parts and paneling for aircraft. Fabrics impregnated with various plastic resin materials would be molded into place and then heated to become lightweight, strong, and very durable parts. The molded parts then were drilled and finished for aircraft assembly.

Personnel working in the manufacture of these interior aircraft parts are mostly entry-level, blue collar workers. The more highly paid, trained, and skilled workers are for the most part male. Female employees generally have the lesser paid and lower prestige jobs. At the time of the events under discussion, Boeing was involved in other classified work using plastic process assemblers. Many of the better workers, once trained at the Auburn facility, were transferred to the other work, leaving behind a lesser skilled workforce.

Working with plastic resin materials while they are still wet is notorious for producing skin irritation. In these buildings which were not air conditioned, drilling and sanding fiberglass flashings with fiberglass all over the place and wet skin, produced an abundance of skin irritations, particularly during summer months. Roughly 20 percent of the workforce got skin dermatitis to the point of requiring a medical restriction and movement to another part of the building. Even so, it was very difficult to get most of the employees to use any kind of skin protection. Even long-sleeve shirts were not worn due to the high temperature conditions.

The episode of concern here was initiated when the Federal Aviation Administration mandated that Boeing would be the first company to put in fire retardant interior materials in their aircraft. Boeing selected a phenol-formaldehyde resin product to meet this requirement. In the manufacturing process, the material is used in a wet and uncured state. The formaldehyde is known as a very strong skin irritant, very active chemically. It will burn the eyes and nose if it reaches those organs but it generally does not because it's so active on the skin surface. A sufficient exposure, however, can cause lung edema and other irritant symptoms of the respiratory tract. The primary problem, though, is with the skin irritation.

The phenol component has long been known in medicine since, about 150 years ago, physicians in Europe began to realize the necessity for cleanliness in surgery and began to clean their hands with a phenol solution. Since phenol easily crosses the skin barrier, a number of toxic problems were encountered. In fact, a sufficient exposure to phenol actually can be fatal.

The new phenol-formaldehyde resin system was introduced in a pilot study program in 1987. There was a shop mandate that workers would wear skin protection because of the phenol component. This mandate was largely ignored by both supervisors and by workers since they were used to working without gloves and they did.

In April of 1988, the weather began to turn warm in Washington and the worksite, being in an unventilated building, likewise became warmer. One woman became concerned about health effects and visited an allergist who evaluated her and decided that she had "aerospace syndrome." He said she had suffered brain damage caused by exposure to chemicals at Boeing and specifically identified phenol-formaldehyde. This woman, needless to say, was quite upset and soon contacted nearly every worker by telephone on all three work shifts to tell them that they should stop working with phenol-formaldehyde since they might also end up with brain damage such as she had. Naturally, Boeing then had a flood of medical filings. The health filings described mainly irritative symptoms. However there were other claims describing memory loss, general malaise, hematuria, and other medical conditions.

The Boeing Industrial Hygiene Department, needless to say, began taking many measurements in the fabrication facilities. Every test made showed that the airborne levels of formaldehyde and phenol were far, far below permissible exposure levels. Figure 1 shows the air monitoring results for both chemicals. In each case, measured levels are minuscule compared with permissible exposure limits.

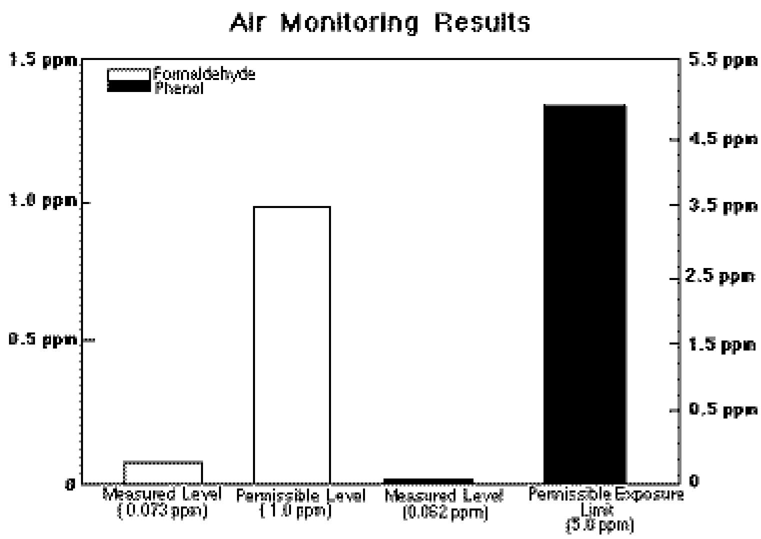

Figure 1

Figure 2 compares the measured level of formaldehyde at the Boeing Auburn facility with formaldehyde exposure under other circumstances. The results show that the exposure found at Boeing is directly comparable with that found in any indoor office area. Also, it can be seen that whereas the Boeing exposure was about 0.07 ppm, a smoker receives roughly 30 ppm of formaldehyde in smoking a cigarette. This means that we actually had much higher levels of formaldehyde exposure in the Boeing parking lot during shift changes than we had at the worksite.

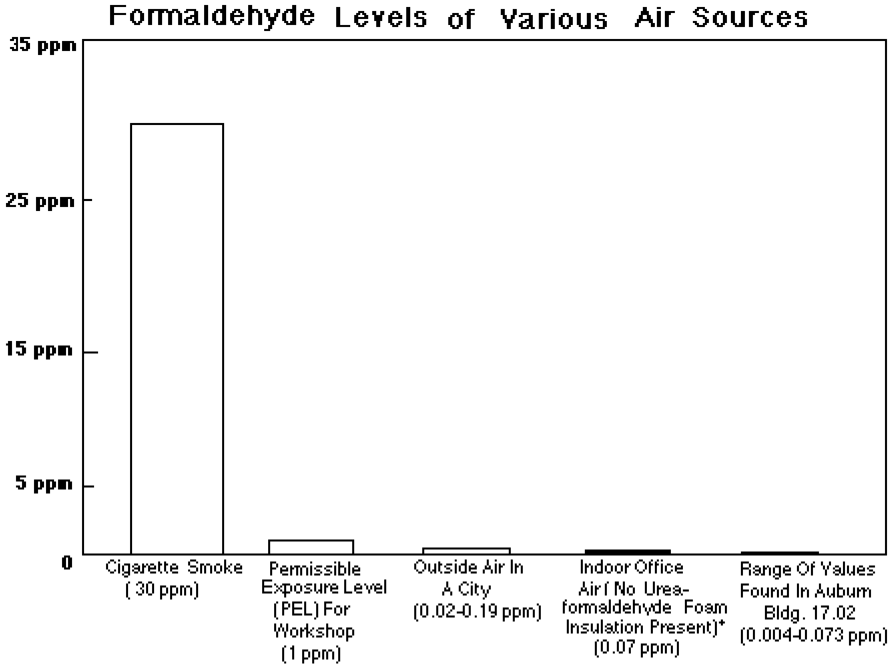

Figure 2

The Boeing Industrial Hygiene Department made many more measurements. Test samples also were studied at the University of Washington. In all instances, nothing strange or unusual was found. Yet, in the middle of all of these negative findings, we might have been missing something. The women working in the Plastics Shop might or might not have been wearing gloves. They might or might not have been wearing protective gowns. They also had lunch right at the workplace and smoked cigarettes which they had been carrying with them during the day, when the cigarette tobacco could well have absorbed airborne contaminants. Thus we have all sorts of potential possibilities for access into the body that were not really being covered.

Boeing now decided to address the issue directly and formed a number of committees. For the most part, these committees did not contribute much, mainly because they were too large to work effectively. Also, there was relatively little input from personnel in either corporate industrial hygiene or from the Boeing Medical Department, who actually were firsthand witnesses to what was happening.

One committee did work well, possibly because it was maintained at a very small size. This was a joint Boeing management/IAM union group. Two representatives of Boeing Human Resources were on the committee as well as a senior superintendent at the Auburn plant. On the union side, the union President was a member and the other two representatives were regular plastics assembly employees who were union members designated as health and safety representatives. This committee brought in a number of specialists to help with particular parts of their investigation. Finally, a number of very good suggestions concerning procedures and protective equipment were made. Worksite conditions, including ventilation, were improved and ultimately the new resin system was removed from production. This committee represents possibly Boeing's best response to the entire matter.

Meanwhile, much was happening in the outside world. A local newspaper took a strong advocacy position, feeling that workers were being poisoned at Boeing. There were many articles and, every Sunday, a cartoon. All showed innocent naive uneducated Boeing and Lockheed workers obviously being poisoned by the evils of the military-industrial program. Banner headlines such as "Aerospace Workers are Afraid" were presented to the public.

The allergist who had seen the first case was interviewed and a headline soon appeared saying "Allergist Says More Aerospace Syndrome Illnesses Expected." The allergist now was seeing a number of retired Boeing employees with inquiries such as "I am losing my memory. Maybe I have been poisoned." These workers, having been diagnosed as having chemical poisoning, now began filing workers' compensation claims many years after retiring from Boeing.

As workers began filing claims, in almost every case I got the worker to agree to a brief physical exam, a chemical panel, a pulmonary function test, and a urinalysis. Without exception, the only negative things we found were high cholesterol levels or, in the case of some women, a low level of iron, a relatively common finding for that age group. I did not find any evidence of liver or kidney abnormalities.

Boeing now assembled a panel of distinguished physicians and outside experts to analyze the individuals filing medical claims. The only problem here was that it required nearly six months to get this panel together and some of the individuals examined had not worked for that entire period, being told by their physician that they should not return to the workplace. The Boeing expert group reported, after extensive examinations, that no unusual findings were encountered with this group.

The outside physician who was seeing a number of the Boeing workers conducted tests and found that many of them had elevated white cell levels and antibodies against formaldehyde. Of course, anyone who has been in a room with somebody smoking a cigarette probably has antibodies to formaldehyde. Nonetheless, based on these studies, the physician involved told workers that 40 percent of their blood was poisoned. He did not send any of his information to Boeing medical personnel although, by state law, he should have. The results of his immune response tests were obtained, purely by chance, from a person working in the site who had the test results to make copies of them.

If the immune response tests are true then, indeed, there might be a problem with workers at the Boeing site. However, the problem is in determining if this represents phenol-formaldehyde poisoning from work exposure. As noted earlier, one receives several hundred times the level of phenol and formaldehyde from smoking than from working in that environment. In any event, the panel of board certified physicians assembled by Boeing examined the data they had collected and reported, in part:

> A multispecialty panel of physicians evaluated a case series of 53 composite workers who had filed claims labeled as "aerospace syndrome." Possible skin and respiratory tract exposures included formaldehyde, phenol, particulates, epoxy resins, and trace organic solvents, but measured concentrations were well below all regulatory and consensus standards. The majority had histories of transient skin or respiratory tract irritation compatible with the known potential toxicity of these materials. Seventy-four percent of the workers met standard psychiatric criteria for major depression and/or panic disorder. Most of these psychiatric disorders were of recent onset, correlating in time with use of phenol-formaldehyde impregnated composite material. Psychosocial factors were thought to have played a major role in the high prevalence of illness in this group.

Lessons Learned

I believe it is worthwhile now to review some of the lessons learned from the Boeing experience. Those of you working in maintenance do so in a work environment not altogether dissimilar from that found at the Boeing facility. You also will deal more and more with composite materials in the future. The principal lessons I would draw include:

1. Just doing the "right" thing may not be enough. Boeing did the right thing. The company studied the problem and assembled a group of experts. However, the response was, in many respects, six months too late. Boeing should have responded in a more timely manner.

2. Good work practices must be mandatory and enforced. These practices involve both management support and employee practices and include (1) no smoking or eating in the workplace, (2) use of appropriate skin and respiratory protection, (3) provision of good lighting, ventilation, air conditioning, and heating and (4) provision of well-placed hand washing/shower/locker facilities.

3. When introducing new processes, do in-shop pilot projects and communicate results. When the new plastics process was being introduced, Boeing brought in special outsiders to do testing and set up. The actual shop workers were not really involved. In current phraseology, the workers did not feel "ownership" of the new process.

4. At all times, communicate, communicate, communicate! Many of the very good things done by Boeing were not truly appreciated because their importance was not communicated. Well planned and conducted safety crew meetings are a natural place for such communication. Union stewards can serve as "natural leaders."

5. When things go wrong it is very important to have a well established corporate "swat team." By this, I mean a group of people that can move and make decisions quickly. They should be individuals who have been around for a while and know the centers of power. In the Boeing experience, essentially nothing happened for four months. In the meantime, weekend after weekend, we would have newspaper headlines without any response.

There should be clear communication within the corporation so that everyone knows what's going on. Communications should clearly address workers' concerns. The corporation should communication well with the public, cooperate will with the union, and retain recognized experts early.

6. Finally, it is my personal belief that whenever you introduce a new process, especially when it involves new chemicals and new exposures, you should ask the question, "Would I want my spouse, child, or parent to work there?" If you can say "yes" without a gnawing feeling, then the work is probably safe.

Conclusions

The Boeing experience in the introduction of composites into the fabrication of aircraft materials was possibly unique; nonetheless, the lessons learned from this experience may be of value for others as composites have greater use in aerospace systems. While the response of Boeing in many respects was excellent, it was not timely. We should have addressed concerns earlier. We should have educated workers from day one. If we cared sufficiently about the facility in which workers worked, we should have had air conditioning in place before the problem instead of after. We should have listened to worker complaints, even from those at the lowest level. This experience was costly for Boeing. These costs might have been avoided through anticipation and earlier planning. I hope that the Boeing experience will be valuable for others as they move into new eras of aerospace operations.

Appendix B: Meeting Program

Fifth FAA/OFFICE OF AVIATION MEDICINE Meeting on Human Factors Issues in Aircraft Maintenance and Inspection

"THE WORK ENVIRONMENT IN AVIATION MAINTENANCE"

Embassy Suites Hotel

Atlanta-Buckhead, Georgia

18 - 20 June 1990

Wednesday - Phoenix 1, 2 & 3

7:30 a.m. **Registration**

MEETING ORIENTATION

8:30 a.m. **Welcome Address** *Phyllis Kayten, Ph.D.* Deputy Chief Scientific & Technical Advisor for FAA Human Factors Federal Aviation Administration

9:00 a.m. **The FAA Human Factors Program in Aircraft Maintenance and Inspection** *William T. Shepherd, Ph.D.* Office of Aviation Medicine Federal Aviation Administration

THE PHYSICAL ENVIRONMENT

9:30 a.m. **Physical Stressors in the Workplace** *Roy L. DeHart, M.D., M.P.H.* Professor and Director Division of Occupational Medicine College of Medicine University of Oklahoma Health Sciences Center

10:15 a.m. **Break**

10:30 a.m. **Industrial Hygiene in Air Carrier Operations** *Brad Baker* Technical Training Manager Mesaba Aviation, Inc. and *Al Schafer* Supervisor, Technical Training/Safety Mesaba Aviation, Inc.

WORK VARIABLES

11:15 a.m. **Factors Affecting Shift Workers** *Donald I. Tepas, Ph.D.* Director Industrial & Organizational Psychology University of Connecticut

12:00 noon **Lunch**

1:30 p.m. **Work Support Systems** *Danny Hoffman* Analyst - Tooling & Ground Equipment Delta Air Lines, Inc.

2:15 p.m. **FAA Interpretation of Maintenance and Inspection Paperwork Requirements** *Joseph Soto* Federal Aviation Administration Washington, DC

2:45 p.m. **Impact of Maintenance and Inspection Paperwork Requirements on Air Carriers** *Eugene (Dutch) Drescher* International Association of Machinists and Aerospace Workers

3:15 p.m. **Break**

3:30 p.m. **Effects of Automation in Maintenance** *Raymond P. Goldsby* Manager, Resource Development United Airlines

4:15 p.m. **Impact of New Generation Aircraft on the Maintenance Environment and Work Procedures** *Daniel Desormiere* Deputy Director Engineering and Maintenance Air Inter

5:00 p.m. **Adjourn**

Thursday - Phoenix 1, 2 & 3

7:30 a.m. **Coffee and Registration**

PRODUCTIVITY EVALUATION

8:30 a.m. **Job Design and Productivity** *Michael A. Campion, Ph.D.* Krannert School of Management Purdue University

9:15 a.m. **Measurement of Workforce Productivity** *Richard J. Campbell, Ph.D.* Professor of Psychology New York University

OVERSIGHT AND LEGISLATION

10:00 a.m. **Legislation Trends** *John Pendergrass, C.I.H., P.E.* Pendergrass Associates, Inc.

10:45 a.m. **Break**

11:00 a.m. **Standards/Regulations Affecting Air Carrier Operations** *J. Russell Dugger* Assistant Regional Administrator Atlanta Regional Office USDOL/OSHA

11:45 a.m. **Lunch**

NEW GENERATION MATERIALS

HOW THEY WILL AFFECT THE PHYSICAL ENVIRONMENT?

1:00 p.m. **Composites in the Workplace -- Some Lessons Learned** *James Mayr, M.D., MBA* Kurten Medical Group

RECOMMENDATIONS AND CONCLUSIONS

1:45 p.m. **Panel Session: Chairmen** *William T. Shepherd, Ph.D.* **and** *James F. Parker, Jr., Ph.D.*

2:45 p.m. **Adjourn**

Appendix C: Meeting Attendees

Fifth Federal Aviation Administration Meeting on Human Factors Issues in Aircraft Maintenance and Inspection
19 - 20 June 1991

The Work Environment in Aviation Maintenance

MEETING ATTENDEES

Lt. Francis X. Amsler, USAF ASD/SDCE WPAFB, OH 45433 (513) 255-5015

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Bonnie Bennett, Honeywell Systems and Research Center, 3660 Technology Drive, Minneapolis, MN 55418 (612) 782-7381

Georgette Buch, Ph.D., Transport Canada Aviation (AARE), Place de Ville Tower C Ottowa, Ontario Canada K1A0N8 (613) 990-1049

Robert Bureau, AirBus Industry, Aerofomation Avenue Pierre LaTaecoere 31700 Blagnac, FRANCE

Richard J. Campbell, Ph.D., Department of Psychology, Room Number 578, New York University, New York, NY 10003 (212) 998-7811

Michael A. Campion, Ph.D., Krannert School of Management, Purdue University, West Lafayette, IN 47907 (317) 494-5909

David Cann, FAA Flight Standards, District Office 19, One Thorn Run Center, 1187 Thorn Run Road, Coraopolis, PA 15108 (412) 644-5450

Jag Chawla, Maintenance Programs & Reliability, British Airways Engineering Viscount House Annex (E87), P. O. Box 10 - Heathrow Airport, Hounslow-Middlesex TW6 21A London, ENGLAND 081-562-5183

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