Meeting 3: Training Issues

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

Report of a Meeting

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FOREWORD

The job proficiency of airline mechanics and inspectors is in large measure a function of the training these technicians receive. The "training establishment" responsible for providing a fully qualified maintenance workforce involves a variety of institutions and activities, ranging from structured technical training schools to less structured on-the-job airline training programs. Each of these institutions and activities has a responsibility and must make its particular contribution to industry training objectives.

The changing nature of the air carrier industry is well recognized. Aircraft being added to the growing air carrier fleet have high technology flight decks, use advanced types of control systems, and incorporate a variety of new structural materials. Sophisticated technology is the order of the day for the air carrier fleet of the 1990's. And yet, at the same time, we still must face the aging aircraft issue. The burden on those responsible for training technicians to support the maintenance demands of this fleet will be heavy.

The Federal Aviation Administration (FAA) is conducting a series of meetings to address human factors in aircraft maintenance and inspection, with the present meeting focusing on "Training Issues." The purpose of this meeting was to review the status of maintenance training for the air carrier industry, to consider problems facing those responsible for this training, and to learn of new training technologies under development. Representatives of all segments of the maintenance community were in attendance, attesting to an industry-wide recognition of the importance to industry success of a well-trained workforce.

I would like to thank everyone who attended the meeting for your participation and would like especially to thank those who gave presentations. Your contributions toward the difficult problems facing maintenance training are greatly appreciated.

William T. Shepherd, Ph.D.
Federal Aviation Administration

EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) sponsored a two-day meeting in June 1990 as part of a series of meetings to address Human Factors in Aircraft Maintenance and Inspection. At this meeting, particular attention was given to "Training Issues" in maintenance operations. Presentations were given by 15 individuals covering the full spectrum of interests in maintenance training. Representatives of all segments of the aviation maintenance community were in attendance. Their participation reflects recognition that changes taking place in the air carrier industry, with the introduction of high-technology systems and new structural materials, present real challenges for maintenance training. Changing dynamics of the workforce also must be addressed. Careful planning and work will be necessary to ensure a fully qualified work force in the coming decade.

The objectives of the meeting were to (1) review the range of training activities now in place to support airline operations, (2) describe the effect of current and planned regulatory oversight, (3) identify specific problems in training, and (4) learn of new technologies that might aid training in the future. Based on presentations given and ensuing discussions, the following recommendations are presented:

The Training Requirement

Recommendations

1. In light of strong support for the train-to-proficiency principle, the FAA should examine ways to move in that direction, possibly through use of the greater internal curricula flexibility to be provided in the revision of FAR Part 147.

Trainee Characteristics

Recommendations

1. The FAA should establish a minimum performance level for communication (reading and writing) skills and for math skills as a prerequisite for all A&P programs. If a sufficient number of applicants can be maintained using these standards, consideration should be given to elimination of math and physics as required subjects in the A&P curriculum.

Training Curricula

Recommendations

1. Airline operators should consider adding to their training efforts formal programs concerning proper use of the general aircraft manual and proper procedures for completion of paperwork required by the FAA. This course should be given very early in the work history of a maintenance technician.
2. The introduction of resource management training into maintenance training programs offers promise as a positive factor for improved productivity. Resource management training should be encouraged by the FAA and should be considered by airline operators.

Training Delivery Systems

Recommendations

1. The FAA should develop a short handbook on training to provide guidance for those planning and conducting in-house maintenance training programs. This handbook should present principles of training, describe proper instructor-student relationships, and discuss informal means of assessing training effectiveness. The handbook should be done completely in maintenance terms and should be structured as a "How To" book.

Measurement of Proficiency

Recommendations

1. The FAA and industry should be sensitive to the need for more systematic procedures for measuring the proficiency of trainee and technician performance in maintenance. The task analysis effort now being undertaken as part of the work

of the FAA Human Factors Team in Aircraft Maintenance and Inspection will provide an excellent starting point for a proficiency measurement effort.

Training Feedback/Follow-Up

Recommendations

1. The FAA should conduct a national survey on the current placement and competency of A&P mechanics. This survey should produce sufficient information to allow meaningful feedback to the training system.

INTRODUCTION

The Federal Aviation Administration (FAA) sponsored a two-day meeting in June 1990 as part of a series of meetings to address Human Factors in Aircraft Maintenance and Inspection. At this meeting, particular attention was given to "Training Issues" in maintenance operations. Presentations were given by 15 individuals covering the full spectrum of interests in maintenance training. These presentations covered regulatory issues, current practices by airline operators, problems and practices of training schools, and new technologies in training.

The broad objectives of the meeting were to (1) review the range of training activities now in place to support airline operations, (2) describe the effect of current and planned regulatory oversight, (3) identify specific problems in training, and (4) learn of new technologies that might aid training in the future. The objectives of the Federal Aviation Administration in sponsoring a meeting such as this are described in the two presentations immediately following.

Each presentation at the meeting, as well as the following question-and-answer period, was recorded for transcription and study. Using these materials, the ideas and opinions of presenters and attendees were reviewed and summarized in a **"Conclusions and Recommendations"** section, which appears after the **FAA Welcome/Meeting Objectives** and **Keynote Address**. The **Conclusions and Recommendations** are organized to present the general feelings of attendees concerning the major elements found in a large industrial training system.

An edited version of each presentation, taken in most instances from the tape transcript, is presented as **Appendix A**.

WELCOME AND MEETING OBJECTIVES

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

At this third meeting on Human Factors in Aircraft Maintenance and Inspection, I am pleased that I see a number of familiar faces from our previous two meetings. As you recall, our first meeting was general in nature and attempted to identify key issues to be addressed in greater depth. The meeting several months ago addressed one of these topics, that of Communications and Information Exchange.

The purpose of these human factors meetings is to facilitate an exchange of information among those in industry and Government concerned with maintenance and inspection in aviation. These individuals include maintenance managers in the air carrier industry, manufacturers responsible for detailing maintenance requirements, those who establish maintenance training programs, and others with similar responsibilities. We plan to continue holding these human factors-oriented conferences for the foreseeable future. As I have noted at previous meetings, we in the FAA are interested in your ideas for the content of these meetings and will be soliciting your input concerning worthwhile topics for the next meeting.

The theme of today's meeting is training. It is my personal feeling that training may prove to be one of the most important methods for dealing with future problems in aviation maintenance. One of these problems is the shortage of maintenance technicians, which is very real and will become crucial. My sense is that many people are not aware of the looming problem concerning the availability of personnel with the required skills. These people are not going to be there in the future.

At this time, we already are seeing a shortage both of experienced and inexperienced workers in maintenance. As the overall level of experience of the entry maintenance workforce diminishes, it will be up to the training industry and training institutions to bring maintenance technicians up to speed rapidly. The latest statistics from the industry support this. Hiring in the air carrier industry has risen steadily from 5,600 people in 1985 to 12,500 in 1989. The Air Transport Association estimates that there is already a shortfall of about 4,000 workers, with a projected need for 50,000 additional mechanics over the next ten years. Also, compounding this situation is the fact that we have an aging workforce. The present workforce totals 63,000 maintenance technicians. Of these, fully 60 percent may retire within the next ten years.

The changing world scene represents another issue to be taken into account. In previous years, the military has proven to be a relatively dependable source of experienced technicians for the airline industry. All of this may change. At this time, the Air Force regularly contracts about 40 percent of its maintenance work, costing approximately $1.2 billion per year. Many of the airlines are no longer willing or able to do this work. One airline, for example, is planning to phase out $150 million in contract maintenance for the Air Force because they need these people for their own work. Their fleet is growing, and it is the same across the industry.

The framework which we in the Office of Aviation Medicine of the Federal Aviation Administration are using to address these issues and some of the accomplishments we hope to achieve are shown in **Figure 1**, which describes our R&D program. We are seeking input to our program from many sources, not the least of which is industry. We need to learn from industry the kinds of human factors problems that can be addressed through research. We also are looking for input from Government agencies, primarily DoD and NASA, as well as the private sector. We are seeking this input through avenues such as this conference as well as through workshops and site visits. Some of you are quite familiar with this process and have been very cooperative by allowing our people into your facilities for site visits. This has been most helpful for us in understanding how maintenance is accomplished and what the problems are. The information we obtain through such visits is being fed into our program management office in the Office of Aviation Medicine, where it is used in the development of work statements and research protocols.

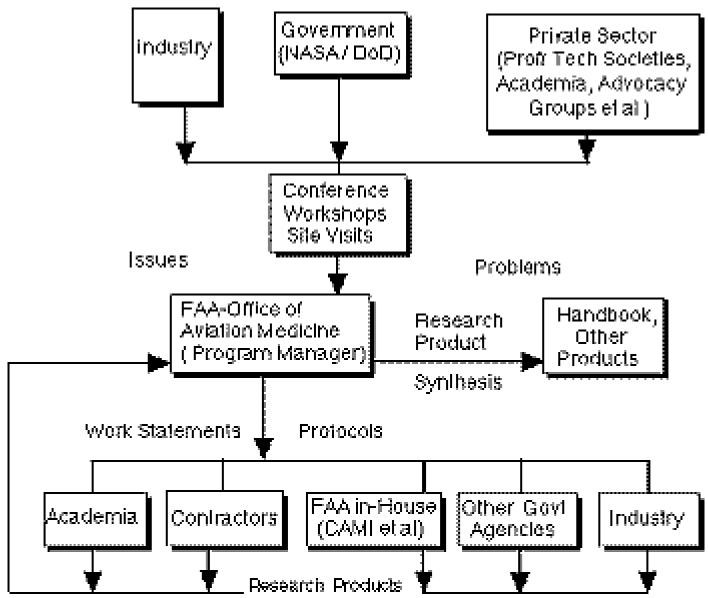


Figure 1 FAA Office of Aviation Medicine R&D Program Supporting Human Factors in Aircraft Maintenance and Inspection

The lower portion of **Figure 1** shows the key participants who are accomplishing our research work. The emphasis in our research is on information. Products of the research will include a human factors handbook, or perhaps a series of handbooks, directed toward identified maintenance issues. We also may produce video tape instructional materials. The role of the FAA here will not be to develop regulations. Instead, we wish to provide as much information as possible to the maintenance industry and to our own FAA inspectors to help both sides address current human factors problems and those likely to appear in the future.

Figure 1 presents the thrust of our R&D program. However, we are open to any suggestions or inputs that any of you might like to provide, since you know what the real world problems are. We welcome your ideas and suggestions so that we can structure a research program that will provide most benefit for all parties.

Since we plan to continue holding these human factors-oriented conferences for the foreseeable future, we would like for you to include among your suggestions any ideas concerning appropriate topics to be covered during our next meeting. Planning for this meeting will begin shortly and your suggestions will be used as guidance for us.

During our meeting over the next two days, you will hear from a number of speakers who are familiar with the maintenance industry, its training problems, and its training initiatives. You also will hear from three members of the FAA Human Factors Team who are working at this time on the research program I described. **Dr. William Johnson**, whom many of you know, will speak to us tomorrow about his findings on the status of computer-based training in the aviation industry. He will also provide some details on a prototype intelligent tutoring system under development. This system is representative of the new technologies being brought to bear on maintenance training.

The meeting also will be addressed by **Dr. James Taylor**, who is developing unique insights into the effects of organizational variables on maintenance productivity, and **Dr. Colin Drury**, who is using a task analytic approach to develop basic information concerning the performance of maintenance technicians. Such data will be invaluable as we proceed toward specific end products in our research activities.

Again, the theme of this meeting is "Training." We in the FAA consider this to be a very important topic and are looking forward to the presentations and to your discussions as a significant step toward the development of improved training procedures and technologies and, as a consequence, a more productive maintenance workforce. I welcome you to the third FAA Human Factors Meeting.

KEYNOTE ADDRESS

Colonel Robert R. McMeekin, MC, USA
Federal Air Surgeon
Federal Aviation Administration

I am pleased to be invited to address today's meeting. In my mind, training has been a second-class citizen. It falls right behind safety in the attention it receives, and yet it is a key element to making the entire aviation system work. Unfortunately, we have focused on the more glamorous aspects of aviation. We are finally beginning to think more in terms of the complete system, but we have not traditionally thought in terms of the system as a whole, especially when it comes to training.

Many things about maintenance training are simple when you stop to think about them. On a day-to-day basis, however, we often forget how we are going to apply the lessons we learn in training. Now this lack is beginning to catch up with us. It is beginning to catch up with us because of several dramatic events which have attracted the public's notice. First, the well-known Aloha incident several years ago demonstrated the difficulties of inspecting for corrosion and metal fatigue. More recently, a British Airways plane had a cockpit window pop out and the two flight attendants had to hold the captain who was trying to keep from going out the window. What has happened all of a sudden? Are airplanes just beginning to come unglued? Airplanes are being flown much longer periods of time. Think about it. We are now flying airframes longer than we would have dreamed of 40 years ago. Take the good old workhorse DC-3. If you told someone at the outset that you were going to fly that airframe 80,000 or 100,000 hours, they would have laughed, but we have lots of airframes approaching these numbers. It should not be too surprising, then, that we are beginning to see some major mechanical problems that need to be addressed. Catastrophic events are not the only problem. Less disastrous problems are day-to-day facts of operational life affecting reliability for dispatch. Bottom line -- if you can't put the airplane in the air, you can't make money with it.

Technology also drives training requirements. Problems with evaluating technology are tremendous. How are we going to select people and train them to deal with all of this new technology? Are we, you and I, the kind of people who are prepared to deal with young students coming through the schools? How many of you are involved with training schools? Some very smart graduates are coming out of these schools. Part of the problem may be that we have a "make them like me" mentality. "I am the best maintenance instructor." and "I will design a curriculum for these students and put it into place and we will run them through that training curriculum. Then we will put them on the job, give them on-the-job training (OJT) for the fine details. Then we'll haze them the rest of the way so they look like me." With the new technologies, we cannot afford to do this. The "make them like me" philosophy will obstruct the productivity of these creative, smart young people.

Technology will determine where we go next. We must see that young students are raised in an environment using that new technology. We also must cope with the older people who have lots of experience but cannot figure out the new technology. We are going to have to grow into the new technology, learning as we go. There will be many new airplanes with the "glass cockpit" technology and, at the same time, there will be many old airframes flying as well. With this situation, we may have to make a choice, because there will be a limited amount of time in the training curriculum. Can we, in fact, train maintenance people all the way from Jenneys to jets, from fabric to aluminum to high tech alloys and digital electronics? Is this going to be a learn-from-your-mistakes training program? Can you really afford to make mistakes with the kinds of airframes we are flying now? If you lost a small airplane or an airliner with 20 to 25 people on it 40 years ago, it would get <u>some</u> notice. But if you lose an airplane now with 300 to 400 people on it, it will get a <u>lot</u> of notice.

How are we going to recruit people into the maintenance field? Is tightening the bolts as glamorous as flying the airplane? I overheard an interesting discussion earlier this morning about salaries. The salaries of maintenance workers can easily be competitive with other salaries in aviation, yet the maintenance business has not been as alluring. I believe there are ways we can make it more attractive.

What types of skills will the new technicians need? Do they have to be the mechanical, hands-on types of skills, or will they have to be the problem-solving, conceptual, electronic skills? Will they be people who can read and absorb large amounts of technical information? If you look at the amount of data and the technical specs for just about any airplane these days, they fill entire shelves.

How are we going to accelerate people through the current technology so they can move on to being supervisors and instructors? How are we going to select supervisors? Perhaps supervisors are the real key to dealing with our maintenance issues. They are the ones who, after the student finishes his/her schooling and training, really determine how that mechanic is going to perform virtually for the rest of his/her career. A maintenance worker's exposure to his first supervisor is going to have a major impact on his performance for the rest of his career. What are these supervisor's going to be like? Will they be receptive to new ideas? Will they be patient? A lot of thought needs to go into the procedures for selecting and training supervisors.

There are two other issues that have potential impact for maintenance. One is the issue of medical standards. There really are no medical standards for maintenance people. Is good color vision important for a mechanic? Does it make a difference where the red wire goes or where the green wire goes? As we began recruiting Federal Air Marshals, we recognized the need to develop medical standards for them. Very strict color vision standards were required for the Federal Air Marshals. Why would that be? The answer is that if, for example, there is an electronically-detonated bomb device onboard an airplane, it makes a big difference where the red wire goes and the green wire goes. With that in mind, can we trust alignment of the digital cockpit and all its color displays to someone who does not have adequate color vision?

Another issue which your industry faces now is the aviation industry drug abatement program. It is a reality. We did not begin drug testing because of drug usage in maintenance, or because anyone demonstrated that there was a big drug problem in the aviation industry. Frankly, we have an industry drug abatement program because the public was scared. We looked around for drug-related incidents in the aviation industry, and they were hard to come by. I, for one, was not terribly enthusiastic about having another drug program to administer. Like many other people, I did not think there was a big problem in the aviation industry. However, when the mandated random testing program was started, we found a higher rate than anticipated. A detection and deterrence program is necessary and we, as part of the Administration, now are committed to the drug-free workplace.

In summary, we face many challenges as we move forward to foster our maintenance industry. How are we going to select mechanics and inspectors? How are we going to train them? What kind of people do they need to be? What type of background do they need to have? What type of culture are we going to establish for them? The culture we establish is going to be the principal influence on career and performance. Supervisors are the key. If you cannot pick good supervisors who will be receptive and patient and nurturing, your training program will fail.

I want to do all I can to support your programs. We at the Federal Aviation Administration will work hand-in-hand with you to foster aviation maintenance programs to meet the needs of the aviation industry and to assure the safety of the traveling public.

CONCLUSIONS AND RECOMMENDATIONS

The U.S. air carrier fleet requires a well-trained maintenance workforce to ensure its goal of flight operations that are safe and on time. Demands on this workforce will only increase in the next decade as newer technology aircraft, such as the Boeing 747-400, are introduced and as passenger travel experiences its projected 50 percent growth. The training of maintenance technicians must be carefully planned and conducted so that the training is efficient and those trained are fully qualified.

Maintenance training consists of a number of different paths, with the Federal Aviation Administration providing a measure of oversight for each. Initial training generally is given by an FAA-certified technical training school. Through this training, one acquires the Airframe and Powerplant (A&P) license. Specialized training is given to those who work in component shops covering systems such as hydraulics and avionics. Company courses and on-the-job training bring a new technician to the desired level of proficiency to work on particular aircraft. Finally, those choosing to become maintenance inspectors undergo additional training. Each of these training activities is an element within a total training system and each has a number of issues and problems.

The purpose of this two-day meeting was to examine maintenance training support provided for air carrier operations. Attendees gave especial attention to issues of technical training schools, recognizing that these schools provide a foundation for the entire training effort.

Attendees at this two-day meeting represent all segments within the air carrier industry, including regulators, manufacturers, airline operators, members of the training establishment, and others. The formal presentations given during the two days covered a variety of topics related to training and training effectiveness. Recommendations for improvement in the training system were offered during formal presentations, during ensuing discussions, and during a final "summing up" period. The following recommendations represent a grouping and synthesis of attendee suggestions according to broad topics, with specific recommendations included within each topic.

This Conclusions and Recommendations section is organized around the principal elements in the training process, as follows:

- The Training Requirement
- Trainee Characteristics
- Training Curricula
- Training Delivery Systems
- Measurement of Proficiency
- Training Feedback/Follow-Up

Each of the above elements is discussed individually. To the extent possible, these discussions represent a status review for each training element, as viewed by meeting attendees. Following the discussion of each training element, one or more recommendations is presented as warranted.

The Training Requirement

The first step in establishing a maintenance training program is to determine the training requirement. To do this, one should look at the entire maintenance system, specify the job functions required within the system, identify the person responsible for each job function, and, by examining individual elements within the job, determine his job training requirements. Then, by careful grouping of individual training requirements, a significant step toward the development of a broad maintenance training program is possible.

No comprehensive and systematic review of the training requirement for the entire aviation maintenance industry has been made, although many parts have been studied. However, considerable work in that direction is being done at this time. The Federal Aviation Administration is planning a Job Task Analysis (JTA) of the occupation of "Aviation Maintenance Technician." This analysis will describe the frequency with which a mechanic performs certain activities, the knowledge and skills required, the manipulative capabilities necessary, and the training required for a mechanic both before and after FAA certification.

These results will be of great value for the revision of Part 65 and, if made available on an industry-wide basis, for industry efforts to improve maintenance training.

Industry also is beginning systematic efforts to determine training requirements. For example, the Boeing Commercial Airplane Group has developed a Task Analytic Training System to address training needs of inspectors working in non-destructive testing (NDT). In this system, a design team consisting of three to five content experts performs a job task analysis of a specific maintenance occupation and prepares training modules for the identified tasks. The objective is to establish written, agreed upon performance standards that are measurable and observable. Employees then can be trained to these standards.

As training requirements are determined, it is important to remember that these training requirements differ from one carrier operation to another. The training requirements for a mechanic or an inspector differ depending on the extent of the responsibilities of that individual within the air carrier operations. For example, a small carrier with a small number of airplanes might not have an engineering department. Maintenance personnel then might be responsible for reviewing Service Bulletins, Service Letters, designing structural repairs, interpreting Airworthiness Directives, and generally providing the continuing analysis and surveillance required by Part 121. For an airline without an engineering department, maintenance personnel may have responsibilities far beyond that of simply being an A&P mechanic or an inspector. His job responsibilities will expand to ensure the continuing airworthiness of his carrier's aircraft. His training requirements will expand in proportion.

Train to Proficiency. Closely allied to the determination of the training requirement itself is a determination of the extent of the training requirement. The key issue here is whether one is required, or should, train to a demonstrable level of proficiency or whether one is required to provide a fixed amount of training, with proficiency measured in some manner at the completion of training. At this time, FAA-certified technical training schools are required to offer a minimum of 1900 hours of instruction in their A&P program. At the present meeting, strong voices were heard for a change to a "train to proficiency" philosophy, with technical training schools being given the freedom to adjust their programs accordingly. One attendee noted that, in his belief, the current training requirements of Part 147 are based on the following erroneous assumptions:

1. All students have the same native ability or capacity to learn.
2. All students will progress at the same rate during the same period of time.
3. Time spent in training is an effective way to measure student progress.

This attendee recommended the elimination of hours as any measure for the shop/lab portion of the A&P curriculum and that training to proficiency be conducted instead. Proficiency would be measured through use of tests based on criterion-referenced performance standards for each key competency area. One suggested value of this approach would be that, as some students complete their work early each day, instructors would have additional free time to provide more one-to-one interaction with those students proceeding more slowly.

The arguments in favor of a train-to-proficiency program are balanced by several counterarguments. A major argument is based on administrative grounds. Since test questions for the A&P licensing exam are public knowledge, and have been deemed to be so by court action, the simple passing of a test may not be an adequate indication of proficiency. It is the belief of some in the FAA that the best way to ensure the competency of an individual is to require that he be at least exposed to a training course of a fixed number of hours and with certain curricula items required by regulation. This, of course, should be supplemented by proficiency testing. This program will prevent short-cuts to a measured proficiency rating, with the actual proficiency being less than desired.

Another counterargument is purely practical. In order to do reasonable planning, students entering a training program need to know the duration of the program. They would like to know that they are entering a two-year program, not one perhaps one and one-half or two and one-half years long. There also is the matter of pricing. The schools need to know how long a student will be in attendance in order to provide realistic pricing for the training program.

Any consideration of the advantages and disadvantages of training to proficiency may become moot in light of the forthcoming revision of Part 147 of the Federal Aviation Regulations. The FAA and industry have been working together over the past several years to develop a new A&P school curriculum. While it is anticipated tha the 1900 hours of required training will be retained, more latitude will be given to schools to adjust their training curricula within this fixed training time.

Recommendations

1. In light of strong support for the train-to-proficiency principle, the FAA should examine ways to move in that direction, possibly through use of the greater internal curricula flexibility to be provided in the revision of FAR Part 147.

Trainee Characteristics

Training programs must be prepared to be compatible with the learning capabilities of those being trained. Innate capacities, educational background, prior work experience, general motivational state, and other factors are important and set limits on both speed of learning and the potential success of the training effort.

Those persons entering A&P programs at technical training schools form an interesting dichotomy. At one school, more than 25 percent of a recent enrolling class already had a bachelor's degree. Most of these degrees had been taken in industrial technology or industrial management programs. These applicants should have been well-qualified to seek the A&P certificate.

In contrast to the above, many new students in technical training schools are found to have real deficiencies in basic reading, writing, and math skills. Several years ago, at least one school was experiencing approximately a 30 percent drop-out rate among new students because of these deficiencies. Some schools now have established academic entrance standards and require applicants to take placement tests in mathematics, reading, and English prior to acceptance. This has improved the drop-out rate considerably. With the establishment of appropriate entrance standards, some educators have proposed the elimination of math and physics as required subjects in the A&P curriculum. They feel these subjects should be mastered sufficiently prior to A&P school, thereby freeing more time within the two-year program for more applied topics.

Recommendations

1. The FAA should establish a minimum performance level for communication (reading and writing) skills and for math skills as a prerequisite for all A&P programs. If a sufficient number of applicants can be maintained using these standards, consideration should be given to elimination of math and physics as required subjects in the A&P curriculum.

Training Curricula

The curriculum content for technical training schools was noted in a number of discussions as being completely out-of-step with the requirements imposed by today's advanced jet fleet. This content includes many topics, such as propeller maintenance and fabric repair, that have no call in the maintenance bay of a large air carrier. Other issues, such as the maintenance of turbine engines, repair of composite materials, and troubleshooting of complex avionics systems, are of great importance. For this reason, there is pressure to allow each school to tailor its curriculum to more closely match the needs of those employers taking most of the graduates of that school.

The FAA is aware of the concern over current curriculum requirements and apparently will allow technical training schools more latitude in establishing their curricula in the forthcoming revision of FAR Part 147. However, some questions will remain. Will the freedom to adjust curricula within the 1900 hours limit be sufficient to provide the requisite avionics skills, for example? If not, must schools offer advanced training beyond the current two-year limit?

Training given by airline operators also was considered. One attendee, with much experience, recommended the introduction of formal training for all maintenance employees concerning proper use of the general aircraft maintenance manual and procedures for incorporating such use into day-to-day maintenance. This training should include instruction in proper completion of required paperwork for different maintenance activities. This attendee felt that a formal training course on these topics, given at the beginning of employment, would produce a notable increase in job productivity.

A recommendation also was made that the curricula for training classes provided by employers be developed in some way so that the 20-year experience of supervisors, lead mechanics, and skilled inspectors can be captured and reflected in these training classes. This knowledge base also should be made available in some manner on the maintenance floor so that an inexperienced mechanic working the night shift can gain access freely and thereby answer his questions on the spot.

Resource Management. The continuing quest for avenues to improvement in aviation maintenance has led some to consider adopting the concepts of cockpit resource management (CRM) training, a program used with flight crews to ensure that crew teamwork and coordination are optimal and that best use is made of all cockpit resources. CRM training now is provided by most of the major airlines and reports are that flight deck performance has benefitted from this training. This positive experience with flight crews implies that the same principles might be used beneficially in training maintenance personnel who also must function effectively as crews.

Pan American World Airways, Inc. in 1989 started an exploratory program using flight-crew CRM concepts with a group of management and senior maintenance personnel. Those who participated in the experimental training program found the concepts to be relevant to maintenance operations. They also judged the information to be useful and felt that participation in this training program would affect their behavior on the job. Pan Am plans to extend this program to include all of its managers and supervisors. Ultimately, of course, evidence must be obtained concerning program impact on actual maintenance performance.

Recommendations

1. Airline operators should consider adding to their training efforts formal programs concerning proper use of the general aircraft manual and proper procedures for completion of paperwork required by the FAA. This course should be given very early in the work history of a maintenance technician.
2. The introduction of resource management training into maintenance training programs offers promise as a positive factor for improved productivity. Resource management training should be encouraged by the FAA and should be considered by airline operators.

Training Delivery Systems

The movement toward use of computer-based training (CBT) in maintenance training is growing and will be a dominant theme in the decade of the 1990's. CBT has many advantages as a training delivery system and apparently is being well received by maintenance technicians. CBT provides one-on-one training and also allows a student to proceed somewhat at his own pace. These are good qualities in the eyes of trainees.

Work is being done with CBT and other training delivery systems to take advantage of the latest computer and display technology to bring maintenance training into the world of "high tech." One program described at the meeting is using interactive video plus expert systems to present a realistic maintenance scenario which then can be reviewed with a critique of the student's performance. Another effort is using 3-dimensional display technology to present maintenance items more realistically. A third effort is a computer-based intelligent tutoring system which incorporates models for a content expert, the instructor, and the student.

The work now being done on advanced training delivery systems is impressive and should have considerable impact in years to come. However, these systems are expensive and may well remain beyond the means of smaller maintenance operations for some time. As feasible, studies will be required to determine the ultimate impact of these training delivery systems on maintenance productivity so that cost-benefit analyses can be made.

Before computer-based testing and expert systems technology become common place, most training still will be delivered by the individual instructor and by the mechanic or inspector who is guiding on-the-job training. While such individuals may be quite knowledgeable concerning maintenance, they are not necessarily trained instructors. The suggestion was made that training materials be developed and training be given to part-time instructors concerning accepted principles of instruction and ways of assessing training effectiveness. A short training program or a brief handbook on training principles were mentioned.

Recommendations

1. The FAA should develop a short handbook on training to provide guidance for those planning and conducting in-house maintenance training programs. This handbook should present principles of training, describe proper instructor-student relationships, and discuss informal means of assessing training effectiveness. The handbook should be done completely in maintenance terms and should be structured as a "How To" book.

Measurement of Proficiency

An essential part of any training system is the ability to measure the proficiency of a student at any point during training and certainly at the completion of training. One presentation at the meeting made the point that "We must be able to assess the proficiency of a graduate in doing the kind of work he will be expected to do as a mechanic. Logging the time a student spends working on a training aid, or watching someone else work with a training aid, is not sufficient."

There are compelling reasons to consider the problem of proficiency measurement. Without valid methods for the measurement of proficiency, no real way exists to determine the true value of new training technologies, for example. There is no way to determine the effectiveness of technical training schools. Realistic training periods for company training programs cannot be established.

The methods used to measure proficiency today, i.e., paper and pencil subject matter tests, etc., undoubtedly measure proficiency to some extent. However, better measurement can be achieved.

Most training programs now being developed for the Department of Defense use a formal process known as Instructional System Development (ISD). One function within the ISD process is the construction of Job Performance Measures (JPMs) for each task. These JPMs are used for a number of purposes with one of the most important being the design and evaluation of training. Some process akin to the development of job performance measures would be very useful for maintenance training. In keeping with the ISD model, such measures or tests must be developed directly from training objectives, rather than from the content of training lessons.

Recommendations

1. The FAA and industry should be sensitive to the need for more systematic

procedures for measuring the proficiency of trainee and technician performance in maintenance. The task analysis effort now being undertaken as part of the work of the FAA Human Factors Team in Aircraft Maintenance and Inspection will provide an excellent starting point for a proficiency measurement effort.

Training Feedback/Follow-Up

Continuing improvement in training requires a follow-up effort, some means of tracking the success or failure of the program and its components. As students graduate from A&P technical training schools, they move on to the airline industry or to other sources of employment. There is no way at this time to follow these students, to document their career paths, and to determine their on-the-job success. Such information would be of considerable value in reviewing the effectiveness of the technical training system and of its individual schools and parts.

Recommendations

1. The FAA should conduct a national survey on the current placement and competency of A&P mechanics. This survey should produce sufficient information to allow meaningful feedback to the training system.

Appendix A: Meeting Presentations

FAA'S PROPOSED REVISIONS TO PARTS 147 AND 65

Leslie K. Vipond
Office of Flight Standards
Federal Aviation Administration

Part 147 of the Federal Aviation Regulations governs the procedures and curricula of technical schools which teach aircraft maintenance. Part 65 of the FARs covers the certification of mechanics and repairmen.

Part 147 was included in the FARs in 1962, almost three decades ago. At that time, the FAA commissioned a study of the aircraft maintenance occupation in order to develop definitive information about the job functions of a maintenance technician. This study was primarily a Job Task Analysis of the aviation technician position. The study, often called the Allen Study after its principal investigator, Dr. David Allen of the University of California, was used primarily to develop curricula for airframe and powerplant (A&P) schools.

The maintenance training curricula presented in Part 147 were based on the needs of the 1960's. Obviously, major changes have taken place in the aviation industry since that time. But, with the exception of some minor changes mostly to clarify language, the regulatory intent of the curricula has remained unchanged since about 1970. The FAA, however, recognizes that the regulation needs change and has initiated a number of actions to do so. In February 1988, the

FAA proposed to revise specific parts of the regulation to upgrade educational requirements. I was assigned to this effort as a full-time Project Officer. Since then, we have held three public listening sessions at which members of industry and technical schools were invited to present their ideas.

The FAA now has a Notice of Proposed Rulemaking (NPRM) to effect changes in Part 147. The current schedule for the NPRM calls for completion during the fall of 1990. The purpose of the revised rule will be to produce a better trained technician, someone who can function more easily and capably in today's aviation environment.

The proposed revisions to Part 147 will produce a number of changes in the training of the Aviation Maintenance Technician (AMT). Instruction in the use of non-destructive diagnostic systems will increase, as well as instruction in electronics and avionics. Avionics will include training in use of built-in test equipment and in the maintenance of electronic flight information display systems. All schools will teach maintenance and repair of composite structures and turbine engines to a new level of proficiency. In contrast, requirements for instruction in wood, dope and fabric structures, welding, radial engines, and propellers will be decreased or eliminated.

Another change will be to allow a technical school to direct its curriculum toward its market. For example, if one school were in an area in which extensive crop dusting operations were conducted, its curriculum could be developed toward that market. The school would probably increase instruction covering radial engines, propellers, and welding. In contrast, a school in an urban market training technicians exclusively for the airlines might wish to change their curriculum to emphasize electronics, turbine engines, and repair of composite structures.

The FAA has evaluated some of the operating rules used by technical schools and hopes to eliminate some inefficient constraints of the past. We recognize that these schools are competing with other industries for students, for example the computer industry. In light of this, we were reluctant to raise the number of training hours. We feel that by intensifying the training requirements and not increasing the training time beyond 1900 hours, the curriculum would still fit within a two year program. By not increasing the training time beyond the two-year level, we hope to retain the attractiveness of these schools and let them be consistent with other two-year programs given at the junior college or the community college level. In short, the new regulation should mean the development of a more streamlined curriculum. It will encourage the use of more innovative teaching methods, such as use of interactive computer-based training. Students will be able to use more advanced training aids and also will be trained on newer technology. The revision therefore is expected to promote the development of new AMT schools and to attract more students to this discipline.

The handbook for FAA inspectors responsible for the inspection of AMT schools also has been revised. As many of you know, each AMT school is inspected at least once a year by the FAA, and often more frequently than this. There also is a new FAA Advisory Circular directed toward interested parties who might want to start a technical school for Aviation Maintenance Technicians. Within the past year, we have had 13 new applications for schools. This is a considerably higher number of applications than we have received annually in past years. The publicity concerning curriculum revision may have contributed to this increased interest.

At this time, the FAA also has a proposed evaluation of FAR Part 65, the regulation which deals with the certification of mechanics and repairmen. Subparts D and E of Part 65 specify the requirements for mechanics and repairmen. This includes the training, experience, privileges, ratings, recordkeeping, and currency requirements for these aviation maintenance personnel. Since Part 65 has not been revised for 23 years, the FAA believes that a complete evaluation of this regulation is in order. Our regulatory evaluation will include, but not be limited to, the training requirements, certification standards, the rating system, mechanic and repairmen currency requirements, their limitations, experience requirements, the inspection authorization, aviation maintenance technician school integration and accompanying standards, impact of the changes on related FAR sections, and impact on bilateral and international agreements, including ICAO standards.

In the development of revisions for Part 65, we will rely heavily on human factors criteria. How can human factors studies provide input? Such studies are based on issues arising in the aftermath of deregulation of the airlines. We all recognize that this includes problems with the aging aircraft fleet. This has demonstrated a need for revision to Part 65, particularly as it should deal with non-destructive testing and corrosion control. Human factors studies will show us the best way to adapt certification standards to ensure that the maintenance workforce is best able to apply the new testing and diagnostic technologies.

To provide a sound basis for the revision of Part 65, we are planning to develop a Job Task Analysis (JTA) of the occupation of "Aviation Maintenance Technician." This JTA will assist us with the following:

Certification Standards. Can these standards be improved? Will any improvement at the same time increase the quantity and quality of applicants?

Rating System. Should this system be changed? Currently there are two ratings, airframe and powerplant. We have had many suggestions for adding another rating, so this issue needs study.

Technician Currency Requirements. Are these adequate? At the present time we do not believe they are adequate, but we need more information before any decision can be made.

Certificate Limitations. Are these limitations appropriate in the highly technical environment of today's aviation?

Training Requirements. Here we are concerned with training both before and after FAA certification. In particular, are appropriate training courses available after the certification and are they accomplishing their objectives?

Inspection Authorization. This is the authorization given by the FAA to an individual holding an A&P certificate for at least three years and who meets certain other criteria. These persons are authorized by the FAA to release an aircraft to service after major repair or alterations and to perform an annual inspection. Are the current limitations, duration, and renewal criteria for the inspection authorization appropriate?

The job task analysis will provide a detailed examination of the mechanic position. It will tell us how often a mechanic performs certain activities, the knowledge and skills that are required, what manipulative capabilities are necessary, and the training required for a mechanic after FAA certification. In short, the job task analysis will help us define the criteria needed for a complete revision of Part 65.

In addition to the job task analysis, the FAA is planning to hold about three public hearings across the nation to allow people from the aviation industry to discuss the proposed Part 65 revision and to provide any inputs they would like. We would like for the revised Part 65 to be the result of our best collective efforts. For this to occur we need the comments and recommendations of all interested parties in the aviation maintenance community.

U.S. NAVY TRAINING FOR AIRCRAFT MAINTENANCE

Captain James Qurollo, USN
Naval Air Maintenance Training Group

The Naval Air Maintenance Training Group provides formal maintenance training for each specific type of aircraft used by the Navy. Maintenance training is given across the United States, but primarily on both coasts at major Naval Air Stations and at Marine Corps Air Stations. Our training program employs about 1,600 instructors, 300 support personnel, and approximately 100 civilians. We have 1,100 trainers, use approximately one and one-half million square feet of floor space, and train between 50,000 and 60,000 students a year.

When a young man or woman enters the Navy, normally just out of high school, he or she generally follows the training path shown in **Figure 1**. The inductee first goes to recruit training for about six weeks of Navy indoctrination and basic seamanship. Depending on expressed interest, qualifications, and test scores, the recruit might next be assigned to an Aviation A School. A School training can be anywhere from six to fourteen weeks and covers basic electronics, basic airframes, and basic hydraulics. Most of the Aviation A School training is done at Memphis facilities.

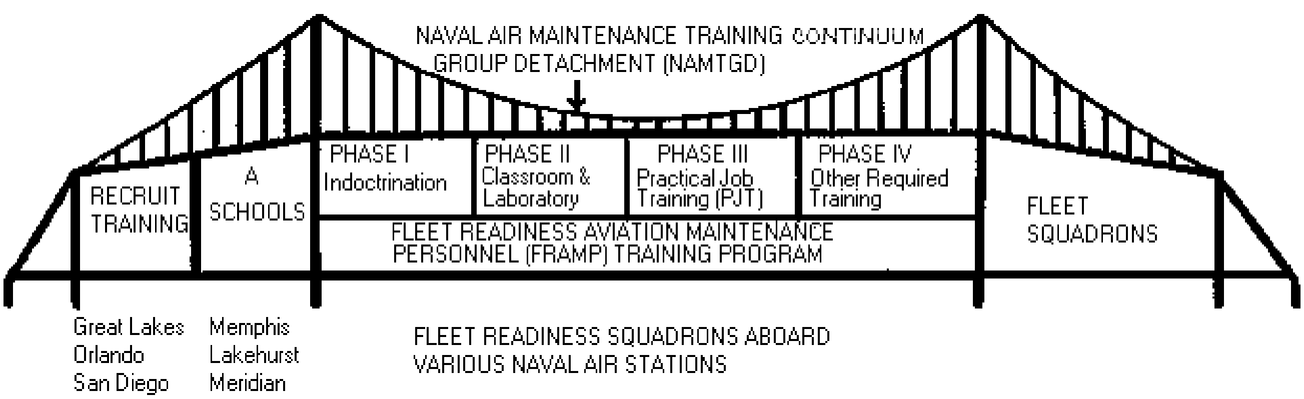


Figure 1

After Memphis, a maintenance trainee goes to one of the Naval Air Stations on either coast and begins Phase 1 through Phase 4 training as part of the Fleet Readiness Aviation Maintenance Personnel Training Program. In this program, Phase 1 is indoctrination. Phase 2 is the formal classroom training, conducted both in the classroom and in laboratories. Phase 3 is the practical job training in which the training is directed entirely toward accomplishing maintenance tasks. In Phase 4, we cover miscellaneous topics such as the maintenance of ground support and aviation support equipment. Finally, trainees are sent to fleet squadrons where they continue to be trained, with training directed toward the specific aircraft flown. This training is primarily on-the-job training (OJT) but may include some classroom work.

Aircraft-specific training takes place during Phase 2 and Phase 3. Depending on the particular aircraft and the particular specialty of the individual, Phase 2 might last from 3 to 19 weeks and Phase 3 from 2 to 6 weeks. The fact that Phase 2 can in some cases last for 19 weeks has caused us to examine one part of the process. When the student moves into OJT in Phase 3, we found that in some cases it was necessary to do a measure of retraining or to have some classroom refresher training on some of the material the student had learned during the early part of Phase 2. In order to eliminate this retraining, we developed a new program in which the Practical Job Training (PJT) of Phase 3 and the formal classroom/laboratory training of Phase 2 were broken into logical sections and combined into one training effort. We currently are using this new training procedure with F-14 aircraft training at NAS Oceana, the F-18 aircraft training at NAS Cecil Field, and two other facilities. We are finding that with this combined procedure we are able to reduce training time by over 20 percent which, considering the number of students we are training, represents a considerable cost savings for the U.S. Navy.

Trainee Issues

The first issues to be faced in the development of a training program are who to train and how much training to give. In the Navy effort, a new recruit will go through the entire training curriculum. However, if the trainee is a mechanic or technician who is changing from one type of aircraft to another, he will go through Phase 2 and Phase 3 only in order to learn the new airplane. He learns to be a mechanic on the new airplane but he does not relearn electronics or engine systems. If he is current on a given airplane, he still may need additional training through his tour of working on that airplane. We handle this through a program called Maintenance Training Improvement Program (MTIP) that we use periodically to test technicians and mechanics and to look for specific weaknesses. Following this, we tailor a short period of training to address these specific problems.

The student-to-instructor ratio is adjusted throughout Navy maintenance training as appears appropriate. In A School training we have a student-to- instructor ratio of ten to one in some instances and even as high as twenty-five to one in others. The class size is relatively large and is taught as would be any course in a college. In Phase 2 and 3 training, the student-to-instructor ratio typically is two to one, with a typical class size of four to six students. When instruction is given in the classroom, this ratio is often two instructors and four students and at times two instructors and two students. One reason for this low ratio is safety. Some of these trainers are dangerous and we want to have an instructor right with the student to ensure that nothing dangerous is done inadvertently.

As opposed to the training of civilian aviation maintenance technicians, the Navy does not have a fixed number of training hours. If a technician is learning to maintain a P-3 airplane, which is a relatively complicated avionics aircraft, he may go through 19 weeks of Phase 2 on an eight hour per day, five days per week basis. For someone going to an airplane which is less avionics oriented, the Phase 2 training might only be six weeks in length. And we also have two different levels. There is the organizational level, in which a trainee would learn how to change an aircraft engine for example, and the intermediate level, where the trainee learns to tear down the engine. These training courses are of different lengths.

If an individual in Phase 2 or Phase 3 training is having any difficulty, the instructor or a subject matter expert will provide additional training. For instance, an instructor might take a student for two hours of individualized training after the normal classroom training. This means that we are training to proficiency rather than providing a training effort of fixed length. The expense of bringing an individual all the way to Phase 2 or Phase 3 training is such that we will go to considerable lengths, in terms of additional training hours, to ensure the success of the training and that the student leaves with the requisite proficiency. To the fullest extent, we train to proficiency.

Training Practices

An on-going question is "How do you train?" Usually the decision is one of deciding the mix of training practices and procedures you will use. After World War II, the original Naval Air Maintenance Training Group worked with mobile training teams. Trainers on flatbed trucks or tractor trailers were taken across the country to provide formal maintenance training courses. Then, after the Navy developed the base loading concept in which each type of aircraft was located at a particular base, we changed to the school house concept for maintenance training. For a number of years now, this has been our primary mode for providing this training. Now, however, we are moving back toward a measure of mobile training, since this concept appears to offer advantages in particular situations.

We also have learned that we need a mixture of formal classroom training and on-the-job training. The two practices can be used to supplement each other or to cover independent aspects of our training curriculum.

Navy maintenance training may be supported by the use of actual hardware trainers, simulators, or may require no trainer. The decision concerning the route to follow here is influenced very much by cost. Hardware trainers initially are very expensive. The initial cost of simulators, by comparison, is less expensive. Nonetheless, for a variety of reasons, maintenance trainers in the Navy are almost always hardware trainers, although we do have some limited experience with simulators. This experience has told us that simulators are more expensive to maintain than hardware trainers and therefore can be more expensive in terms of life-cycle costs.

In selecting training equipment, we always consider the requirement for fidelity. If we are teaching hands-on procedures, remove and replace, we may require a hardware trainer or a simulator. On the other hand, if we are teaching theory only, standard classroom training, using no equipment, may be most appropriate.

Another variable we encounter is "frequency of change." As an example, the P-3 Orion aircraft has been in use by the Navy for about 30 years. During this time, there have been over 1,100 engineering changes, or close to 400 a year. We also have some 87 maintenance trainers associated with the P-3. When it becomes necessary to change the maintenance trainers because the aircraft has changed, one must look closely at the life cycle cost of these changes. As we have found, changing simulators to match aircraft changes can be quite expensive. For this reason, we have a number of simulators that have not been changed. These simulators now are sitting in the back of a classroom with a canvas cover over them because they don't look like the airplane anymore. We can't use them to train and they are too expensive to update. In many instances, it would cost more to update a simulator than simply to buy a new one.

Another variable influencing our decision regarding use of trainers is the type of students we have. Maintenance trainees in the Navy have a wide range of educational background and learning ability. Most, but not all, of our students are high school graduates. Some, but not all, read at the tenth grade level. We must choose our equipment so that it is capable of being used by students through the full array of ability.

At one training site where we teach maintenance for the AV-8B Harrier aircraft, we use a lot of simulation in maintenance trainers. With these simulators, we have large training panels which can be plugged into the simulator to demonstrate theory of operation and different troubleshooting procedures. These training aids are quite useful. One graduate of this program was interviewed at a later time when working at the squadron level. He said he thought his training was good but he did not understand why, when he got to the squadron, he no longer had the fancy troubleshooting devices but, instead, only had a small multi-meter. He did not understand that what he was seeing in the classroom was a trainer. This had not been pointed out to him and wasn't considered necessary, although apparently it was.

New Directions

One new direction for Navy maintenance training is in an increased use of simulators. While hardware trainers may be best for maintenance training, their high initial cost is turning us more and more to simulators. This being the case, we are trying to make our simulators as good as we can. Depending on our assessment of the fidelity requirement, the simulator should look, feel, and act like the hardware. We are also attempting, to the extent feasible, to ensure that our simulators can be changed in a timely manner and without great cost, in order that the simulators can stay abreast of changes in the aircraft. We do not want to have obsolete trainers on our hands.

Computer-Based Training. The Navy is also moving toward increased use of computer-based training systems, particularly for training topics involving theory of operation, interpretation of flow diagrams, and similar issues. For these topics, computer-based training can be quite useful and also can be changed quickly when a change becomes necessary. However, we are being quite careful not to use our computer-based training systems to replace hands-on maintenance training that we give in laboratories. For instance, a trainee cannot safety-wire a system on the computer. Hands-on training is required to learn this kind of activity.

Imbedded Training. The Navy is using imbedded training increasingly to meet many training requirements, particularly in operator training with pilots and other aircrew members. However, imbedded training now is moving into maintenance. As an example, our latest intermediate level test bench will provide considerable imbedded training. An individual working with this test system can have on-going training in which the system will teach him both new techniques and refresh him on certain procedures with its own training programming.

A key advantage for imbedded training in the Navy concerns space requirements. Floor space and deck space both are limited. In the intermediate maintenance area on a ship, there are many test benches and just about every square inch of space is taken. If some of that deck space must be used for trainers, many conflicts can occur. However, if the test bench is computer operated and can be used to provide its own training, there is a considerable savings in deck space. This is an important reason for our movement toward imbedded training.

Early Involvement in Trainer/Course Procurement. We have found that the Navy can save considerable costs in maintenance training by having an early involvement of the subject matter expert. The person who is responsible for the training content should have early involvement in the training equipment procurement process, including involvement in developing the request for proposal (RFP), evaluating the proposal, writing the contract, conducting design course and curriculum reviews, and in general following the trainer until it arrives at the training site. In the past, we have had experiences where we received trainers that were not what we needed to train as well as courses that we had to rewrite before we could use them. This early involvement program should be very cost-effective for the Navy.

The "New Directions" I have just described illustrate some of the changes now taking place in Navy maintenance. We are always receptive to other ideas and procedures in a continuing program to ensure that Navy maintenance is as good as it can be. The aviation resources of the Navy must be maintained in a maximum state of readiness to meet our nation's world-wide commitments.

TRAINING WITHIN THE INDUSTRY

David S. Wadsworth
Professional Aviation Maintenance Association

The Professional Aviation Maintenance Association (PAMA) is a non-profit, non-union, 20-year old association of aviation maintenance technicians dedicated to promoting safety and professionalism in the field of aviation maintenance. Support and improvement of technician education and training at all levels are a large part of PAMA's mandate. I am here today as a representative of PAMA to share some ideas and, hopefully, to help find answers to some of our problems in aviation maintenance training today. In equal measure, I am here to learn. I want to thank our hosts for this opportunity to do both. I will be touching on several of the topics we have already heard about this morning, and I hope I can shed a bit more light on some of them.

We probably all agree that the most talked about facet of aviation maintenance today is adequate training of technicians in today's technology in numbers sufficient to fill today's and future needs. I would like to share with you some observations we at PAMA have made about our profession and its needs, and offer some suggested approaches to make it better.

For at least three years, predictions of a shortage of technicians have been trumpeted throughout the industry. As a result of the recent aging aircraft issue, the advancing of our veteran technicians to retirement age, and the rapidly advancing technology in the field, we are now face-to-face with that shortage. We in the industry have grappled with the problem long enough to know that it is a problem of singular complexity, and that it will not go away of its own accord. To solve it, we must have a realistic picture of the situation in the aviation maintenance field as well as in the training field.

I would suggest that this shortage, as it is called, is composed of at least two major facets. First, there is the lack of pure numbers of technicians coming into the market today. Second, those graduate technicians who are entering today's market possess an overall lower experience level than did the group entering the field ten or fifteen years ago.

Let's look at the lack of pure numbers. PAMA`s research shows that only about 50 percent of A&P graduates in this country enter the field of aviation maintenance. This is a mixed blessing. Other technical fields have recognized that A&P certificates are golden. It also means, however, that we are losing valuable, highly trained individuals to professions that offer better pay, better benefits, and possibly a better perceived image. The lack of pure numbers can be seen further by looking at some facts from Mike Murrell, publisher of FBO Magazine. Following are some of Mike's comments from the June 1990 issue of that magazine:

- The U.S. labor force will grow only 1.2 percent a year from 1986 to 2000, down from the annual rate of 2.2 percent from 1972 to 1986.
- The number of people from 16 to 24 years old has been declining by around half a million a year, and will continue to do so until at least 1995.
- In 1980 there were roughly 26 million people from this age group in the civilian labor force; by 1995, that will drop to 20 million.

These numbers indicate that "while in 1973, 13 of every 100 males were between the ages of 16 and 24 ... the 1990 and 1995 estimates are 9 and 8, respectively." The baby-boom supply of people traditionally targeted for entry-level jobs is rapidly running out.

The concept of less overall experience is, by necessity, a bit less quantitative in its discussion. It has to do with the traditional supply of aviation-experienced veterans who have come into our technician schools and into our industry with some years of experience in certain facets of aviation maintenance. From World War II through the Korean conflict to the Vietnam era veterans, this industry has reaped the benefit of A&P technicians with a basic practical experience level sometimes equaling several years before even beginning their A&P training. This flow is obviously no longer anywhere near previous levels, and the technicians who do benefit from military training find their areas of expertise have become highly specialized. Broad spectrum experience is no longer there.

In PAMA's own in-house referral service, we continue to see a demand for technicians with three to five years of experience while tendering a vast majority of applicants who are fresh out of A&P school. This would indicate that there is a disparity in the various concepts of what entry level really means. The indication here is a general failure to recognize that the basic A&P certificate is a license to learn, an opportunity to polish and specialize, and a certain lack of willingness in our industry to enter into the training process at this most crucial point.

The technology in today's corporate and commercial aircraft calls for training and techniques never before demanded in this profession. Again and again we have all heard about the need to supply specially trained technicians to handle state-of-the-art structural materials known as composites, glass cockpit technology, fly-by-wire, and fly-by-light systems. It is safe to say that the sophistication of this technology will continue to increase in the coming years,

Who is not familiar with our industry's most recent crisis, that of aircraft structural failures attributable to our aging fleet? This problem has touched literally every sector of the U.S. registered fleet and most areas of commercial and private aviation around the world. Caring for the aging fleet has taken top priority in the aviation maintenance world for the past two years, and will hold this position until suitable methods for tracking, inspection, maintenance, and repair are identified and implemented. Extensive training and education is playing, and will continue to play, a major role in conquering the problems of the aging fleet.

In this regard I will quote our FAA administrator, Admiral James Busey, from a message he delivered at the PAMA Awards Banquet in Houston this spring. Admiral Busey said, "The Aloha Airlines accident of 1988 focused public attention on the important role maintenance plays in aviation safety." He went on to say, "Aging aircraft are creating problems for both airlines and general aviation." In summary of this point, he said, "Aviation maintenance technicians have a double-barreled challenge -- they need to maintain older aircraft and get ready for the new technology that's coming."

Much of the view I have just shared with you is not new, and I am sure that many of you have been party to hashing and rehashing various parts of it. You should know, then, that there are some other educational factors to be reckoned with in our profession which are not as obvious and which require training and education on a more far-reaching and subtle level. Some of these factors have to do not only with training of technicians, but also with educating various parts of the public.

One of these is the public awareness, or lack thereof, about our profession. Knowledge of the aviation maintenance field, the training required, and the career opportunities available is poorly distributed. Most references to aviation careers available to young people today are about pilots and air traffic controllers. Little, if any, mention is made of maintenance and its varied possibilities. Sometimes knowledge of our profession has limited scope even among our own ranks. When speaking to classes of A&P students, I have noted with disturbing regularity a lack of understanding of the opportunities and career choices available to them. It seems that we may be training a generation of technicians whose future is, in large degree, a mystery to them. How can we expect them to understand the scope of their professions when parents, grade and high school officials, teachers, and even guidance counselors have little idea of what it's all about?

The area of recurrent training for technicians in the field is of utmost importance in considering the problems we are facing. I would suggest that there is ample opportunity among factory schools and the private enterprise training facilities such as Flight Safety International or SimuFlight for keeping up with needed training demands today. What is lacking is acknowledgement by management of the need for this recurrent training. I can personally testify to a managerial attitude, especially in the FBO, private and corporate sectors, that formal recurrent training is a waste of time and money for the company. A common argument is, "We need our technicians here on the hangar floor maintaining our aircraft," or "Anything we need to know about our equipment is in our manuals."

This lack of understanding helps to create and maintain another factor requiring education outside of our ranks. From the beginning days of our profession, the aviation maintenance technician and the profession in which we work have suffered from a misconception about what we do, the knowledge and expertise needed to do it, and the safety and reliability levels involved with our responsibilities. Because the image of the cigar-chewing, grease-stained, semi-literate mechanic remains with us today, there is a need for education and training that is directly related to the advancement of our field other than that normally associated with training technicians.

Lest you think my object here is to paint a bleak picture of our lot today, I want to talk about what is being done right. I said earlier that we need to have a realistic picture of the situation in the aviation maintenance field as well as in the training field. There are many indications of that picture coming together, and steps have been and are being taken to accommodate the problems that we know are there. As you heard in this morning's session, FAA and the industry (notably the Aviation Technician Education Council) have worked successfully on a review and revision of FAR Part 147, which addresses our A&P school curriculum. This revision has provided a much-need adjustment in areas of emphasis to more closely align training with current technology. (There are people here who can more readily answer questions about Part 147 and its new form.) Another area of progress is the FAA's current review of FAR Part 65, Certification: Airmen Other Than Flight Crewmembers. The concept used here is, again, to use industry expertise and experience from as broad a spectrum of our field as possible to analyze and suggest adjustments to our certification process. I am proud to say that PAMA has been instrumental in organizing our industry talent in this effort, and working groups are currently doing just that -- working on Part 65.

In recent years the airlines have been spreading the word that they want specialized training in their technicians -- training more fitting to the airlines' needs and methods of maintenance in the airline structure. At least two major airlines in the United States today have plans to start and run technician training schools. In this case, the basic A&P certificates will be enhanced by more specialized exposure to subjects addressing specific airline needs. I expect that **Dr. Ken Govaerts** will address this subject during his session tomorrow.

One of the most encouraging trends in aviation maintenance training today is evident in our forward-looking A&P schools. Institutions that see the current shortcomings and future needs in aviation maintenance are offering training in specialty areas such as avionics and composites. Technicians in training can choose to extend their education, abilities, and worth to the industry and increase their earning power by taking advantage of these programs.

A good example of this concept can be seen in the Pittsburgh Institute of Aeronautics' Avionics Technician Training Program, or AVT. I would like to draw from a recent article in this institution's news magazine. The article announces the addition of a sixth semester to the school's avionics program, the objective being to provide PIA students with training in aircraft instrument repair and familiarization with commercial aircraft systems. The article goes on to explain, and I quote:

> "The decision to add this new training came after many months of research into ways which would make our AVT graduates even more successful as they enter the industry. The research included substantial input from major air carriers, instrument

> manufacturers, and instrument overhaul facilities. The research indicated that, while modern aircraft design trends feature fully electronic components and systems . . . there is (and will continue to be) a substantial number of aircraft equipped with electromechanical instrumentation. Many of the cockpit displays and indicators in even the newest aircraft are electromechanical in nature; designed, built, and maintained with time-proven technology. There is thus a need for an avionics technician to have a working knowledge of the proper operation and care of both electronic and electromechanical instruments."

The article goes on to describe the equipment and facilities that will be and are being committed to this expansion. This is one example of progressive thinking and planning that will help meet the needs of our industry, and I imagine that **Mr. Jack Moore**, who is next on today's agenda, may enlighten us further in this area.

I am proud and excited to announce that PAMA is embarking on a traveling program of two-day seminars designed to help fill the training gap, not only in the technical area, but also in promoting better understanding of FARs and the safety and legal aspects of our profession.

Contrary to the gloom and doom of our training status today there seems to be a great deal being done to meet the challenges. Industry and the FAA are cooperating to review and revise our training and certification guidelines. Modern, progressive A&P schools are coming to the fore with advanced programs in specialty areas, and airlines are attempting to address their own special needs by producing technicians specialized for their own demands.

Even with such progress, there are still many changes to be made and much planning work to be done in order to catch up with industry`s needs and to ensure the replenishment of our dwindling supply of competent technicians. One of the first problems I mentioned was the shortage in pure numbers of technicians. Time and again, FAA and PAMA have said that there is no sure, accurate method to count our active A&P technicians. Washington's list of A&P technicians was begun in the 1950s, and has accumulated names of all certificate-holders since that time. No method of tracking those names or of purging the list is currently available. There is no way to determine even how many of these people are deceased. Consequently, determination of how severe our technician shortage really is has become a problem in itself. PAMA suggests, therefore, that a major step in helping to solve our industry's technician shortage problem is to implement a technician re-registration program on a basis adequate to developing and keeping quantitative records about A&Ps, repairmen, and authorized inspectors. This proposal does not suggest or promote retesting of technicians. It supports a common-sense method of statistical tracking of our industry's resources. This is a system used throughout the United States to track nurses, real estate agents, and hairdressers. Reasonable fees to carry out such a program should be borne by the individual technicians.

Additional training of basic A&P certificate-holders in such areas as avionics, exotic structural materials, and non-destructive inspection must continue to be encouraged. Progressive A&P schools are taking the lead. Industry can encourage those by recognizing various levels of expertise through higher positions and better pay. We must also ask if FAA should recognize these levels by the establishment of federally recognized standard specialties other than airframe and powerplant; for instance, an A&P technician with a specialty certificate called non-destructive inspector or avionics technician. Possibly, authorized inspectors should carry these added designations.

Standard interpretation of FARs across the board is essential to training and education in aviation maintenance. Schools in each region need to have one standard upon which to base curricula and policy. PAMA and, I think it is safe to say, the industry as a whole supports regional standardization by FAA.

Finally, in order to assure a continuing supply of qualified technicians for the years ahead, we must educate the public about this profession. In particular, we must get into our grade schools and high schools -- we must create the opportunities to do so -- and tell young people about the real world of aviation maintenance. How it is structured, and what the opportunities really are. They need to know that aviation maintenance is a profession that stands on its own, and not a stepping-stone to becoming a pilot. In our own way, PAMA is attempting to get this message out by creating career brochures and acting as a clearinghouse of career information for all who call us. Additionally, PAMA is proactive in seeking new ways to distribute this information through our company members and chapters.

I sense in this industry today a new awakening to the problems and shortcomings we face and to the responsibility we have to clean our own back yard and to keep it that way. In National Transportation Safety Board surveys going back 20 years, aviation maintenance has an admirable safety record. It reflects an accident rate attributable to maintenance at no more than 3 percent. On behalf of PAMA and our industry, I call for cooperation and assistance from all of you in an effort to not just maintain but improve that record. With intelligent approaches to our system of training and education in aviation maintenance, we can ensure a renewable supply of highly qualified technicians for today's needs and for future needs throughout all sectors of the industry while raising the image of the aviation maintenance technician both in the eyes of the public and within our own ranks.

TECHNICAL TRAINING SCHOOLS

Jack Moore
President, Aviation Technician Educational Council and
Professor, Clayton State College

Technical training schools are responsible for providing a good measure of today's input of maintenance technicians to the air carrier industry. While I feel that these schools generally are doing a good job, they are being buffeted by a number of forces which are worthy of mention. To the extent that we understand these forces and can develop programs to address them, we will be able to improve the product we deliver to the industry.

Budget considerations and regulatory oversight are two of the most important forces acting on technical training schools today. Cost constraints dictate the highest student/instructor ratio and the minimum time to do the job. Regulatory constraints impose rules for operation that have not changed in keeping with the changing characteristics of aviation. Both of these forces must be dealt with if training schools are to meet the demands of the coming decade, both for quantity and quality of aviation maintenance technicians.

A major issue today, and one that will be addressed to some extent through the coming revision of Part 147 of the Federal Aviation Regulations, is that of determining the best curriculum to be followed by technical training schools. Training curricula should reflect the needs of the particular part of aviation which technicians will enter. For instance, the Navy has emphasized corrosion control as part of its curriculum ever since they began taking airplanes on aircraft carriers. They know what they want their maintenance technicians to do and this in turn causes them to decide the appropriate curriculum mix. At the Aviation Technician Educational Council we feel that each technical training school, just as in the Navy, should have some latitude in making the final determination of an appropriate curriculum. There are those who feel that oxyacetylene welding is important in aviation maintenance. Frankly, I feel that it has little relevance for the occupation of airline mechanic. I do not like being forced to deal with it to any great extent. In fact, at one time I asked all airlines in my area how important they considered welding. Their response was that "We don't hire A&P mechanics to do welding. We hire welders to do welding." I share their sentiments entirely.

There are many more examples of skills not appropriate or out-dated for the aviation maintenance crew of tomorrow. One certainly is the ability to prop an aircraft. In this day of high bypass ratio fan jet engines, there certainly is little call for an individual who knows how to prop an aircraft. As an example of a skill not appropriate for initial maintenance training, consider the ability to taxi an aircraft. How many airline operators will take a fresh A&P school graduate and let him taxi a 757? These skills are better learned on the job.

Many skills, such as welding and taxiing an aircraft, are important but do they belong in the curriculum of a technical training school? In such curricula, we must make room for more important issues such as the maintenance of turbine engines and the repair of composite materials. We indeed need to be doing more work with the latter topics but are faced with the issue of how to fit such additional training into our currently allotted training time. As we add new subjects, what will we give up?

The curriculum coverage in technical training schools directly affects the amount of time a student must spend in school. At Clayton State College, the age of our students is between 22 and 26 years. It may be surprising to find that the average student is over 22 years old. In fact, in most A&P programs in this country, there are few people going directly from high school into an aviation maintenance training program. When these people do decide to consider a career in aviation maintenance, it makes a big difference whether they are facing a two-year or a three-year commitment. If they look at a three year program of seven hours a day, five days a week and compare that to a four-year baccalaureate program or training for a profession such as medicine or law, they may well decline the maintenance challenge. A three-year commitment to obtain entry-level qualification into an occupation which may involve working in drizzling rain on an airport ramp to change an aircraft generator may not be that attractive.

The reasons for remaining with a two-year technical training program are strong. I have always chosen to stay within the 1900 hour curriculum and feel that it is appropriate not to have a proliferation of hours. However, this 1900 hour limit does bring its own set of problems. As an example, consider the 750 hours allocated to airframe and the 750 hours allocated to the power plant. Within each of these, there are a number of subcategories to cover topics of obvious importance. One not covered is basic electronic troubleshooting, which every major airline operator has reported to ATEC for the last ten years to be the most significant need. Most delays at the gate occur because of electrical or electronic/avionics interface problems. Mechanics need troubleshooting skills for electrical systems so that they can approach the airplane secure in the knowledge that they will be able to troubleshoot the system and identify the problem. However, if we were to put in an additional 150 hours for basic electronics, how would we adjust the other parts of the curriculum?

As we review issues in the operation of a technical training school, let us examine use of other resources. At one time I considered having students take math and physics courses in on-campus departments since I felt that the instruction there would be quite good. Certainly a qualified teacher in mathematics at a college will do a better job in presenting this information than will a mechanic. However, I found that I could not use the campus resources unless I listed all instructors, all facilities, all equipment, and everything else associated with these courses and then obtained FAA approval for such use. Obviously this was more than I was willing to do, so I developed an alternative system in which students take these as regular on-campus courses and then do merely a review on math and physics. This review is very brief and concerns aircraft applications. So, in effect, I am reducing the 1900 hours of instruction by 50 hours for math and 50 hours for physics. However, I feel this system is designed to provide a better basis in conceptual physics and allow them to better understand the relationships of temperature, of pressure, and so on in air masses, all of which is part of our curriculum by requirement.

Improving instruction in math and physics is only one of many issues we must face if our schools are to turn out a product that the airline industry finds completely acceptable. And industry needs and standards are changing rapidly. Twenty years ago, who would have known that airliners today would have the integrated cockpits, glass cockpits, flat displays, fly-by-wire systems, and other high technologies? Could we have begun to prepare for these aircraft 20 years ago? How many of us would have had the money in restrained budgets and the available equipment to seriously prepare for today's aircraft? Yet perhaps we should have known because this technology was common 20 years ago in military fighter aircraft. The glass cockpit, the fly-by-wire, and all the rest were there at some level in the military in 1970. We must learn to anticipate trends and certainly the trend of movement of aircraft technology from military systems into commercial aircraft has been well established.

As we look at today's aircraft, the Boeing 747-400 represents the full advent of new technology. This aircraft has five cathode ray tube (CRT) displays and three computers. If we are to provide maintenance support for these aircraft, it is obvious we must move more toward computer training. How else will a mechanic troubleshoot Boeing 757 and 767 cockpits, which have an array of built-in test equipment, unless the mechanic has experience in interfacing with computer-based systems?

The transition to training for maintenance of higher technology aircraft may not be as difficult as we might think. Interestingly, the qualifications of some of our entering students are higher than one might expect. Last year more than 25 percent of my students enrolling for the A&P certificate already had a bachelor's degree. In fact, 20 percent of them had bachelor's degrees from Georgia Tech University, where they had taken industrial technology or industrial management programs. After graduation, they found they could make possibly $17,000 per year employed in those fields. Then, when they learned of the shortage of mechanics and the kinds of skills required in aviation maintenance, they became interested in our program. The glass cockpit airplanes and use of new composite materials represent challenging matters for students with mechanical aptitude. Apparently these students decided it would be worthwhile to spend an additional two years to enter an occupation with these challenges.

As we move into a new era of aviation and attempt to train people to meet the maintenance requirements of high technology aircraft, we must confront the issue of proficiency measurement. We must be able to assess the proficiency of a graduate in doing the kind of work he will be expected to do as a mechanic. Logging the time a student spends working on a training aid, or watching someone else work with a training aid, is not sufficient.

I recently heard a Navy Commander in a television show discuss carrier operations and make the comment that "We are flying aircraft designed by Ph.D.'s, the production of which is overseen by people with master's degrees. They are flown by pilots with at least a bachelor's degree and are maintained by high school dropouts who came into the military to get away from something worse." While the comments of the Commander may be a bit overstated, he does make a point. We should recognize that, in aviation, we ask a lot of aircraft designers, manufacturers, pilots, and others at visible positions in the industry. I feel that we expect the least of people in the maintenance area and that we have the poorest measures of how they achieve their goals. We must be able to do a better job of measuring proficiency at many points during training and certainly at the time of graduation.

To conclude, our focus in the training establishment must be always on ways to improve instruction and the quality of our product, the trained Aviation Maintenance Technician. One way to improve our product is to train to proficiency, not to train by hours. A second way is to integrate the training to the fullest extent possible. The theoretical and the practical must be integrated. When a student has had an explanation of the theory of operation of some system, he then should immediately be able to disassemble, inspect, and reassemble the system even if it is not something he would be expected to do as a mechanic. This is how students learn how a system works and how they learn to do effective troubleshooting.

The final point I would like to make concerns ways in which individuals are considered eligible for certification as mechanics. At this time, we will accept without question the ex-military individual with experience in military aviation maintenance. We feel that this experience provides capabilities equal to those of an individual who has covered the same subjects in an approved school. Yet, at this time we will not do the same for a student who may have acquired his skills in any system other than the military. In this case, the individual must be approved by the FAA as being qualified for all general subjects and all A&P requirements. The maintenance industry and the training establishment should apply standards of qualification evenly to all applicants, regardless of the particular situation in which they might have acquired their capabilities.

I have outlined a number of issues which we in the training establishment feel must be addressed if we are to provide qualified maintenance personnel to meet the needs of the air carrier industry in the future. I hope that we can work together toward solutions for these problems.

AN INNOVATIVE APPROACH TO NDT INSPECTOR TRAINING AT BOEING

Diane Walter
Boeing Commercial Airplane Group

Introduction

The Task Analytic Training System model was developed to address training needs in the **NDT** areas of the Boeing Commercial Airplane Group. Specifically, to address on-the-job training. New and experienced inspectors need a comprehensive, structured training system designed to continuously improve the quality and reliability of inspections. They need a system that will provide first-time, remedial and recurrent training.

Any type of training must take into account three factors: skill, knowledge, and attitude. In order to blend these factors, the Task Analytic Training System is composed of three interacting components: job task analysis; job instruction training; and social psychology theory. These components are not new. The packaging, however, is unique. The job task analysis and job instruction training methods (which have been modified to meet the training needs of client divisions at Boeing) first appeared during World War II and earlier. The social psychology theory is based on the philosophy and psychological theory of Alfred Adler, a contemporary of Sigmund Freud and Carl Jung.

Skill and knowledge alone are not sufficient to ensure a well-trained and productive employee. An attitude that values work is critical to the success of any training program. Productivity relates directly to both ability and willingness to do work. Knowledgeable, skilled employees produce little when they dislike the job, have no personal goals for the work, and see limited personal reward for the effort. Attitude must be designed into the training system. One of the salient features of the Task Analytic Training System is the positive effect it has on employee attitude and morale.

The discussion today will follow this agenda:

1. Problems with traditional training methods and common pitfalls that can result in industrial training program failures.
2. The WHAT, WHY, HOW, WHERE, and WHEN of the Task Analytic Training System.
3. The five basic assumptions of social psychology theory.
4. A description of the training system - the working elements of what you can expect from the system once implemented.
5. The Task Analytic Training System process.
6. Benefits of the training program to both employees and the company.

Problems with Traditional Training Methods

There are several drawbacks with traditional industrial training methods. First, the training staff normally write the program. Typically, they have either little hands-on experience or none at all. The result is that the training material has little resemblance to what actually occurs on the job.

Second, the terminology is often unfamiliar to the staff. Training, to be effective, must be in the same "language" the worker uses.

Third, and extremely important, there is generally no employee ownership of the training program because of little or no participation from the workforce. Worker participation is crucial to the success of any training program. A basic assumption in the Task Analytic Training System is that people deserve the right-to-know what is going on around them, especially when it influences their jobs. A fourth problem with traditional training programs is that frequently they get put on the shelf and are forgotten. There is no follow-up or evaluation of the programs.

Fifth, the training system can become a "degenerating buddy system" subject to the following pitfalls:

1. Experienced workers are not always knowledgeable.
2. Without an outline to follow, valuable skills get left out.
3. Mistakes are perpetuated.
4. There is no consistency from employee to employee.
5. Shortcuts develop due to lack of understanding.

What, Why, How, Where, When

WHAT is the Task Analytic Training System?

It is a generic process, applicable to any job. It provides comprehensive, structured on-the-job training. The system incorporates proven training techniques/methodologies and is a performance based, hands-on approach. Training is accomplished through practice.

WHY was the training system developed?

1. To provide new employees with structured on-the-job training.
2. To provide recurrent and remedial training to experienced employees.
3. To establish standardized procedures.
4. To positively affect attitude and morale.
5. To provide consistency between workers.
6. To incorporate changes in materials, equipment, and processes.

HOW was the system developed?

The first step in the development of any training program is to obtain management commitment. Management has to agree that training is important and be willing to dedicate the necessary time and resources; otherwise, the program is already doomed to failure. The Task Analytic Training System is based on full workforce participation. Everyone is encouraged to participate in some way. During the development stage of the program, key personnel are a design team, an approval team, and a team facilitator.

The design team consists of three to five content experts(knowledgeable workers). Their primary task is to perform a job task analysis and write training modules on the identified tasks. The modules are short step-by-step procedures required to perform specific tasks. Criteria used in selecting employees to serve on the design team are:

1. Credibility with peers, supervision, and staff.
2. Willing and able to communicate what they believe.
3. Experts on most of the job being analyzed.
4. Willing to go along with the group even if they don't completely agree.

The approval team is made up of other knowledgeable workers, key supervisors, and technical experts. They review and approve all modules for accuracy and completeness.

The facilitator, a third party consultant, functions as a process expert and is present at all design team meetings to keep the team on track, help handle disagreements, and coordinate all activities.

WHERE can the training be applied?

This training system can be used with new operations or with those already in existence. The program can be effectively applied in areas of high turnover or in any situation that requires workers to be retrained. A primary advantage of having a structured, comprehensive on-the-job training program is that employees are very quickly trained in new skills with minimum disruption of the day-to-day work schedule.

The design team may decide to apply the system to critical elements only or the entire job. The team has ownership of the system and directs its development to answer the needs of the workforce. Critical tasks may be addressed right away, if necessary, since modules may be written in any order.

The system can exist alone as a new training program or can be easily integrated into an existing program. The design team is encouraged to use material from sources already available and not to reinvent the wheel.

WHEN can the training system be applied?

Training can begin early in the development process. It is not necessary to wait until all modules are written to begin training.

The training can be remedial, recurrent, or first-time training. The system (or process) is ongoing. Modules are written and used as needs arise - new materials, new equipment, changes in processes, etc. The flexibility of the modules (short procedures) allows for individual training plans. Due to prior experience, everyone will not need training in all areas.

Social Psychology Components of the Task Analytic Training System

A fundamental component of the Task Analytic Training System is the social psychology theory of Alfred Adler. Adler is the founding father of social psychology which is at the very heart of present day management and organizational theories. There are five basic assumptions to the theory, and each is reflected in the training system.

The first assumption is that **all human behavior is goal-directed.** Each person's primary goal is to belong and feel significant. This striving for belonging and significance is the basis for motivation. People can only feel significant if they contribute. When employees are not given the chance to contribute, they become counterproductive, rebellious, avoid tasks, try to sabotage the system, etc. When given the chance to contribute, they become productive, task-oriented employees.

The second assumption is that **people are creative decision makers.** They are active problem solvers. Having an active role in solving problems is a hallmark of job satisfaction. People who are encouraged to be creative and active feel that they can make a difference and have an impact on the work environment. The Task Analytic Training System uses work teams to generate solutions by having them ask questions like, "What is the best way to do this job?"

The third assumption is that **humanity is socially imbedded.** People do not operate in isolation - everything we do, as individuals or in groups, relates in some way to other people. Problems cannot be solved by one person in isolation. Cooperation and contribution solve problems.

Fourth, **use is more important than possession**. The knowledge and skills a person has do not count unless they are put to use. The Task Analytic Training System is structured to develop and use people resources. In order to put skills and knowledge to use, employees must have attitudes that value work. Without attitudes that value work and see personal fulfillment in its accomplishment, it is doubtful whether employees would ever attain the classification as skilled, knowledgeable workers.

The fifth assumption is that **people (and organizations) function holistically**. The whole is greater than the sum of the individual parts. The Task Analytic Training System is based on teamwork. The quality and quantity of a group effort is greater than that of the same individuals working independently.

Description of the Task Analytic Training System

The working elements of the Task Analytic Training System consist of: needs analysis; outlining targeted jobs; writing and verifying procedures (modules); an approval system; sequencing training; implementing; debugging; evaluating; and establishing a maintenance/audit plan. The system, when in operation, will do the following:

1. Establish written, agreed-upon performance standards which are measurable and observable.
2. Train and verify that employees are working to established standards.
3. Audit, on a regular basis, to assure sustained performance and to initiate appropriate corrective action.
4. Provide a plan to continue using the system with a trained facilitator.

The Task Analytic Training System Process

Figure 1 shows a typical process for installing the Task Analytic Training System in a work area.

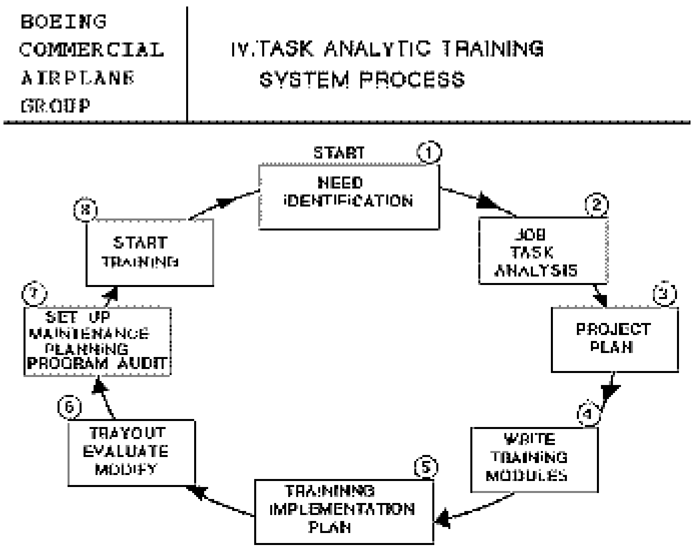


Figure 1

Need Identification - Step 1

Identification of the problem as a training concern is the first step. If workers are able to do the job but are prevented from doing so because of organizational constraints, there is not a training problem. Once the need is established and a job is identified, the facilitator discusses the training system process with the workforce. Together they evaluate the usefulness of the system in that area. The facilitator then gains their commitment to continue.

Job Task Analysis - Step 2

In breaking the targeted job down into task segments, the design team asks the following two questions:

1. What do you need to know or be able to do to be a qualified (Job title)?
2. Can you teach and can someone learn that in one-half hour?

Answers to question 1 are written on wall charts. Question 2 results in further breakdown of the major tasks into smaller segments. Repeated use of the two questions ends when the job experts agree that the branch of the "tree" takes no more than one-half hour to teach/learn. The left column in **Figure 2** shows a sample of the tasks associated with the job of liquid penetrant inspectors (resulting from applying question 1). The next two columns of Figure 2 show the task breakdown which continues until the tasks take no more than one-half hour to teach and learn. One-half hour segments:

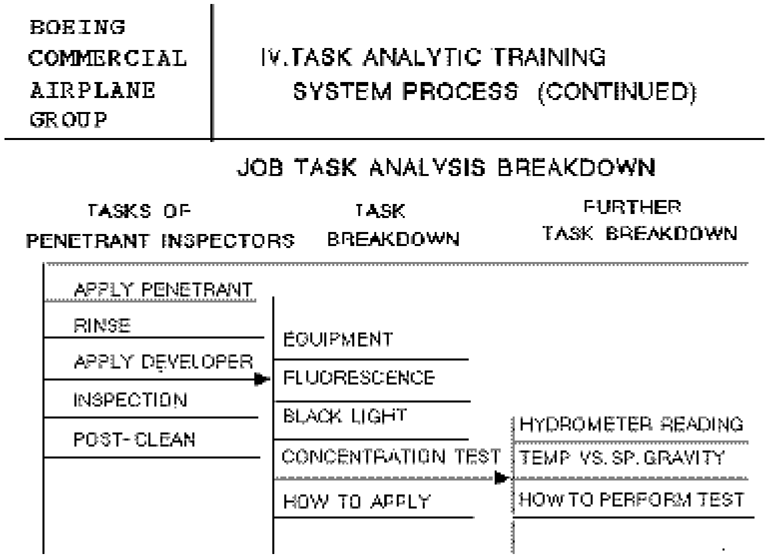


Figure 2

1. Fit the attention span of average learners.
2. Provide manageable blocks of material for ease of instruction and learning.
3. Allow flexibility in situations where operating conditions require short periods of training away from the job.
4. May be modified as specifications chance.
5. Give trainees a sense of accomplishment as they build a solid skill base.

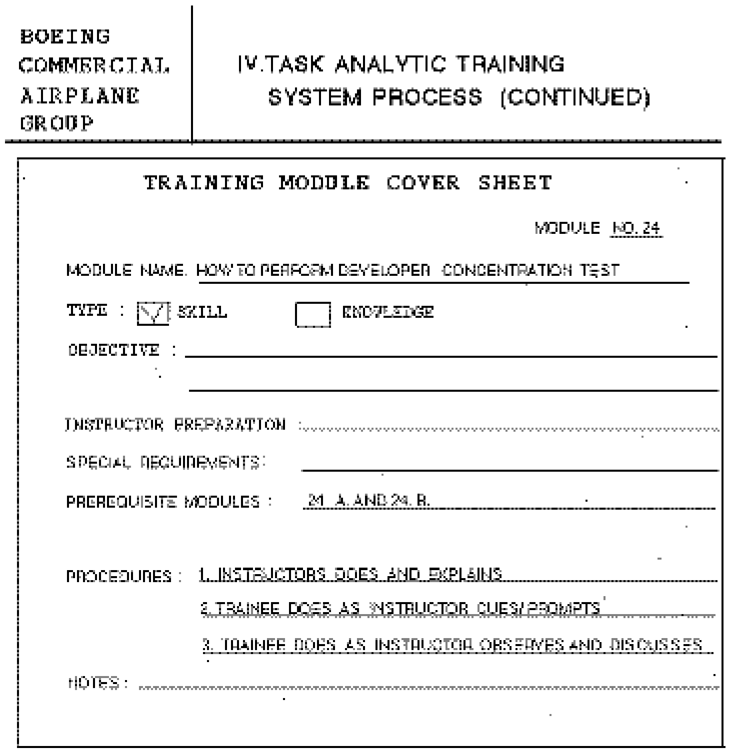
Project Plan - Step 3

After the job breakdown is complete, the design team creates a plan to keep the rest of the project on schedule. Identified tasks are ranked according to frequency, criticality, difficulty, degree of danger, etc. Some modules may need to be completed first in order to begin training on those tasks right away. A benefit of putting the project plan together as a group is the assurance of buy-in or group ownership. People tend to support their own ideas. Upon completion of the plan, the team obtains supervisory approval. This helps to strengthen management involvement and commitment.

Write the Training Module - Step 4

Initially, two or three modules are selected in order for the team to learn the writing format. The level of complexity written into a module is critical. Too little detail means the module is unusable because of insufficient information. Too much detail results in a standard operating procedure that is cumbersome and difficult to modify. Generally, writers include enough material to serve as memory joggers for an instructor experienced doing the job. During the writing phase, the team engages in varying activities: meeting other teams in different areas; discussing forms and formats; providing periodic reviews to management; and verifying modules on-site. Each module is verified on-site at least twice: (1) by a trainee with an instructor, and (2) by at least one member of the approval team. Also, during the writing phase the team conducts workforce overviews to review modules with workers not on the design or approval teams. All members of the workforce are encouraged to contribute.

Figure 3 shows a typical learning module cover sheet. The cover sheet prepares the instructor and trainee to try out the tasks written in the module. **Figures 4**, **5**, and **6** provide examples of the training modules. The easy-to-read-and-use format promotes workforce acceptance and increases the likelihood of the modules being used for quick task references.



BOEING COMMERCIAL AIRPLANE GROUP

IV.TASK ANALYTIC TRAINING SYSTEM PROCESS (CONTINUED)

TRAINING MODULE COVER SHEET

MODULE NO. 24

MODULE NAME. HOW TO PERFORM DEVELOPER CONCENTRATION TEST

TYPE : [✓] SKILL [ ] KNOWLEDGE

OBJECTIVE :

INSTRUCTOR PREPARATION :

SPECIAL REQUIREMENTS:

PREREQUISITE MODULES : 24 A AND 24 B

PROCEDURES : 1. INSTRUCTORS DOES AND EXPLAINS
2. TRAINEE DOES AS INSTRUCTOR CUES/PROMPTS
3. TRAINEE DOES AS INSTRUCTOR OBSERVES AND DISCUSSES

NOTES :

Figure 3

BOEING COMMERCIAL AIRPLANE GROUP

IV. TASK ANALYTIC TRAINING SYSTEM PROCESS (CONTINUED)

TRAINING MODULE NO. 24

TITLE: HOW TO PERFORM DEVELOPER CONCENTRATION TEST

COLUMN 1. WHAT	COLUMN 2. WHY, WHEN, WHERE, HOW
1. LOCATE EQUIPMENT	1. SHORTAGE CABINET NO. 2
2. CLEAN EQUIPMENT IF REQUIRED	2. WATER RINSE AND DRY
3. PERFORM TEST	3 A. FILL CYLINDER WITH DEVELOPER B. INSERT HYDROMETER C. TAKE READING OF SPECIFIC GRAVITY (SEE MODULE 24.a.) D. LOCATE TEMPERATURE VS. SP. GRAVITY CHART AND FIND SP. GRAVITY ON CHART (SEE MODULE 24. b)

Figure 4

BOEING COMMERCIAL AIRPLANE GROUP

IV. TASK ANALYTIC TRAINING SYSTEM PROCESS (CONTINUED)

TRAINING MODULE NO. 24.b.

TITLE: HOW TO READ TEMPERATURE VS. SPECIFIC GRAVITY CHART

COLUMN 1 WHAT	COLUMN 2 WHY, WHEN, WHERE, HOW
1. LOCATE CHART FOR APPROPRIATE DEVELOPER	1. RECORD BOOK
2. LOCATE TEMPERATURE AND SPECIFIC GRAVITY ON CHART	2. SEE DIAGRAM
3. DETERMINE IF WITHIN ACCEPTABLE LIMITS OF ±10 PERCENT	3. SEE DIAGRAM

Figure 5

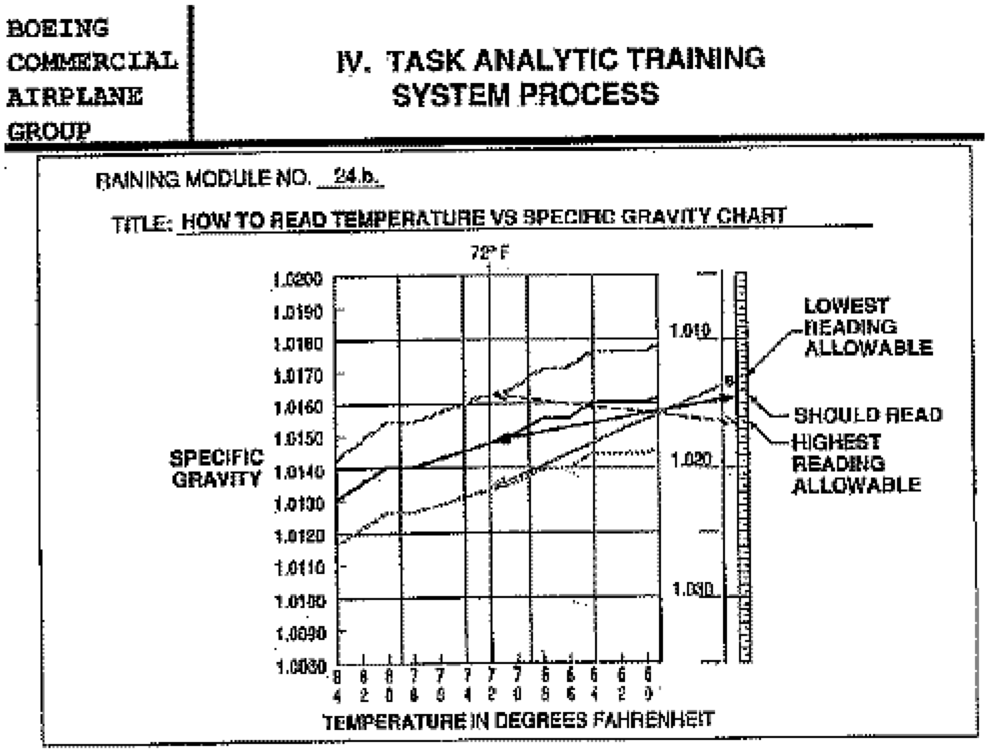


Figure 6

Training Implementation Plan - Step 5

Near the completion of module writing, the team, together with supervision, prepares a preliminary implementation plan. They conduct workforce evaluations to determine:

1. Who needs training in which modules and by what dates.
2. Who will do the training.
3. How results of training will be measured.

A person is assigned to prepare individual plans, taking into consideration:

1. Prior skills and knowledge brought to the job by trainees.
2. A logical sequence for presenting the modules.

Tryout, Evaluate, and Modify - Step 6

Important with the first and subsequent use(s) of the training module is the attention paid to the "fitness for use" of the documents. This term refers to how closely the training materials meet the needs of the workers. The Task Analytic Training System encourages any additions, deletions, or corrections. Anyone may suggest changes, including the trainees.

Set-Up Maintenance Plan and Audit - Step 7

Teams distribute manuals in work centers for use as resource guides. All personnel, from line managers to operating staff, have some ownership of the system. To keep the manuals up-to-date, each manual includes copies of change sheets. Change sheets are simple forms for identifying modules and the changes required. One member of the workforce is assigned to serve as an administrative coordinator to handle the records, forms, manual updates, etc.

The facilitator schedules annual audits to assess the status of the Task Analytic Training System in the particular work area. The audit is a checklist evaluation of critical areas of the process. During this evaluation, the facilitator looks for:

1. Signs of program obsolescence.
2. Identification of new training needs.
3. Opportunities to streamline the process to make it more cost-effective.
4. Organizational changes that impact training.

Start Training - Step 8

The on-site training in the Task Analytic Training System incorporates traditional job instructional training (JIT) techniques. First, an instructor demonstrates the skills to the trainee. Next, the instructor coaches the trainee through the elements of the task while the trainee performs them. Finally, the trainee does the task without coaching. Both instructor and trainee discuss results afterwards. Trainees are then encouraged to practice the new skills until they feel comfortable with them. At the conclusion of training, evaluation questionnaires are given to both trainees and instructors. The questions are open-ended to solicit as much spontaneous information as possible.

Benefits of the Training System to Employees and the Company

The numerous benefits of this system to employees include:

- Job satisfaction
- Improved attitude and morale
- Boosts to self-esteem
- Ownership of the system
- Improved communication with management
- Training directly related to the job
- Immediate and specific feedback
- Flexibility.

The results for the company are:

- Better trained workforce
- Reduced process variation
- Employees interested in doing the job
- Increased productivity
- Lower turnover
- Decrease in time to learn a new job/task
- Higher quality work
- A program where results of training are observable and measurable.

Summary

The Task Analytic Training System is uniquely based on three interacting components:

1. job task analysis;
2. job instruction training; and
3. social psychology theory.

All three components interact to tie in skill, knowledge and attitude. Attitude is the key and must be designed into the program. The training system is a generic process applicable to any job. It provides a program that is ongoing. By the nature of its design, it addresses remedial, recurrent, and first-time training. The Task Analytic Training System produces a trained workforce whose performance can be observed and measured against carefully identified standards.

The critical role of teamwork and full worker participation in the training program development is key to the success of the program. It is a system that develops the people resources of the company by encouraging the contribution of all and stressing cooperation with others as the solution to problems.

Currently, the Task Analytic Training System is evaluated subjectively by the recipients of the program. Future research may yield data to support the system's claims of higher output in terms of productivity and quality.

DEVELOPMENT OF MAINTENANCE TRAINING FOR A NEW AIRCRAFT COMMERCIAL TILT ROTOR PROGRAM

Thomas Cooper
Bell Helicopter Textron

I am very pleased to represent Bell Helicopter Textron here this afternoon. I would like to talk about some initial considerations for development of maintenance training for a new aircraft.

First I would like to present the aircraft; then I will identify some of the challenges to be met in developing a maintenance training program and some of the resources available at this time that will facilitate the development of a maintenance training program for the Commercial Tilt Rotor Airplane.

We at Bell Helicopter Textron feel that training is the major variable in aviation safety and accident prevention. We also feel that training plays a major role in direct maintenance cost reduction, and that it is a significant key to business success.

Tilt rotors are coming and will bring a new era in aerial flight. Actually, tilt rotors are already here. The first patent for a tilt rotor was issued to George Lehburger in the United States in September of 1930. Some 25 years later, the Bell XV-3 flew for the first time. Twenty-two years after this, the Bell XV-15 made its first flight. Then, in 1989, the Bell-Boeing V-22 Osprey, shown in **Figure 1**, had its maiden flight. Finally, to complete this development program, by the end of the century, the Bell-Boeing Commercial Tilt Rotor airplane will fly for the first time.

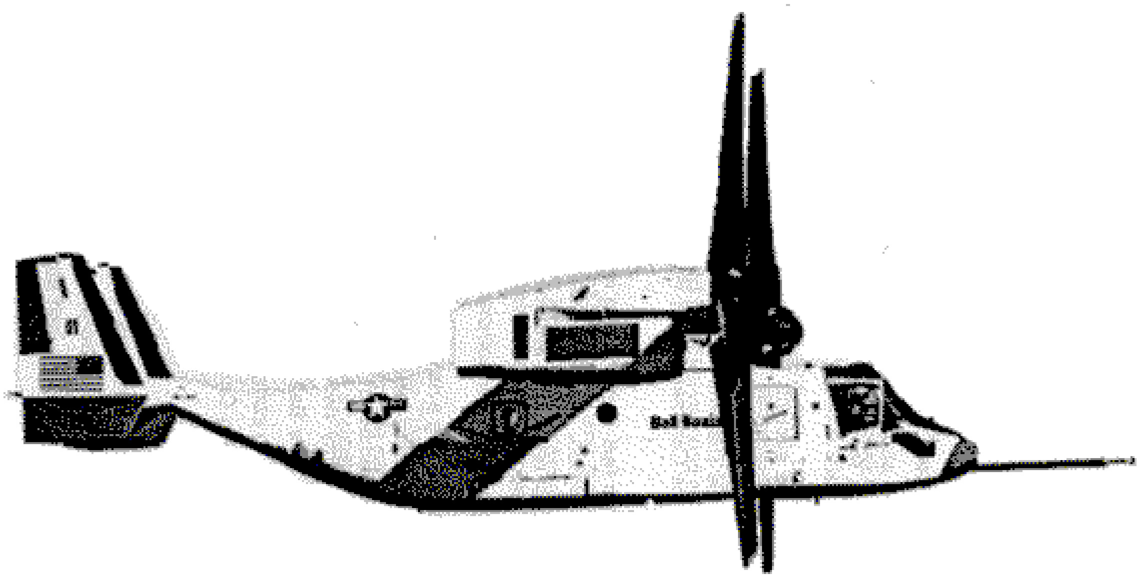


Figure 1 The Bell-Boeing V-22 Osprey aircraft, a predecessor of the Civil Tilt Rotor Airplane

A tilt rotor is a turbo-prop airplane that does not need a runway and is not bothered by airfield obstructions. It is a turbo-prop airplane that requires a verti-port for operations of about four and one-half acres. This is just over half the grazing area required by one Texas cow, 4.5 versus 7 acres. The Civil Tilt Rotor will find use in three major areas. First in air transportation; and in air cargo operations; and in public service.

In air transportation, a tilt rotor airplane will relieve airport congestion. It will operate at feeder hubs and provide portal-to-portal service. It also will be capable of operating from both skyports and verti-ports, offering transportation both for corporate and private users. Verti-ports, airports designed for vertical takeoff and landing aircraft, add to the advantage of tilt rotors because they are easy to locate and relatively cheap to build when one considers the cost of airports. Also, verti-ports can be located at waterfront space not being used today.

In air cargo service, a tilt rotor is capable of carrying internal cargo to unimproved areas where construction might be ongoing or where other work is being done. The airplane also can handle package services to inner-cities, such as provided by overnight delivery companies today. The tilt rotor also can support offshore oil production activities located as far as 600 miles off shore.

The tilt rotor aircraft also can work in public service and provide emergency medical services. One good feature of the tilt rotor for search and rescue is that, when hovering over a person in open water, the water remains calm. The tilt rotor does not create the turbulence that comes from the rotor wash of a helicopter. Tilt rotors also can be used in disaster relief, such as for floods or hurricanes, by reaching areas inaccessible to fixed-wing aircraft.

Design objectives for the Civil Tilt Rotor include normal operating route segments in the range of 600 to 800 nautical miles. The aircraft will offer a pressurized cabin, all-weather operation capability, and noise levels that meet both cabin interior requirements and community noise requirements. Utilization objectives include 2,000 to 3,000 hours per year with dispatch and completion rates of 99.5 percent or better. The tilt rotor will work as a turbo-prop airplane 90 to 99 percent of the time while in the air carrier business operating as a regional airline. It will operate as a helicopter from one to ten percent of the time. Speed range of the aircraft will be from -45 knots to +316 knots. It will have an altitude service ceiling of over 26,000 feet, with an endurance of over five hours, and a range in normal configuration of 1,100 miles. In ferry configuration, range will be 2,100 miles.

The envisioned economic impact of the Civil Tilt Rotor is impressive. The Tilt Rotor Program will mean a several billion dollar increase in national economic activity during the first decade of the 21st century. This will have a considerable net effect on balance of trade and will create over 100,000 jobs. The Civil Tilt Rotor will retain a unique technology in the United States.

Maintenance and Training Challenges

Challenges for maintenance and training associated with the Civil Tilt Rotor airplane derive principally from the fact that this is truly a new aircraft. First, the fuselage is made of composite materials, including graphite, fiberglass, kevlar and other materials, with the greatest percentage being graphite. The aircraft uses a prop rotor rather than either a propeller or rotor. Rotor blades are independently removable and work as a fail/operate system. If an engine fails on one side, the other engine carries both prop rotors. The same with the tilt axis. If one fails on one side, the other will tilt the other side. The fly-by-wire flight control system will incorporate considerable software, with all the maintenance and training considerations that go with such software use. The plane has a 5,000 lb. psi hydraulic system, primarily for weight and convenience, because this permits hydraulic actuators to be smaller and hydraulic lines to be smaller. The plane will include an advanced cockpit display and avionics systems. It will also offer an advanced health monitoring system, providing information to the pilot on current functioning of the aircraft, and utilization monitoring system, being information taken for evaluation at a later time.

The development of training resources to provide a maintenance capability for an aircraft such as the Civil Tilt Rotor represents a challenge. Management, facility, curricula, and utilities all are important and must be considered at this time even though the aircraft itself is some years in the future. We must identify the skill levels required for mechanics and the future availability of these skills. Building an efficient maintenance workforce will not be a simple matter. I have talked with repair station operators in the Dallas area who tell me they must hire about five people before they get one who stays on the payroll and who provides a return on their investment.

The Bell Training Academy is looking toward the 21st century maintenance and inspection environment. We can see there will be a tremendous change in that environment over the one existing today. Our training resources must begin even today to gear for this future period, and we think the Bell Training Academy is doing that. Our academy is an FAA-approved flight school with an FAA- approved maintenance or manufacturer's maintenance facility. We train mechanics but they only receive a Certificate of Training. They are already qualified mechanics when they arrive at the Bell Training Academy. As a rule, these mechanics have been in the field for at least two years and are usually sent by their company. Since we provide advanced training and deal with a rather select group of trainees, we do not see some of the problems others of you have with those persons initially entering a training school.

One of the variables an advanced training school does have to deal with is the diversity of background in its students. In 1989 we trained some 2,399 people in our flight and maintenance training programs. These students represented 48 different countries, representing nationalities as far apart as Tahiti and Norway.

One of our more significant accomplishments concerns the provision of training for organizations using helicopter transportation to provide emergency medical service. **Table 1** shows the accident rate for emergency medical service (EMS) operations, beginning in 1984 with a rate of 14.2 per 100,000 patients transported. This high accident rate was attributed both to those persons who were dispatching EMS missions and to pilots who would accept any mission as given to them. In 1986, Bell Helicopter, in concert with other manufacturers, established a training program and delivered this program to field operations. We taught dispatchers how to dispatch and pilots how to determine whether they should say yes or no. The resulting dramatic drop in the accident rate, a value of 3.8 per 100,000 missions in 1987, surprised everyone.

Table 1

EMS Accident Rate History
(Accidents per 100,000 patients transported)

YEAR	RATE
1984	14.2
1985	15.3
1986	15.4
1987	3.8
1988	4.8
1989	6.6

The training program we are building now for the V-22 Osprey aircraft is positioning us for the Civil Tilt Rotor Program. This is true both for flight training and for maintenance training. For flight training, we have developed our training and training equipment plan, have held eight training conferences, have conducted initial pilot training, and are well on our way toward development of the Operational Flight Trainer. We also are proceeding with the development of a maintenance trainer for the aircraft. Specifications for the maintenance trainer have been approved and competition for its development and production is completed.

We are developing maintenance training facilities at the Academy to be as modern and efficient as we can make them. Our maintenance training staff includes a number of instructors with advanced degrees, as well as others who are multi-lingual. Our classrooms are structured to make training as efficient as possible. In the shop area, we have a number of systems trainers in order to provide hands-on experience in assembly and disassembly for trainees. We also use the latest training aids developed for the aircraft we support.

The key ingredients for the development of a maintenance training program for a new aircraft are the aircraft itself, the development of knowledge of its systems and their operation, and the prudent use of existing training resources. A good maintenance training program is essential; first for safety and second for reducing direct maintenance costs. The data we have collected at Bell show us that the more a mechanic knows about the piece of equipment he is maintaining, the less it costs to operate it. Since it is good business to keep one's costs down, it follows that it is good business to develop an efficient training program. Maintenance and inspection training must have high priority. The attitude of management, pilots, and mechanics toward training must be positive. Nothing must compete with training requirements, and nothing must have priority over the best maintenance and inspection practices. Recurrent training and constant management are essential parts of the maintenance process. New aircraft, such as the Civil Tilt Rotor Airplane, will be very sophisticated vehicles. In order to ensure that the maintenance process is as effective as it can be, we at the Bell Training Academy are working today on the development of this process. Through proper training and support, an effective maintenance program will offer benefits in terms of workforce efficiency, improved safety, and cost reductions.

MAINTENANCE TRAINING -- A VIEW FROM THE FLOOR

John Goglia
International Association of Machinists and Aerospace Workers

I am a mechanic with USAir and, since 1972, have been either lead mechanic or an inspector on the midnight shift where a considerable amount of aircraft maintenance is accomplished. The years that I've spent as an inspector required that I be qualified in non-destructive testing (NDT) methods and the use of radiographic, eddy current, and ultrasonic test equipment. Additionally, since the early 1970's, I have been the mechanic representative to a number of on-site crash investigations and subsequent follow-up investigations. It is from this background that my comments flow.

I am sure that everyone here would like to find a source of mechanics with an A&P license, five years experience, good troubleshooting ability, and some electronics background. Well, that person is just not out there looking for work. As a result, airlines are now selecting new hire mechanics with little or no experience. Since today's training for an A&P license is geared toward general aviation, with the main objective being to pass the test, it is imperative that a new hire mechanic receive formal training on the type of aircraft he is working on, plus training on the policy and paperwork procedures of that airline. This should be required by regulation. A serious effort should also be made to provide meaningful on-the-job training and skill transfer from the more experienced mechanics. This does not occur as much as it should when one considers the number of new mechanics in today's airline maintenance activity.

Although there is hope that Part 147 will be revised in such a way that airlines are provided more qualified graduates, many in the air transport industry fear that the Federal Aviation Administration (FAA) will simply "shoot themselves in the foot" once more. In fairness to the

FAA, it would be much easier to prepare a regulation that would accomplish these goals if it were possible to eliminate the requirement for input from politicians, political appointees, and special interest groups.

Although it is just another factor in our work life, new, low-experience mechanics will be with us for a long time. I can tell you from first-hand experience that you haven't lived until you've tried to accomplish a "full plate" of RON work with a low-experience crew, and still make schedule in the morning. It is an experience that I wish we could share with the Vice Presidents of Maintenance and others in management.

During the last 10 years my employer, USAir, has experienced tremendous expansion of both its fleet size and its maintenance staff to support this fleet. As a result of several mergers, the fleet mix has become quite different. In fact, it is not uncommon to have five or six 737-type aircraft in on RON maintenance and not have two of the same type. This problem is not unique to USAir. It is experienced by most, if not all, air carriers today.

As a result of this fleet mix, the proper use of the aircraft maintenance manuals becomes critical. During many years of observing maintenance work, I noticed that mechanics who mastered the use of maintenance manuals were better performers. The spotty use of the maintenance manual crossed experience lines. It didn't matter whether the mechanic had 25 years of experience. Some would use the manuals, while others would not. And some new hires would use the manuals very well while others would not look at them. I don't know why some mechanics think that going to the manual means that they are not knowledgeable, but we must take steps now to put our people back into the manuals.

The first training a new mechanic receives should be on the use of the aircraft manuals. This training should be conducted on the mechanic's first day on the floor. Mechanics already working on the floor should receive recurrent training on use of maintenance manuals.

In addition to maintenance manual training, a thorough explanation of required paperwork is essential. The largest single problem I as a Union representative face today in dealing with enforcement action taken by the FAA is incomplete or incorrect paperwork. Therefore, we believe that training in both the use of maintenance manuals and completion of required paperwork should be provided at the beginning. We also support a program of requiring this training by regulation.

Another issue that bears discussion is that of regularly scheduled recurrent classroom training. This type of training is essential in order to stay current with today's complicated integrated aircraft systems. The IAM&AW advocates a minimum of 40 hours of classroom training per year for all mechanics working in the line maintenance areas. Another recommendation is that aircraft manufacturers provide pocket size guides to component locations with access panels and station numbers identified. Basic system operation and normal indications should also be observed. This would do much to assist the mechanic and would lessen the tendency to rely on one's memory when checking out a system.

Another important matter is communication. The ability to communicate is a basic tenet of modern society, and yet poor communication is cited repeatedly as the cause of many workplace problems. We have the good fortune to work with some of the most sophisticated pieces of machinery that technology can produce, and yet we continue to have miscommunications between departments, within departments, and between companies. Maintenance information systems can go a long way in helping with this problem, but they must be maintained, and they must have the support of everyone.

My last point of discussion concerns interpersonal skills. I believe we need to train our supervisors more in people skills. Supervisors today are chosen for a number of reasons, but usually not for people skills. Yet people skills are an important part of a supervisor's job. He has to motivate, to communicate, and generally see that his workers are working to their best. Supervisors should receive some training in people skills -- in the ability to work with and to motivate others.

I thank you for your time and attention. It has been a pleasure working with all of you.

AIRLINE MAINTENANCE TRAINING - EXPERIMENTAL TRAINING SYSTEM THE HUMAN FACTORS OF ADVANCED TECHNOLOGY MAINTENANCE TRAINING SYSTEMS

Kenneth Govaerts, Ph.D.
AMR Technical Training
and
Andrew Gibbons, Ph.D.
WICAT Systems, Inc.

"Aviation in itself is not inherently dangerous, but, to an even greater extent than the sea, it is terribly unforgiving of any carelessness, incapacity, or neglect."

Introduction

This unreferenced quotation, although credited to an aviator of a generation long past, is still applicable to modern conditions. The human factor in aviation has always been and will continue to be of critical importance. Even with the vast technological advances that have occurred in aviation, it is still the experienced vigilant pilot and mechanic along with a host of competent support staff who keep the industry functioning. Aviation is definitely a labor intensive industry. With the unprecedented development and growth of aviation during the last decade and projected into the 21st century, there is reason for all of us to be concerned about training the people who will become responsible for operating and maintaining the large fleets on which the world's commerce increasingly depends.

Many dramatic occupational changes have occurred in aviation in the past decade with the introduction of the advanced technology aircraft. It will no longer be the "mechanic" who works on the aircraft, it will be the "aviation maintenance technician." The job now requires much more than a mechanical aptitude and a box of tools. The change in title is only an indicator of real changes in the job caused by advances in technology. Obviously, there are implications for training resulting from these changes. Those of us responsible for training must, at the very least, examine our old philosophies, curricula, and methods. If the curriculum is inadequate, and if educational methods are outmoded, they can, and should, be revised. Just as technology has radically changed the way aircraft are operated and maintained, there is an equal opportunity for innovative approaches to training that will keep pace with the sophisticated job requirements of the modern aviation work environment.

Our purpose today is to discuss an instructional concept that is intended to advance the use of the computer as a tool for aviation maintenance training. We will demonstrate a prototype segment of competency-based instruction through the use of a device called an evaluator. This concept of CBT will show how the computer can be used to a much greater advantage through practice of real job applications with immediate feedback. The prototype will form the basis for a much larger curriculum design and development effort over the next four to five years.

The Computer in Aviation Training

It is no longer doubted, as it once was, that the computer can function effectively as an instructional tool. The mass of evidence from both education and training is sufficient now to convince even the strongest skeptic that computer-based instruction can equal the best instruction delivered by traditional means in most content areas and for most types of outcome. Though none would maintain that a computer can replace an instructor, it is now clear that the computer can act very effectively as a supplement to the instructor by performing mundane, repetitive tasks, and leaving the instructor more freedom to consult, guide, and motivate. However, even this time tested use of CBT is less that ideal. There is a more sophisticated role for the computer in education that will more effectively utilize its power and capacity. This new role is the subject of our discussion and demonstration.

As is the case with other instructional innovations, CBT has tended to follow traditional lines rather than those defined by its unique instructional abilities. It is the "new wine, old bottle" syndrome that has plagued most instructional innovations of this century. Just as early video productions consisted of talking heads on the screen in imitation of the classroom instructors, the computer too often is assigned the mundane task of conveying information and asking verbal quiz and test questions. The result is the equivalent to using a sledge hammer to drive a ten-penny nail.

In computer-based instruction, the early use of computers tended to be in two major areas. One was the creation of tutorials, which can be mass produced at a relatively low cost and which take over a certain amount of the telling function of the instructor and a small portion of practice. The second was in simulation, for example, electrical control panels and indicators related to the operation of systems. Behind the control panel is a schematic of the electrical system which is alive to our manipulations. The computer-based simulator constitutes a live model of the electrical system which allows one to operate it from the panel. All the switches, controls, and indicators are operative and will give a realistic manifestation of what would normally happen if any switch or control is operated.

The computer-based simulator exceeds the functions normally performed by a portable mock-up maintenance training device. The instructor is capable of demonstrating panel controls and indicators as well as their relationships to the schematic and what is actually happening inside the system. It provides a cause/effect illustration and allows introduction of faults into this system. Once this is done the system operates faithfully to the faulted version of the system. This becomes a very effective instructional tool, particularly for use by instructors. It gives them the power of display that they need and yet the flexibility of control that they want. If this was as far as computer-based instruction had progressed, it would be a very useful tool, but we believe that one gap has developed in application of computers for instruction.

Even with sophisticated simulations, what very often gets left behind is trainee feedback. Feedback is an important part of the instructional process for two reasons. First, it gives students knowledge of results so they can understand whether their answer was correct. Second, it helps students to establish a self-monitoring capability which is essential for real-world performance. This is one of the aspects of feedback that is often overlooked. It is the very thing that allows the student to become an independent agent in the field. This self-monitoring capability is very important in a person. For this reason we have begun exploring a concept which we call the Maintenance Evaluator.

The Concept of an Evaluator

A more appropriate way to use computers in training is to use them as actual instructional devices. Designers of CBT lessons may argue that this is precisely how computers have been used in the past. Admittedly, tutorials and equipment simulators are being used effectively in the context of the traditional learning environment. But instruction consists of much more than the temptingly simple processes of conveying information and simulating equipment. Instructing is a multi-functional process that includes among others, setting problem scenarios, providing feedback and prescribing remediation.

An example of this use of the computer is the concept of the evaluator. Evaluators are simulations to which have been added: (1) a specific scenario or problem to be solved by the student, (2) an action environment in which the student is to solve the problem (3) an extended feedback mechanism capable of reviewing student performance in detail during problem-solving. Because the evaluator is based on a situation simulation, the student may take actions in any order and observe realistic results. Feedback is given after the conclusion of the problem or at the student's request.

The use of simulation exercises for higher levels of learning is common today in some areas of training. Airline pilots both train and certify using costly but realistic aircraft simulators. These simulation exercises and others like them which are used in other fields for training fill the first two criteria listed above for evaluators; scenario-basing and the use of simulation in a problem-solving environment. However, they do not satisfy the third, which is critiquing or providing feedback to the student.

The uncommon feature of the evaluator, the one that distinguishes it from the standard simulators, is the extended and detailed feedback provided following practice. Though trainers generally recognize the desirability of this type of feedback, the tools for providing it have not been easy to use or easily accessible. Moreover, the principles to guide this extended feedback process have not been identified and tested by instructional theorists.

The feedback given by an evaluator should be modeled after that which would be given by the most expert, patient, and painstaking of live instructors. This does not suggest that an evaluator should or even could be used to replace a live instructor, but it does mean that the evaluator should be capable of providing a more detailed level of feedback than most instructors have the time or ability (due to the extreme pressure it would place on memory) to provide. Moreover, it should do so under the control of the student, allowing repeated replays, restarts, and rehearsals of problematic sequences of action and offering appropriate remediation or review experiences to bolster areas of need.

The Evaluator focuses on higher level skills rather than on basic skills that are more appropriate to tutorials. It emphasizes the integration of skills rather than fragmentation of skills which is typical of traditional training methods. Finally, it frees instructors from a more subtle problem, which we call the lexical-loop, which has hampered a good deal of our training.

The lexical-loop is the emphasis on training at a verbal level for skills which are not verbal in nature. An example of the lexical-loop can be found in sports. A football coach or a soccer coach is caught in the lexical-loop if his training consists of chalk talks, followed by a verbal test. We would not be satisfied with a coach who only gave lectures. We would say that the coach is caught in the lexical-loop, and so much of training unfortunately also is caught in the lexical-loop. There is an example of an Electronics Maintenance Training Course given by the Army for radar technicians. The course had 26 weeks of classroom training with perhaps a total of five days of hands-on equipment experience. For the five days of hands-on work, most of the equipment was broken. There was a 75 percent performance rate on that equipment. This means the students had 75 percent of five days of experience, and since that experience was conducted in groups one can imagine how much actual learning took place.

Training programs are not the only systems caught in the lexical-loop. The education system also suffers. At one time, research was conducted to determine how much of each day a student actually spends in interactive learning; that is, in individual practice with feedback. The answer we found in the literature was six minutes or less per six-hour day. The educational system has fallen into the lexical-loop. Teachers are doing a tremendous amount of telling; they are not doing much interacting; and are doing even less feedback. The presentation that follows will describe an evaluator created for use in ab-initio maintenance training. This is a scenario-based simulation and is representative of the type of maintenance problems that can be dealt with by the Maintenance Evaluator. The essence of this problem, in the manner in which it is presented to the trainee, is as follows:

> **The trainee is notified, by computer printout, of a problem on an incoming flight. The problem says that at flight level 320, in cruise, the left air conditioning pack light illuminated, and the maintenance alert system showed a temperature message. As the aircraft now is shown to have arrived at the gate, the trainee has thirty minutes in which to deal with the problem before the plane must be released. In this computer simulation, the trainee finds himself in a maintenance shop. Through use of control icons, he has manuals, a parts room, a telephone that can be used to call various service organizations, a computer containing a maintenance data base for**

this aircraft, a microfilm reader for the maintenance manual, a printer which can be used to print out data base-records, and the aircraft itself.

The trainee first goes to the manuals. Here he can find the minimum equipment list and can learn that he is dealing with a normal complement of two air conditioning packs. The manuals provide descriptive information concerning these packs and could offer initial guidance as to the problem.

The trainee also can turn to the computerized data-base for this particular aircraft. Here he can get a thirty-day history of all systems, a five-day history of all systems, a thirty-day history of the aircraft itself, and a five-day aircraft history of this problem. If the trainee wishes, he can request a printout of these histories which he then will be able to carry with him on his clipboard.

The trainee also can go into the parts room, where he might decide to look at control modules for the air conditioning system. He can also determine which parts for the air conditioning pack are on the shelf. In the simulation, when the trainee orders a part, it disappears from the control room shelf and now is listed as being carried by the trainee.

Next the trainee may wish to go to the aircraft. The simulation allows him to leave the maintenance shop and proceed to the aircraft cockpit, where he may speak to the Captain concerning the aircraft status. He may also want to look into the aircraft logbook or proceed directly to the control panels to examine the air conditioning panel. Here, he can activate the air conditioning system and test it as appropriate. In this particular scenario, a lamp test indicates the left pack compressor outlet sensor is at fault. However, the trainee proceeds with replacement of the part he brought, the left pack controller.

Finally, having made an incorrect repair, the trainee returns to the shop to make an entry into the aircraft logbook. As he is doing his evaluation and repair, he is reminded by way of "Announcements" that so much of his allotted repair time has been taken. When the trainee feels the problem is resolved, the problem scenario is closed and the critique can begin.

At this point, The Maintenance Evaluator, a computer program designed to critique maintenance simulation problems, is used. The Maintenance Evaluator works from a student's event file which has a record of every action and information request made by the student. The Evaluator uses an expert system program for assessing the actions of the student.

The Evaluator works on the basis of three priorities, in this order. First, actions must ensure inflight passenger safety. Next, actions must ensure safety of airline personnel and integrity of equipment. Finally, actions must maintain the airline flight schedule. The expert system will use these criteria to judge the actions of the trainee in solving this particular problem. A detailed assessment of performance is provided. This assessment lists actions which were not done, those done improperly, and reviews the proper route to a solution. In this scenario, it tells the student he replaced equipment but did not review the repair procedures. It notices that he bypassed the maintenance manual and made a repair without proper reason to do so. It also notes that he did not carry all items needed for the replacement as prescribed in the maintenance manual. He replaced equipment but did not test such equipment following the repair. In all, The Evaluator reviews each action taken by the student, describes its appropriateness, and presents proper actions toward a solution.

The Maintenance Evaluator just described is a prototype version. Designers are in the process of improving the variety and kinds of feedback that can be provided to trainees. In the course of building this system, it was discovered that principles for providing feedback following extended exercises of this sort are almost non-existent. Such information resides in the experience of expert instructors. For this reason, there is an attempt to identify rules used by excellent instructors and to build a model of the feedback process. This will provide a basis not only for improving the computer program but also should provide information for improved training of actual instructors.

Conclusion

The unprecedented technological advances and the growth that has occurred in the past decade in commercial aviation are expected to continue unimpeded into the future. An educational system that supports progress in any technological field also must advance in order to accommodate the changing role of qualified professionals in these fields. In aviation maintenance the educational system has not kept pace and there is an urgency worldwide among training professionals to re-design the curriculum content and instructional methodologies to accomplish this goal.

Although technology-based training methods have been used extensively in aviation for a decade, the costly full-flight simulators used for training pilots have provided the first success in keeping pace with the greater demands for training. Aviation maintenance remains essentially entrenched in conventional classroom, instructor-led training methods.

The concept of the evaluator with its scenario-based problem solving, practice and feedback may be the breakthrough for maintenance training equivalent to the full-flight simulator.

The new system is capable of bringing students from entry-level through a training experience to real world capabilities. These attributes, along with performance orientation it fosters in training design and development, make it a valuable step forward in improving the relevance and completeness of training systems to meet the challenges of aviation in the future.

INTRODUCING CRM INTO MAINTENANCE TRAINING

William R. Taggart
Resource Management Associates/
Pan American World Airways, Inc.

Cockpit resource management (CRM) training is a program to ensure that flight crew teamwork and coordination are optimal and that best use is made of all cockpit resources, including people, information, and equipment. Over the past ten years, most of the major airlines have adopted some form of CRM training and the Federal Aviation Administration (FAA) is preparing to make CRM training mandatory. Use of this training is based on the recognition that most airline accidents have resulted from failure of crews to interact properly or to use effectively all available information as conditions deteriorated. By all accounts, including NASA-sponsored research, CRM has been accepted by airline management and by flight crews and flight deck performance has benefitted. With this experience to draw on, the operations management of Pan Am felt that the type of training being provided for flight crews might also be useful for maintenance managers.

The maintenance CRM program at Pan Am began in November 1989 when a group of maintenance management personnel attended one of the flight crew CRM training programs. As a result of their positive response, a Steering Committee was formed to review the flight crew program and to tailor it for use with maintenance managers. These managers range from maintenance supervisors to the Vice President of Maintenance and Engineering.

The Pan Am CRM program for maintenance is called MELD, an acronym standing for Maintenance, Engineering, and Logistics Development. The purpose is to improve performance within these three areas through improved teamwork and coordinated use of available resources. Several test programs have been run in recent months and initial results are available. I would like now to describe the foundations of the Pan Am program, and review the initial results.

The basis for CRM programs, as with all activities directed toward flight safety, can be found in the track record of aircraft accidents. Boeing has been studying accident trends, and **Figure 1** shows the trends in accidents and fatalities for the commercial jet fleet over the past 30 years. The initial drop in the accident rate in the early 1960's, of course, can be attributed to increased experience with jet airliners and the introduction of second generation jets. Since about 1970, the rate has been relatively constant, with fatalities showing fluctuations up and down roughly each year. However, the most recent chart, just completed in 1989, shows a sharp increase. Airplanes are bigger and the number of departures continues to grow.

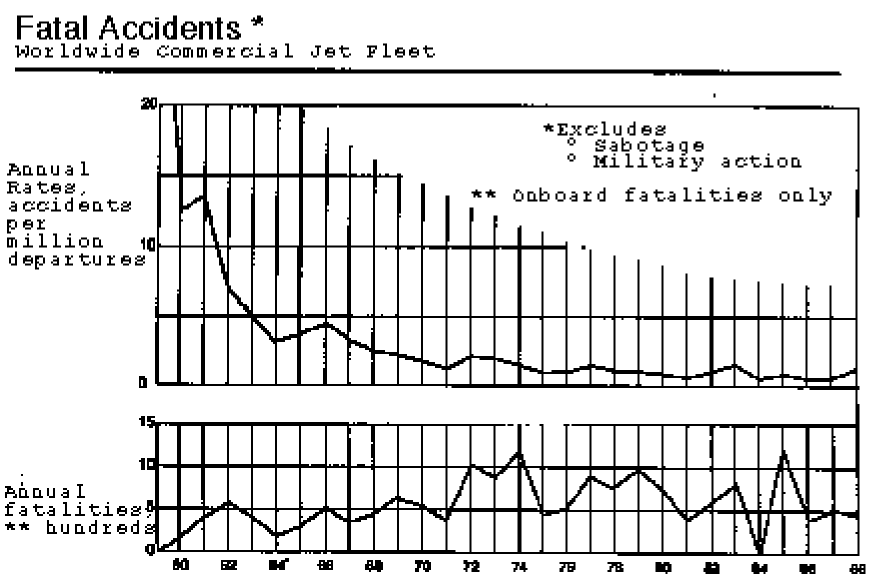


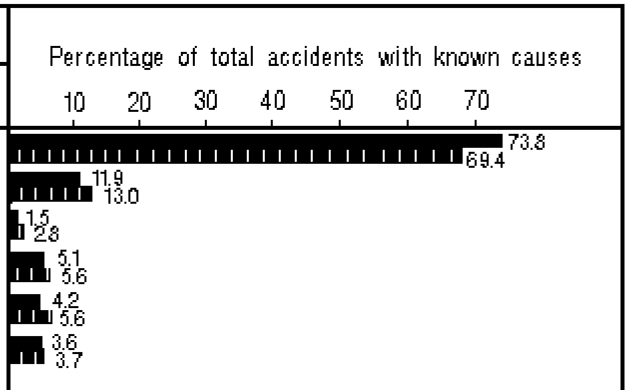
Figure 1 Fatal Accidents

The traditional response to this accident footprint is to strive for improved safety through greater use of technology. Increased use of computers, better automatic test systems, introduction of composite structures and fly-by-wire control systems, and greater reliance on system redundancy all have been employed. These technological advances are used primarily to improve the flight vehicle but also are intended to enhance flight safety. To some extent, they succeed. However, accidents and major incidents continue.

Investigations of accidents in the commercial jet fleet generally attribute from 60 to 80 percent of them to flight crew factors, as shown in **Figure 2**. Studies also show that a large percentage of accidents occur during initial and final approach phases, just prior to landing. The response to both the flight crew involvement and the phases of flight in which accidents occur has been to initiate programs to improve operating procedures. These involve better policies, better checklists, and, in short, more and better paperwork. When the focus moves to the pilot, correction often involves additional technical training or supervision, or possibly more regulation. Again, accidents continue to occur world wide at an undesirable rate.

Primary Cause Factors -- Hull Loss Accidents*
Worldwide Commercial Jet Fleet

Primary factor	Number of accidents	
	Total	Last 10 years
Flightcrew	248	75
Airplane	40	14
Maintenance	5	3
Weather	17	6
Airport/ATC	14	6
Micellaneous (other)	12	4
Total with known causes	336	108
Unknown or awaiting reports	66	38
Total	402	146



*Excludes
°Sabotage
°Military action

Legend:
1959-1988
Last 10 years (1979-1988)

Figure 2 Primary Cause Factors

Traditional training of flight crews and safety improvement has concentrated on three main areas: Improving technology and reliability; better procedures, and higher quality pilot training. But in the case of pilot training, the historical focus has been on the individual, not on the crews and the resources available to them. The FAA has now recognized that flight crews should be both trained and evaluated as a team as well as concentrating on individual proficiency. The premise that the MELD program is built on is that these same concepts apply to maintenance. In spite of improved technology, better procedures, computer-based training, etc., the frequency of human factors-related incidents is simply too high.

In our MELD effort, we borrowed concepts from the CRM program that have been shown to improve crew teamwork and effectiveness. We deal with issues such as assertion and advocacy. In our first effort to develop a CRM context, we drew on the chain of events in the Air Florida PALM 90 accident at Washington National Airport. Here, the copilot did recognize that something was wrong and he spoke up, but he did it in such a diplomatic, indirect, and oblique manner that the message never got through to the Captain. Other similar accidents of this type include Pan Am/KLM at Tenerife, United 173 at Portland, Oregon, and Avianca at Long Island. We were interested in whether information on flight crew related accidents, with good documentation from cockpit voice recorders and the NTSB investigation, would be seen as relevant to situations paced by supervisors and managers from maintenance, engineering, and logistics.

We were surprised to find that the supervisors and managers did indeed find the flight crew information to be relevant. Furthermore, they could relate information concerning a First Officer who did not do an effective job in communicating his position to actual events in maintenance. The participants were able to reflect on times when they felt an item should be voided or where they had a different proposal concerning a particular engineering change, yet allowed themselves to be overruled. They were able to develop a better appreciation of the importance of teamwork in maintenance operations just as in flight crew activities. In addition, new skills and attitudes about teamwork were developed for use in future job situations.

As we began structuring the MELD program, we developed a list of seven key resource management principles. In large measure, these were taken from similar principles used in flight crew CRM programs. These principles represent topics to be dealt with in detail in the MELD program. The seven principles include:

1. Delegating tasks and assigning responsibilities.
2. Establishing a logical order of priorities.
3. Monitoring and cross checking resources.
4. Assessing problems carefully, avoiding preoccupation.
5. Using all available data to conduct an operation.
6. Communicating clearly plans and intentions.
7. Assuring sound leadership by the person in charge.

Using the above principles, several seminars were conducted for supervisors and managers. The instruction in these seminars was done through use of eight course modules, each using material relating to one aspect of resource management considered to be of particular importance. The topics for these eight course modules were:

1. Interpersonal communication and skills
2. Assertion and conflict
3. Stress
4. Critique skills
5. Value of briefings
6. Situation awareness
7. Leadership behavior
8. Case studies

It is also important to note that the method of training used in the seminars is different from traditional techniques. Participants are grouped into five or six person teams and there is very little in the way of traditional "lecture" style teaching. Instead, line maintenance managers and supervisors work as a pair to administer the seminar, introduce concepts, and manage the various team experiments, case studies, and learning activities. This learning method is interactive and involves the participants in a way that stimulates them to explore new ways of managing and using resources.

Upon completion of the seminars, several measures were taken in an attempt to judge the effectiveness of MELD training. A NASA-validated questionnaire on attitudes is used on a pre/post basis. This survey is included as **Appendix I** of this paper. Results of a question concerning the perceived usefulness of the MELD training are shown in **Figure 3**, based on responses from about 75 to 80 participants. Note that none of these supervisors and managers found the training to be waste of time. This is particularly encouraging since many of the participants were attending the training against their better judgment since there were a host of continuing problems at Pan Am they felt more deserving of their time and attention. Also, many of the participants had been at work since 5:00 a.m. before attending the training program at 8:00 a.m. Many considered this to be a serious imposition on their schedules. However, as seen in Figure 3, over 80 percent of the respondents found the training to be "extremely useful" or "very useful." These responses were quite encouraging.

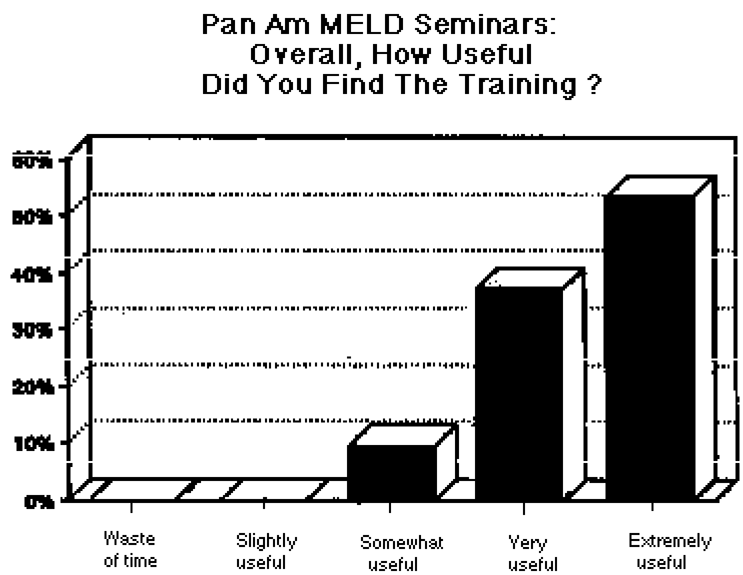


Figure 3

Participants also were asked to rate the usefulness of each of the eight course modules used in the MELD program. Results are presented in **Figure 4**. The module dealing with "interpersonal communications and skills" was considered to be most useful by the respondents although not a great difference is found among all modules. In fact, each module was considered to be somewhere between "somewhat useful" and "extremely useful." It is interesting to note, however, that the top three modules in this evaluation dealt with classic CRM topics concerning the value of communications training and skills, developing assertion skills and conflict management, and recognizing the influence of stress on job performance and how such stress can affect the day-to-day problem solving process.

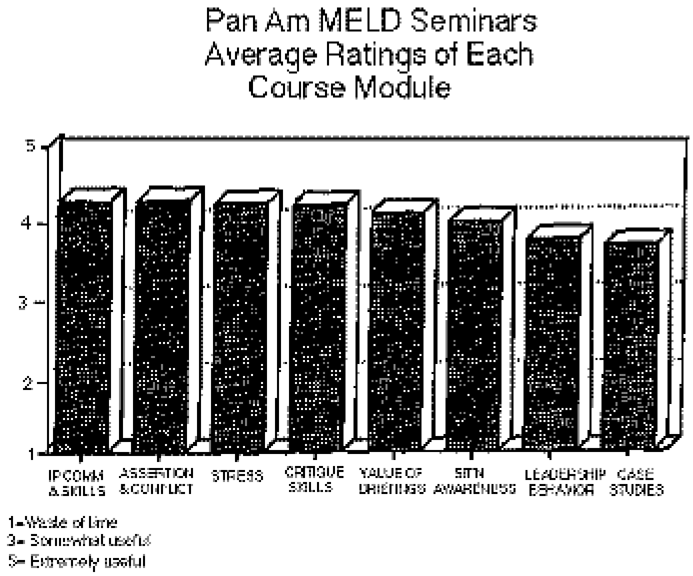


Figure 4

The course module judged to be least useful by comparison was that covering case study analyses. Perhaps one of the reasons why the case study section is lower is that all of the studies used dealt with flight crew cases. One issue on our agenda, therefore, is to develop a better list of case studies and examples that will deal with events strictly in the maintenance and engineering area.

In one of the flight-related case studies presented in the MELD seminar, we used the scenario of the Northwest Airlines Flight 255 in which the flight crew took off without flap extension. In this event, there were a number of distractions ranging from concern about the weather, interruptions from others, use of out-of-date information, a missed radio frequency, a missed taxiway, and computers not set properly. This accident is a good example of the impact of distractions coupled with a lack of situational awareness.

Based on the Northwest experience, we attempted to develop a set of warning signals to which any crew, whether in flight operations or in maintenance, should be sensitive as possible indicators of imminent trouble. The list of warning signals developed from the case studies include:

1. Deviation from standard operating procedures
2. Inadequate cross check
3. Not using available resources
4. Preoccupation
5. Violating established limits
6. Not minding the store
7. Not communicating
8. Not addressing discrepancies

One of our final, and possibly one of our most important, evaluations of the MELD program was in the question concerning the extent to which a participant felt that this training would change his behavior on the job. Participants were asked the question "As a result of being exposed to some of these concepts, are you going to do anything differently when you go back to work?" The results, shown in **Figure 5**, indicate that most of the participants felt that there would be at least a moderate change in their on-the-job behavior as a result of attending the MELD seminar.

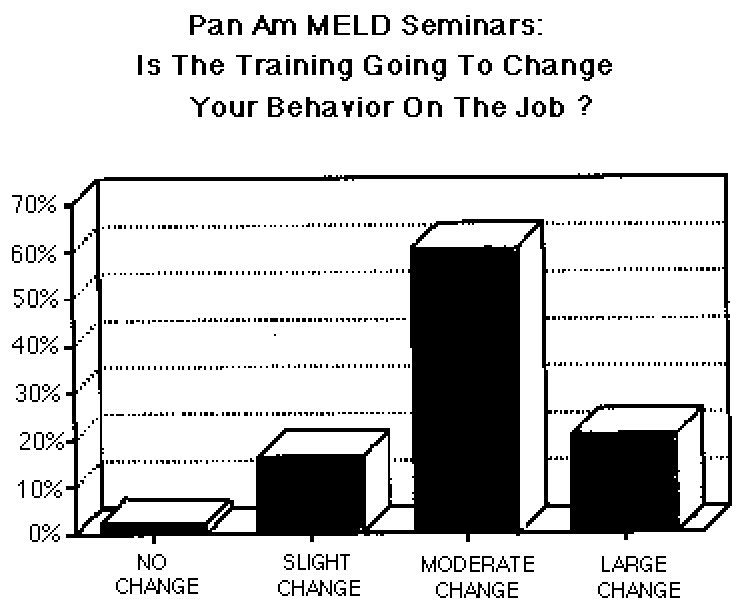


Figure 5

The MELD participants also were asked the extent to which they felt resource management training would benefit others. The response was favorable, with most indicating that all groups working in aviation should benefit from this type of training. This response is consistent with our concept of synergy in which all parts of aviation will have to work together closely to solve problems as the aviation environment grows more complex, including the introduction of advanced technology aircraft and the problems of dealing with aging aircraft. The world is no longer simple enough that problems can be solved by one person working on a job on a one-on-one basis. New concepts in team-work training are required. Such training should aid all groups trying to develop effective solutions using incomplete and ambiguous information to resolve unforeseen problems.

We plan as a next step to extend the MELD program to cover roughly 750 managers and supervisors at Pan Am. Our objective is to systematically introduce self-managed, high-performance, self-directed work teams in maintenance.

Appendix 1

PAN AMERICAN WORLD AIRWAYS MAINTENANCE/ENGINEERING/LOGISTICS NASA RESOURCE MANAGEMENT SURVEY

SEMINAR DATE_______

PART I

As part of NASA sponsored research, we are collecting data on attitudes about Maintenance, Engineering, and Logistics (M/E/L) resource management at Pan Am. You will greatly assist our research if you complete the survey. Please do not put your name on this form. Your data are strictly confidential. However, we would like to link your responses on this survey to later questions. To do this, please enter a four digit Personal Identification Number below and record it where you can find it at a later date.

Identification Code _____ _____ _____ _____

Please answer by writing beside each item the letter that best reflects your personal attitude. Choose the letter from the scale below.

***** Scale *****

A	**B**	**C**	**D**	**E**
Disagree	Disagree	Neutral	Agree	Agree
Strongly	Slightly		Slightly	Strongly

_____1. M/E/L team members should avoid disagreeing with others because conflicts create tension and reduce team effectiveness.

_____2. M/E/L team members should feel obligated to mention their own psychological stress or physical problems to other M/E/L personnel before or during a shift or assignment.

_____3. It is important to avoid negative comments about the procedures and techniques of other team members.

_____4. Managers should not dictate technique to their subordinates.

_____5. Casual, social conversation on the job during periods of low workload can improve M/E/L team coordination.

_____6. Each M/E/L team member should monitor others for signs of stress or fatigue and should discuss the situation with the individual.

_____7. Good communications and team coordination are as important as technical proficiency for aircraft safety and operational effectiveness.

_____8. We should be aware of and sensitive to the personal problems of other M/E/L team members.

_____9. The manager in charge should take hands-on control and make all decisions in emergency and non-standard situations.

***** Scale *****

A	**B**	**C**	**D**	**E**
Disagree	Disagree	Neutral	Agree	Agree
Strongly	Slightly		Slightly	Strongly

______10. The manager or supervisor in charge should verbalize plans for procedures or actions and should be sure that the information is understood and acknowledged by the other M/E/L team members.

______11. M/E/L team members should not question the decisions or actions of the manager except when they threaten the safety of the operation.

______12. M/E/L team members should alert others to their actual or potential work overloads.

______13. Even when fatigued, I perform effectively during critical phases of work.

______14. Managers should encourage questions during normal operations and in special situations.

______15. There are no circumstances where the subordinate should assume control of a project.

______16. A debriefing and critique of procedures and decisions after each job assignment is an important part of developing and maintaining effective team coordination.

______17. My performance is not adversely affected by working with an inexperienced or less capable co-workers.

______18. Overall, successful M/E/L management is primarily a function of the manager's technical proficiency.

______19. Training is one of the manager's most important responsibilities.

______20. Because individuals function less effectively under high stress, good team coordination is more important in emergency or abnormal situations.

______21. The pre-assignment team briefing is important for safety and for effective team management.

______22. Effective team coordination requires each person to take into account the personalities of other team members.

______23. The manager's responsibilities include coordination between his or her work team and other support areas.

______24. A truly professional manager/supervisor can leave personal problems behind.

______25. My decision making ability is as good in abnormal situations as in routine daily operations.

PART II: BACKGROUND INFORMATION

Year of birth __________

Total Years at Pan Am _________

Sex (M or F) ____________

Current Department

____ Maintenance

____ Engineering

____ Quality Control

____ Planning

____ Logistics

____ Shop

Job Title: ____

Years in present position: ____________

Past Experience/Training (No. Years):

Military ______________

Trade School ______________

College ______________

Other Airline ______________

PAN AMERICAN WORLD AIRWAYS MAINTENANCE/ENGINEERING/LOGISTICS NASA RESOURCE MANAGEMENT SURVEY

SEMINAR DATE_______

PART II

Please enter the four digit Personal Identification Number that you selected at the beginning of the seminar.

Identification Code _____ _____ _____ _____

Please answer by writing beside each item the letter that best reflects you personnel attitude.

Choose the letter from the scale below. All data are strictly confidential.

***** Scale *****

A	**B**	**C**	**D**	**E**
Disagree	Disagree	Neutral	Agree	Agree
Strongly	Slightly		Slightly	Strongly

______1. M/E/L team members should avoid disagreeing with others because conflicts create tension and reduce team effectiveness.

______2. M/E/L team members should feel obligated to mention their own psychological stress or physical problems to other M/E/L personnel before or during a shift or assignment.

______3. It is important to avoid negative comments about the procedures and techniques of other team members.

______4. Managers should not dictate technique to their subordinates.

______5. Casual, social conversation on the job during periods of low workload can improve M/E/L team coordination.

______6. Each M/E/L team member should monitor others for signs of strss or fatigue and should discuss the situation with the individual.

______7. Good communications and team coordination are as important as technical proficiency for aircraft safety and operational effectiveness.

______8. We should be aware of and sensitive to the personal problems of other M/E/L team members.

______9. The manager in charge should take hands-on control and make all decisions in emergency and non-standard situations.

______10. The manager or supervisor in charge should verbalize plans for procedures or actionsnmand should be sure that the information is understood and acknowledged by the other M/E/L team members.

______11. M/E/L team members should not question the decisions or actions of the manager except when they threaten the safety of the operation.

______12. M/E/L team members should alert others to their actual or potential work overloads.

***** Scale *****

A	**B**	**C**	**D**	**E**
Disagree	Disagree	Neutral	Agree	Agree
Strongly	Slightly		Slightly	Strongly

______13. Even when fatigued, I perform effectively during critical phases of work.

_____14. Managers should encourage questions during normal operations and in special situations.

_____15. There are no circumstances where the subordinate should assume control of a project.

_____16. A debriefing and critique of procedures and decisions after each job assignment is an important part of developing and maintaining effective team coordination.

_____17. My performance is not adversely affected by working with an inexperienced or less capable co-workers.

_____18. Overall, successful M/E/L management is primarily a function of the manager's technical proficiency.

_____19. Training is one of the manager's most important responsibilities.

_____20. Because individuals function less effectively under high stress, good team coordination is more important in emergency or abnormal situations.

_____21. The pre-assignment team briefing is important for safety and for effective team management.

_____22. Effective team coordination requires each person to take into account the personalities of other team members.

_____23. The manager's responsibilities include coordination between his or her work team and other support areas.

_____24. A truly professional manager/supervisor can leave personal problems behind.

_____25. My decision making ability is as good in abnormal situations as in routine daily operations.

II. TRAINING EXPERIENCE AND EVALUATION

1. For each of the topic areas or training techniques listed below, please rate the value of this aspect of the training to you. Rate each item by choosing the letter on the scale below which best describes your personnel opinion and then write the letter beside the item. If the topic was not included in your training, please put "NA" in the blank.

A	B	C	D	E
Waste	Slightly	Somewhat	Very	Extremely
of time	Useful	Useful	Useful	Useful

_____Training In Interpersonal Communications And Skills

_____Assertiveness, And Conflict Resolution

_____Value Of Effective Team Briefings

_____Stress Effects And Stress Management

A	B	C	D	E
Waste of time	Slightly Useful	Somewhat Useful	Very Useful	Extremely Useful

______Analysis Of Personal Styles And Dimensions Of Team Crew Leadership

______Situational Awareness And Impact of Distractions

______Training in Critique Skills Using Dilemma Situations

______Case Studies Of Aircraft Accidents And Incidents

______Overall, How Useful Did You Find The Training?

2. MELD Resource Management training has the potential to increase aviation safety and teamwork effectiveness.(circle one)

A	**B**	**C**	**D**	**E**
Disagree Strongly	Disagree Slightly	Neutral	Agree Slightly	Agree Strongly

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

No Change	A Slight Change	A Moderate Change	A Large Change

4. How useful will such training be for others? (circle one)

A Waste of time	Slightly Useful	Somewhat Useful	Very Useful	Extremely Useful

5. What aspects of the training were particularly good?

____

____

____

____

____

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

____

____

____

____

____

THIS COMPLETES THE QUESTIONNAIRE

TRAINING AT THE REPAIR STATION

Michael Rose
Lockheed Aeromod Center, Inc.

I would like to take this opportunity to explain some of the issues faced today by repair stations such as Lockheed Aeromod today. In order to set the stage, I would like to tell you first a bit about Lockheed Aeromod itself. Repair stations represent a rapidly growing industry. Since our beginning in 1985, we have grown at an average rate of 400 people a year to our present size of 1800 employees. We work in facilities which are set over approximately 144 acres. Our size and our rate of growth have presented us with training problems and with recordkeeping problems as we attempt to manage our personnel expansion and our turnover. Today I will discuss some of these problems, solutions that we have developed, and will describe some innovations that we are considering.

A major problem we face is that of maintaining a fully-qualified workforce. Much of this comes from the number of different kinds of aircraft on which we work. We do maintenance for all the major carriers, including Federal Express, UPS, Delta Airlines, and numerous others. We also work for the U.S. Government and for foreign governments. The different customer contract requirements present problems. One customer will want his work done in one specific way, while another will want it done in quite a different manner. Thus, when we are training employees to work on aircraft for both companies, in effect we are working to dual standards which creates problems for us. On top of this, our recent expansion has brought with it problems in employee turnover. Each time we lose qualified personnel, our training load increases correspondingly.

To help us maintain a fully qualified workforce, we recently have implemented an exclusive training program involving both academic courses and on-the-job training (OJT). To develop a sound basis for this training program, we assembled a team which went through our operation and identified all tasks being accomplished by different members of our workforce. This included the General Aircraft Mechanic, the Electrician/Avionics Technician, the Structures Technician, and even included aircraft painters. With painters we identified tasks ranging from the aircraft going into the hangar, to the stripping, and to the final painting and aircraft release. Now, under our OJT program, we can maintain a detailed record of training accomplished for each task for each individual.

We also have a program to identify the various skills of employees so that they can be properly assigned. When an individual comes to Lockheed, we review all training records to identify the training that has been accomplished on different types of aircraft. We take certificates from any previous trainings, such as for the 727 aircraft or the JT-8 engine, and enter this into our computer database. By so doing, we now have an excellent tool for personnel management and tracking. For example, if a customer inquires as to the number of technicians employed by

Lockheed who are qualified and trained on A-300's, we can get an immediate computer print-out which will tell us the number of people, where they work, and the and the experience level of these individuals.

Another program of interest we have developed is one with the local high schools and middle schools, specifically to support our work in aircraft structures. For the past two years, I have visited middle schools and talked to younger students, explaining to them the opportunities and advantages of work as an aviation maintenance technician. At the same time, representatives of Lockheed go to local high schools on "career days" and talk to those students. We have implemented a program through local career centers, which now is in its second year, in which they teach a two-year Metal Fabrication and Aircraft Structures Training Program, which is presented quite in-depth. Once students graduate from these programs, we take the individuals that have been selected as the highest student and give them a scholarship to a local A&P school or to a local college A&P school. After that, they go to an 11 week Advanced Structures Program, which is sponsored and completely funded by the Special Schools Division of the State of South Carolina. This program has given us a good working relationship with the state. One reason for the above program is the aging aircraft problem, which brings with it a lot of aircraft structures work. We have identified all of these structures tasks and all such tasks have been incorporated into the training program for these students. The shop we have set up in the local career center offers realistic training. The metal used in shop is the same as that in the aircraft. We also use the same curvature on the panels, so in reality we provide almost an actual situation. For the student, it is just like working on the aircraft.

Another in-house program at Lockheed was started as a way to improve communications. In this program, we attempted to capture our in-house expertise to support our on-the-job training efforts. In this program we began with the Avionics Department, which has probably the hardest subject to teach because you do not teach it that often. In any familiarization course at Lockheed, avionics may receive only four or five hours, or perhaps a day at most. In avionics, we selected an individual and then went through the procedures as to how to prepare a lesson plan. Then, for presentation of the lesson plan we used that individual. We asked him simply to come in and to explain the component location for the avionics and a bit about the operation of the systems. During this training, employees started asking a number of questions because they could relate to this person. The first class he conducted was to have been one hour as a short familiarization course. It ended up being six hours in length. Now we have progressed until it is is two-day course where this individual actually does the training for us.

Finally, I would like to describe what I consider one of our major efforts to improve our overall effectiveness. The Technical Training Department at Lockheed Aeromod is being reorganized to develop a closer tie between training activities and day-to-day operations. Since we feel that our problems are not in the classrooms but are on the floor where the work is being conducted, we are putting a number of instructors on the floor to identify problem areas that we have and then to develop appropriate training measures to address these problems. In the course of doing this, we are indeed getting a better handle on some of our training issues. For example, we recently were requested to provide a two week Advanced Structures Program to include blueprint reading. When we went on the floor and talked to technicians, we found that the need for training in blueprint reading was only one person's opinion. What they actually needed was training in reading the Structural Repair Manual. So instead of providing a two week program, we taught a three day Structural Repair Manual course, which dealt with the actual problem.

The different programs at Lockheed Aeromod that I have just described all are directed toward maintaining a fully-qualified and effective workforce. We are always working to improve our training programs as well as our management-employee communications. Both are essential to a quality maintenance effort.

ADVANCED TECHNOLOGY TRAINING FOR AVIATION MAINTENANCE

William B. Johnson, Ph.D.
Galaxy Scientific Corporation

Introduction

The human is an important component in the commercial aviation system that provides safe and affordable public air transportation. Much attention to the "human factor" in the aviation industry has focused on the cockpit crew. However, the FAA and the airlines recognize that aircraft maintenance technicians (AMTs) are equal partners with pilots to ensure reliable safe dispatch. The job of the AMT is becoming increasingly difficult. This is a result of the fact that there are increasing maintenance tasks for the ever-aging aircraft fleet while, at the same time, new technology aircraft are presenting complex digital systems that must be understood and maintained. Sheet metal and mechanical instruments have given way to composite materials and glass cockpits. These new technologies have placed an increased training burden on the mechanic and the airline training organizations.

The FAA Office of Aviation Medicine, as part of the National Aging Aircraft Research Program, is studying a number of human factors-related issues that affect aviation maintenance. Examples of the projects under investigation include the following: a study of job aiding for maintenance tasks (**Berninger, 1990**); design and development of a handbook of human factors principles related to maintenance; a task analysis of aviation inspection practices (**Drury, 1989** and 1990); a study of maintenance organizations (Taylor, 1989 and **1990**); and the assessment and specification/demonstration of advanced technology for maintenance training. The advanced technology training research, reported here, is exploring alternatives for the effective and efficient delivery of a variety of aircraft maintenance training.

Research Phases

The training technology research is divided into three phases that will be conducted over a three-year period. Work began in January of 1990.

In the first six months we have assessed the status of training technology for maintenance technicians. This was done with a series of telephone interviews and site visits to manufacturers, airlines, and schools operating under Federal Aviation Regulation Part 147 (FAR 147).

Currently, the research team is designing and building a prototype intelligent tutoring system (ITS) that can be used as a demonstration of the application of expert system technology to maintenance training. ITSs are described later in this paper. The prototype will also be used to help finalize the specifications for a fully operational, intelligent tutoring system that will be finalized in the second year.

The operational intelligent tutoring system will be built in conjunction with a school and airline that were identified during the first six months of the project. The intelligent tutoring software will be designed so that it is generic and can be modified for a variety of aircraft maintenance training applications. The product will be a turn-key training system for maintenance. The important by-product will be a field-tested approach to develop, efficiently, subsequent ITSs for aircraft maintenance training.

The third phase will be dedicated to evaluation of the intelligent tutoring system for maintenance training. The system will be integrated into a training program at a school or airline. We will assess the user acceptance and training effectiveness of the intelligent tutoring system for maintenance training. In addition, we will conduct an analysis of the cost effectiveness of such training technology. **Table 1** is a summary of the three phases.

Table 1 Phases of Research Plan

Phase 1	1990	Technology Assessment and Prototype
Phase 2	1991	Build Complete Intelligent Tutoring System
Phase 3	1992	Conduct System Evaluation

Definitions of Advanced Technology and ITS

Over the past decade, instructional technologists have offered numerous technology-based training devices with the promise of "improved efficiency and effectiveness." These training devices are applied to a variety of technical training applications. Examples of such technology include computer-based simulation, interactive videodisc, and other derivatives of computer-based instruction. Compact Disc Read Only Memory (CD-ROM) and Digital Video Interactive (DVI) are two additional technologies that will offer the "multi-media" training systems of the future.

The application of artificial intelligence (AI) to training has captivated the instructional technology literature of the 1980's (Sleeman and Brown, 1983; Wenger, 1987; Kearsley, 1987). The AI-based training systems are called intelligent tutoring systems (Polson and Richardson, 1988; Psotka et al, 1988). This section will define the ITS technology as it exists today. The section will show examples of systems that are currently in use and/or development. The examples are those for which the author has responsibility. There are many other excellent ITSs in development today. Intelligent tutoring systems are usually described with some version of the diagram in **Figure 1** (Johnson et al, 1989; Mitchell and Govindaraj, 1989; Yazdano, 1987).

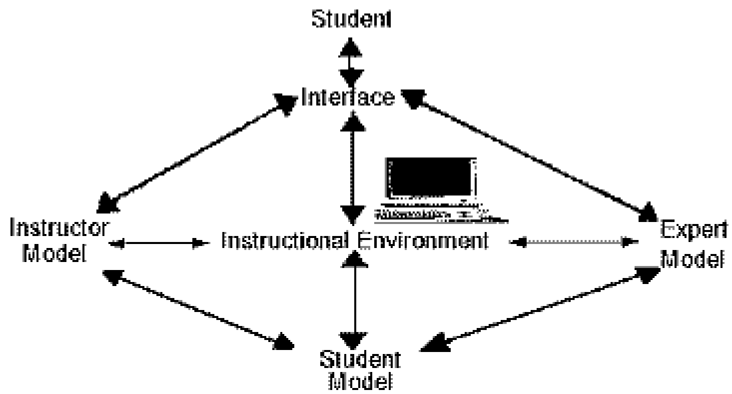


Figure 1 An Intelligent Tutoring System

At the center of the diagram is the instructional environment. It can include any of the techniques that have been available with conventional computer-based instruction (CBI). This could include the following: simple tutorials, drill and practice, problem solving, simulation, and others. It can be argued that the design of the instructional environment is the most critical element in a training system. However, an ITS is only as strong as its weakest module.

Between the instructional environment and the student is the user interface. The interface permits the student to communicate with the instructional environment. The interface can be as simple as text with a keyboard. However, today's interfaces are more likely to include sophisticated color graphics, animation, audio and video disc. Example input devices are keyboards, touch screens, mice, trackballs, voice, and other such hardware.

The software that differentiates ITSs from conventional **CBI** are the models of the expert, student, and instructor. The expert model contains an understanding of the technical domain represented in the instructional environment. There are numerous ways to encode this expert understanding. The most common is with production rules. When the instructional environment is a simulation, a portion of the expert model is often embedded in the simulation. This is true with microcomputer Intelligence for Technical Training (MITT) (Johnson et al, 1988 and 1989) and with the Intelligent Maintenance Training System (IMTS) (Towne and Munro, 1989).

The student model is a dynamic accounting of student performance within a given problem. Most student models also contain a historical record of previous student performance. The final model, the instructor, compares the student model to the expert model to assess student performance. The instructor model, sometimes called the pedagogical expert, offers appropriate feedback and/or suggestions for remediation. The instructor model also sequences subsequent instruction based on a perceived level of competence of the student. The instructor model is an expert system with production rules about training and feedback. This model does not necessarily know anything about the content matter within the instructional domain.

Example Systems

Research on artificial intelligence in training has been going on for quite some time (Carbonell and Collins, 1973). However, few systems have made a successful transition from the laboratory to real training environments (Polson, 1989; Johnson, 1988b). Johnson has offered a number of reasons why the transition has been difficult. He also described how to build ITSs for real application (Johnson, 1988a, 1988b, 1988c).

Flowcharts and diagrams, like the one in **Figure 1**, are helpful to gain a broad understanding of the ITS concept. Examples of operational ITS are a better way to understand and appreciate their potential for technical training. This section will briefly describe three systems that have been developed by the author and his colleagues. These systems represent many of the features that are emerging in the ITS development community.

Microcomputer Intelligence for Technical Training

The Air Force recognizes that intelligent tutoring systems must be developed and delivered on computers that are available today and are affordable to training organizations. Therefore, the Microcomputer Intelligence for Technical Training (MITT) research and development had the goal of building intelligent tutoring systems on small microcomputers, like the IBM-AT or a compatible. Nests (1989) has described the trials and tribulations of developing robust systems within the constraints of the microcomputer environment.

MITT was developed with the cooperation of the NASA Johnson Space Center Operations Training Department. The student audience for MITT is comprised of astronauts and flight controllers. The domain for the first MITT tutor was the electric power distribution system for the Space Shuttle. A second domain in development is for training electronic technicians on United States Air Force missile systems.

The MITT system has evolved from over a decade of research, beginning in the late 1970's at the University of Illinois, related to training humans for troubleshooting (Johnson, 1987). This includes research with the development and evaluation of computer-based instruction for diagnostic training in nuclear power plants (Johnson et al, 1986; Maddox and Johnson, 1986; Johnson, 1986).

MITT has all of the modules shown in **Figure 1**. At the heart of MITT is a simulation-oriented diagnostic training program called Framework for Aiding the Understanding of Logical Troubleshooting (FAULT) (Johnson, 1987). FAULT permits the ITS to have a model of the functional connectivity of each component in the system. For example, a functional connectivity matrix for the fuel cell would show that the oxygen and hydrogen valves must be functioning properly in order for the cell to operate. The functional connectivity matrix forms a framework for such data as component descriptions or how to perform tests. In addition, FAULT provides MITT with advice about the quality of any diagnostic action in regard to information gain per action. This is called the functional expert. The functional expert uses logical actions, almost common sense, to provide advice. It uses such techniques as splitting the system in half for troubleshooting actions or testing the parts with the highest history of failure. FAULT provides only generic logical advice - it does not know anything about the technical subject other than connectivity.

The common sense approach offered by the functional expert is necessary for safe operation and diagnosis of any system. However, it is not sufficient. Therefore, the functional expert is supplemented by the procedural expert that has system-specific information. This expert is comprised of production rules (e.g., if gauge reading is above 200 degrees Fahrenheit, then check gauge Y) generated from the system's operating and diagnostic procedures. For the MITT fuel cell tutor the astronaut's flight data file malfunction procedures were directly translated to production rules for the procedural expert. The same approach is being used to develop the ITS for the missile domain.

The student model of MITT keeps an accounting of all student actions. Specifically, the model keeps a count of number of actions, number of displays accessed, number of errors committed, number of problems solved, kind of advice sought by the student, and other such information. This information is used by the instructor model to provide feedback and to structure the subsequent instruction. For example, the instructor model might notice that the student has made numerous mistakes related to one portion of a system. The instructor model can direct the student to specific sources of additional information or offer additional problems applicable to the remediation needed. More extensive descriptions of the MIT&T fuel cell tutor are offered elsewhere (Johnson et al, 1988).

MITT Writer: An Authoring System

MITT was designed to be developed and delivered on computer systems that already exist in training departments. It's most important characteristic is that production of the necessary database, rulebase, and graphic files is a clearly defined and manageable task that can be accomplished in a reasonable time for reasonable dollars. This attractive characteristic of MITT will be amplified with MITT Writer.

MITT Writer, scheduled for completion during 1990, will permit technical training personnel to develop MITT Tutors for new technical domains. Therefore, technical training personnel will be able to build MITT intelligent tutoring systems without using computer programming languages. Like the tutor, MITT Writer runs on a microcomputer that is readily available to training departments.

Advanced Learning for Mobile Subscriber Equipment

Another example of a new microcomputer-based technical training system is Advanced Learning for Mobile Subscriber Equipment (ALM) (see **Figure 2**). ALM trains operators and maintainers of the U.S. Army's newest tactical communications equipment. Like MITT, ALM has the constrained computing environment limited to 640k of memory. Since the Army has thousands of such computers, called the Electronic Information Delivery System (EIDS), new training systems must be developed for such hardware environments.

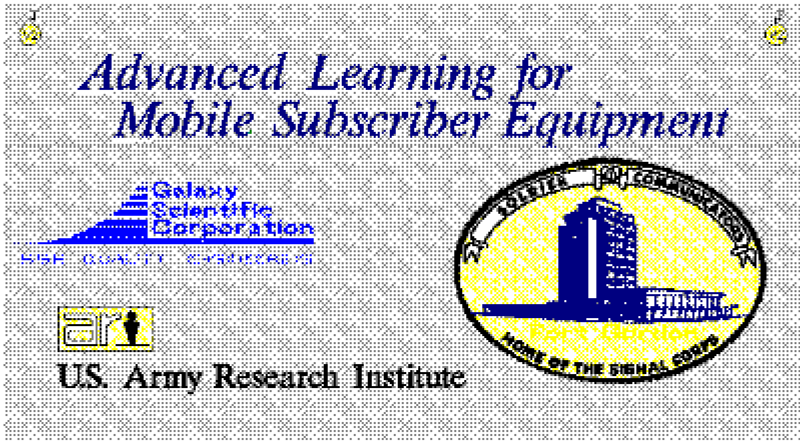


Figure 2. ALM Title Screen

ALM permits the Army student to learn about and operate the MSE. The student can build an MSE network, learn about MSE, and solve MSE system problems.

ALM uses an approach to software development different than that used by MITT or other intelligent tutoring systems. ALM uses a hypermedia approach where the various submodules are arranged in "stacks" of cards (Coonan et al, 1990). In order to complete problems or add more problems, the developer simply completes the data for each new card in the stack. **Figure 3** shows the stack-like layout of ALM. Stacks can be dedicated to features like help, diagrams, problems, tutor, and any number of additional attributes. As with more traditional approaches to ITS, the hypermedia must contain an expert approach to training as well as to system operation and repair. This expertise is encoded with production rules, written in C or generated with an expert system shell. The combination of production rules and hypermedia software ensures that ALM is readily modifiable by the end user with some programming experience.

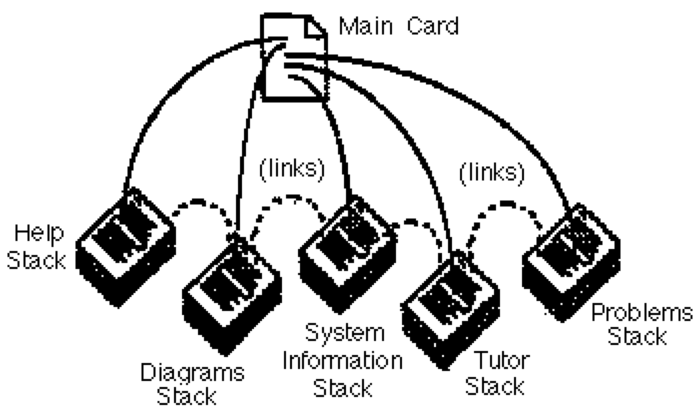


Figure 3 ALM 'Stack of Cards' Architecture

Summary of Examples

MITT, MITT Writer, and ALM are but few examples of ITSs that have transitioned from the laboratory to the operational training environment. This transition was possible because the systems were designed to meet the hardware, software, and budget constraints associated with real training. These systems operate on hardware that is available, in place, today. If intelligent tutoring systems are to become a part of technical training, they must be sensitive to these constraints. Each will be briefly discussed here.

Hardware is the first constraint. Most of the early ITSs were developed on dedicated artificial intelligence workstations. Such hardware is considered to be obsolete and impractical by most developers. However, the early ITS development on the Xerox and Symbolics workstations permitted the initial design principles for today's systems.

The hardware problem is history. Today's computers, the IBM-AT, compatibles, and the MacIntosh, have the capability for ITS. The faster 80386 and 80486 processors are providing significant capability to deliver intelligent training. Such hardware is becoming increasingly affordable and reasonable for training applications.

Software has also evolved to become more suitable for ITS. The new operating systems, with new hardware, permit parallel processing and direct access to unlimited memory. These two changes, by themselves, will have a major impact on new training software. In addition to these advances are a variety of software tools that facilitate the development of interactive graphics, as an example.

Budget considerations are a third constraint to the development and implementation of ITS in technical training environments. The advent of ITSs on available microcomputers is driving down such costs. The development of authoring systems, like MITT Writer, will also bring down the cost of ITSs.

Advanced Technology for Aircraft Maintenance Training

With definitions and demonstrations of advanced technology in hand, we proceeded to assess the status of such applications for aircraft maintenance training. To accomplish this goal, we visited or spoke with a sample of the population of airlines, schools, and manufacturers. The organizations visited are shown in **Table 2**.

We began the interviews with a discussion of the situation as we perceived it. **Table 3** summarizes the preconceptions that served as a basis for initial discussions.

Table 2

Sources of Information for Technology Survey

AIRLINES:

American Airlines Maintenance Academy
Continental
Delta
Northwest
United

ATA Maintenance Training Committee
British Airways

SCHOOLS:

Clayton State College
Embry-Riddle Aeronautical University
The University of Illinois
West Los Angeles College

MANUFACTURERS:

Boeing Commercial Airplanes
Douglas Aircraft
ATA Maintenance Training Committee

Table 3

The Perceived Situation for Discussion Purposes

- Maintenance training is traditional.
- Training personnel do not have time to develop advanced technology training systems.
- FAA has not encouraged the use of advanced technology as a substitute for laboratory practice.
- Advanced technology is an effective maintenance training alternative.
- There are few vendors of advanced technology for maintenance training.
- Most **CBI** systems require proprietary hardware.
- Training personnel want advanced technology training systems.

The interviews confirmed that our initial perceptions were accurate. However, there were noteworthy exceptions. Perhaps the most significant of the incorrect assumptions was the FAA position on advanced technology for maintenance training. Our discussions with FAA personnel and training personnel through the industry confirmed that advanced technology training systems have the potential to substitute for real equipment in certain laboratory tasks. For example, an AMT trainee can learn to start and troubleshoot a turbine engine using a simulation rather than the real engine. Advanced technology cannot substitute for many psychomotor activities but is especially useful where students must practice the integration of knowledge and skill for problem solving, decision making, and other such diagnostic activities. It appears, therefore, that simulators and other advanced technology are becoming an important component of maintenance training

A Discussion of Hardware for Advanced Technology Training

All of the interviews resulted in a discussion about the appropriate hardware systems for advanced technology training. While there is not unanimous agreement, the current favorite is the 80286 or 80386 operating in the DOS environment. VGA seems to be the acceptable video hardware standard. Many airlines managers were outspoken about their dissatisfaction with the lack of standards among the various **CBI** vendors. The Air Transport Association (ATA) Maintenance Training Committee (ATA, 1989) has strongly recommended that all manufacturer-produced courseware be designed for a common non-proprietary system like the IBM-AT and compatible computers. That is not currently the case, although the trends are in that direction. Software developers who meet the ATA standards are more likely to succeed in the new marketplace.

The two largest producers of **CBI** for aviation maintenance are Aero Information (for the Air Bus) and Boeing Commercial Airplane Company. Both systems require some proprietary hardware but are somewhat compatible within the 80286/386 family. Douglas Aircraft is developing CBI that will be compatible with the ATA standard. Another committee that is promoting standards is the Aviation Industry Computing Committee (AICC). They have published hardware guidelines and a catalog of current and planned CBI developments by its members (AICC, 1990).

Among the major airlines there is some hardware variance. Delta Air Lines, one of the few to have a significant **CBI** development staff, is using a large number of 80386 processors with advanced graphical displays. The Delta systems are also DOS-compatible in order to maximize applications.

The majority of Boeing training software is for the 747-400. Developed under contract to a large **CBI** company, the training requires proprietary equipment. The advanced technology training development group at Boeing are cooperating with United Airlines and Apple Computer Company to explore the concept of "Instructor-led CBT." Using MacIntosh computers and a variety of color graphics and hypermedia tools, they have created a variety of dynamic displays to be used for group training. Eventually this approach should find its way to individualized CBI.

The Prototype Specifications

The prototype will be developed on hardware that is aligned with the ATA recommended standards. The specifications are listed in Table 4. This hardware will ensure that the prototype will be of value, for demonstration, to the most people. It will not require special hardware.

Table 4

Hardware and software for Prototype

- 80286 or 80386 Processor
- 640 Kb of Memory
- VGA Display
- Hard Disk Storage
- Mouse
- MS-DOS
- Off-the-shelf software for graphics and windows
- C Programming Language

The instructional and pedagogical design is a more important consideration than hardware. While the design is hardware and software dependent, it must be emphasized that robust and expensive hardware will not make up for poor design of the instruction. An incomplete listing of the instructional specifications is shown in Table 5. These specifications will evolve with the software.

Table 5

Instructional Specifications for Prototype.

- Extensive Freeplay and Interaction
- Problem Solving and Simulation
- Explanation, Advice, and Coaching
- Orientation Towards Maintenance Tasks
- Adaptable to Student Skill Level

The Instructional Domain

The primary criteria for selection of the instructional domain for the prototype was that the finished ITS by of immediate value to the airlines and to the FAR 147 schools. In order to accomplish this goal, the domain had to be a complex system that is prone to failure. Candidate systems included the following: hydraulics, auxiliary power unit (APU), engine information and crew alerting system (EICAS), electric power distribution, fuel distribution, and environment control system (ECS).

The current choice is ECS. This system is ideal for many reasons. On the ECS, diagnostic information and maintenance checks occur throughout the aircraft. The system is integrated with the APU and the main engines. The ECS is critical to passenger safety and comfort. Further, the ECS principles can be generalized to many aircraft. Therefore, currently the ECS will be the prototype domain.

Prototype Development Partners

As the prototype development proceeds, we anticipate participation from at least one FAR 147 school and at least one major air carrier. A large number of schools and airlines have offered to participate. That is encouraging to the research team and to the FAA sponsor.

At this time, the most likely partners are Clayton State College and Delta Air Lines, both in Atlanta, Georgia. The combination of a major airline and an approved FAR 147 school will ensure that the ITSs will meet the instructional needs across a wide spectrum of AMT personnel. The combination will ensure that the training system is technically correct and instructionally sound. Further, the airline/school combination will be ideal to conduct evaluations of training effectiveness and cost efficiency.

Summary

This paper has described the ongoing research and development related to the application of advanced technology to aircraft maintenance training. The research has characterized current use of advanced technology for maintenance personnel. Subsequent phases of the research will design, develop, and evaluate an intelligent tutoring system for aircraft maintenance training.

Training humans to learn new skills and to maintain current skills and knowledge is critical to the safe operation and maintenance of manufacturing, power production, and transportation systems. As the U.S. labor force changes, the criticality of such training becomes even more eminent. Intelligent tutoring systems, combined with human technical instructors, offer a cost-effective, reasonable alternative that can impact training immediately and into the future.

Acknowledgements

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USE OF 3-D PRESENTATIONS IN MAINTENANCE TRAINING

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My topic today is three-dimensional presentations in maintenance training.

Since we started in the A&P school business nearly 20 years ago, there has been dramatic improvement in teaching aids. I came to the school industry back in the 1970s, after ten years with Lockheed where professional visual aids for presentation were standard procedure. I remember my initial look for visual aids for A&P training. About all that was available were some slides on oxy-acetylene welding that had been developed for non-aviation high school vocational courses.

The textbook situation at that time was equally meager. Most of the schools were using the Northrup series of textbooks. The AC65-9, 12, and 15 series had been written and printed, but the Government Printing Office (GPO) could not find them. They had been stored in a Washington, D.C., warehouse, but GPO could not identify which warehouse.

During the late 1970s and 1980s there were significant developments in the teaching aids field. When I refer to teaching aids, I include both software and hardware. I consider the textbooks, computer programs, slides, and videos the software. The mockups, actual aircraft, computers, projectors, etc., are hardware.

International Aviation Publishers has a series of textbooks and videos that constituted a significant step forward in the 1970s. During the 1980s, computer-based training (CBT) with laser disks and interactive capabilities have become popular. The evolution to having the material displayed on computer screens is with us now. Training schools are working with computer simulations such as engine starts on a King Air. This is a typical example of CBT. The simulated engine start is portrayed on the computer screen. This is a preliminary to an actual engine start later in the training cycle.

In this coming decade of the 1990s, we at Advanced Educational Concepts see the display moving from the computer screen to three-dimensional imagery in the classroom. We call this concept SEE -- Special Effects Education. In this approach, imagery will "wrap around" the student and immerse him in the material being presented. The entire classroom will become like a "simulator." It is multimedia, using three-dimensional simulation, computer-based techniques, dynamic sounds, interactive interfaces, and all available sensory stimuli. It is education in its most interesting, motivating, and captivating form. The student is captured by programmed audio, visual, and graphics presentations. This technique improves retention. Difficult material is grasped more readily. Lightning flashes, stereo sound, strobes, lasers, and smells such as jet fuel, lubricants, and burned insulation will be part of the presentation. The student will "live" the experience.

The engine start on the computer, for example, can be the base program for a darkened classroom with three-dimensional stereoscopic projection of the cockpit, actual engine instrument display, and audio of the engine noise. This type of training will give the feel of a simulator. It won't be a $5 to $10 million piece of equipment with motion, but it will hopefully "trigger" all of the senses, making the material more "live," and provide a total learning experience. All of education is "simulation." This is where we are headed as we approach the end of the century. As we become more sophisticated with imaging and the use of computer technology, we will improve the delivery system in the classroom.

A recent article in *Forbes* magazine typifies what I am talking about. The article is about a dual eyepiece miniature television screen and a glove that fits on your hand. The glove has electronic sensors on it. The article starts out saying:

> "Why settle for the real thing if you can live in a dream world that is safer, cheaper, and easier to manipulate? Computers will soon make such a world possible."

The author relates his experience further:

> "Five minutes into cyberspace and I'm submerged into a pool of computerized water, looking at a computerized fish finning in the far corner. 'Try to go inside the fish,' suggests my handler in the physical world. I make a fist - the cyberspace command to grab objects - the computer gets the message via electronic sensors in a glove in my hand. My eyes see a disembodied, computerized hand pass through the fish's body. The fish sticks to my hand without putting up a fight. I pull my fist down, towards my face and the fish pops over my head. I'm inside a hollow fish with two eyes at the far end. This is is autodesk's whimsical world of three-dimensional computer images."

The system described in the *Forbes* article is still a year or more away from production. Its cost (for one student) would exceed $40,000 to $50,000 for the hardware alone. It will not be cost effective for the educational environment, but some form of imaging will.

For the past year and a half, we at Advanced Educational Concepts have researched imaging techniques in the classroom. We started with an examination of the holographic approach and did some initial work with the University of Dayton. They do a lot of optics for the Air Force at Wright-Patterson Air Force Base. Our conclusion on holograms was that they are presently too expensive for use in the classroom. (One hologram of a Pratt-Whitney Engine about 3x4 feet costs $18,000.) We have focused on stereoscopic interactive video and stereoscopic 35mm slides. These require polarizing glasses, where holograms do not. The costs, however, are much more realistic.

I have brought a couple of projectors and a few slides to give you an idea of what I am talking about. We can forward-project objects so they appear to be floating in front of the screen. We did not bring any audio, lighting, strobes, or special effects, but I thought you could still get a feel for the approach with these slides. We have a trademark on this approach to educational delivery. It is called "SEE" -- Special Effects Education. We are convinced that this is the educational wave of the future. The fact that the current generation is so graphically oriented points to this as the way to go. It is our job to make it economically feasible.

> *The audience now dons 3-D polarizing glasses to view a series of slides that illustrate the extent to which this process can provide a three-dimensional view of objects under study.*

These 3-D slides by themselves involve the student more than 2-D does. The darkened room with the colorful visuals, stereo sound, explosions, thunder claps, strobe lights, and simulated lightning holds their attention. These effects keep the students involved. They unconsciously forget their resistance to the material. They stay interested and, most importantly, they retain the material.

In summary, during the 1990s we need to upgrade our approach to maintenance training to make it as real as possible. <u>We must develop and</u> <u>make use of simulation as we have done in the flight area.</u> We can no longer be satisfied with the technique of passing a "show and tell" general aviation item around the classroom. The schools cannot typically afford a current transport category aircraft as a training aid, but we <u>can</u> afford to provide simulated transport category imagery that will build more rapidly the real-time experience level we need. We must explore this type of technique to make up for the shortfall of knowledge and experience that faces us in the human resource area today and in the coming decades.

HOW THE BRAIN PROCESSES INFORMATION

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The training process is a matter of continuous learning. A trainee must learn initially to do something. Then, as the task changes, he must learn new aspects of the task. All of this obviously involves the brain and we now are beginning to understand how specific parts of the brain are used in different kinds of learning activities. These insights into the manner in which the brain processes information can be applied profitably in programs to improve education and training.

There is a prevailing belief that everyone learns the same way. Certainly, this is the general belief within the public school system. However, we now recognize that there are several different ways in which humans learn. In fact, some individuals simply do not learn materials presented in the traditional manner. The manner in which these persons process information is not consistent with standard educational approaches.

In today's elementary school system, 20 or 25 children usually are placed in a single classroom with a single teacher who presents materials to every child in the same way. Teacher-student interaction at an individual level is low. The result is that those students who do not learn in the way they are being taught become conduct problems. They don't learn the material even though the school tries as much as it can to see that they do learn. Also, if the student has a troubled home life, he may not have anyone to go to the school and insist that the school teach them in some different way. The result is a student who is by no means achieving his potential and who may well become a problem rather than an asset for society.

In terms of our understanding of brain functioning, we have missed the boat in some parts of our educational system. We are not paying proper attention to how the brain processes information. We also are not making full use of the clues that a student's personality may give us concerning the best way in which he should be taught.

A student's personality can be considered a pathway between brain functioning and the real world. Personality concepts can be used in education and in the development of educational procedures. For instance, the impulsiveness of a student may tell you much about how that student should be taught. I have worked for almost 40 years studying impulsiveness. Recently my research has been with members of our prison population. Impulsiveness is characteristic of a large percentage of prisoners. These are people who act without thinking, make up their mind quickly, and do not plan ahead. This trait of impulsiveness offers one clue concerning the manner in which these persons process information.

Figure 1 shows the general structure of the cerebral cortex of the brain and points out in a very general way some of the areas which control specific human activities. Note that the frontal portion of the brain is responsible for selected forms of higher intelligence and also helps provide inhibitory control of behavior. The impulsive characteristics of aggressive and violent individuals are believed to be in part a function of the type of control actions of this part of the brain. The important thing to note, however, is that specific parts of the brain support specific human activities.

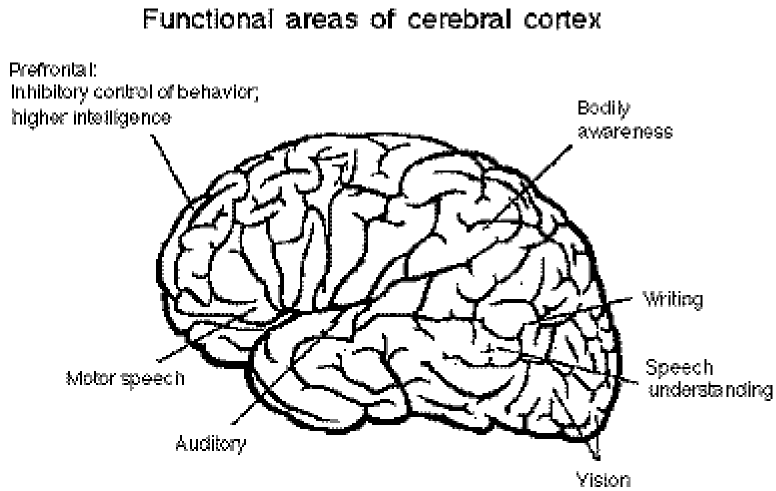

Figure 1

The specificity of brain function extends to the left and right hemispheres. The left and right cerebral hemispheres clearly support different activities, with one hemisphere or the other being dominant in its action for most people. In a general way, the left side of the brain is more disposed toward detailed activities whereas the right side is more disposed toward a "holistic" look at the world. **Table 1** shows a brief listing of functions which different investigators have ascribed to either the left or right hemisphere.

TABLE 1

Various Functions Ascribed to the Left and Right Cerebral Hemisphere

Left Hemisphere	Right Hemishere
SPEECH	SPATIAL ORIENTATION
LANGUAGE	SPATIAL INTEGRATION
COMPLEX MOTOR FUNCTIONS	CREATIVE ASSOCIATIVE THINKING
LIASON TO CONSCIOUSNESS	NONVERBAL IDEATION
WRITING	FACIAL IDENTIFICATION

As noted earlier, our educational system is not set up to deal appropriately with all students. The school system favors those students who are left-side dominant. Schools are set up for students who use words. If a student is more comfortable in seeing the holistic view of something, he may have difficulty right away. A prime example of this is the story of Albert Einstein, who had great difficulty with words. In fact he did not speak until he was three years old. According to his sister, up to the age of 7, if someone said something to him, he would repeat it to himself so that he could try to understand it. In later life, Einstein was asked what was the most difficult thing for him and he repeated; putting his thoughts into words. It surprises those of us who use words with ease to learn that people can think without using words.

Those persons who think, i.e., who process information, without heavy reliance on word structures are usually right-side dominant. The right hemisphere of their brain is used more in visuo-spatial information processing than is the left. While handedness is related to which side of the brain has which functions, the relationship is not one-hundred percent. Therefore, other procedures are used to identify hemispheric dominance. In some instances, the corpus callosum of the brain has been cut for medical reasons; the two sides of the brain cannot communicate. Another approach is to use drugs to block a cranial artery and therefore interfere with the functioning of one side of the brain so that we can study it. In studies of hemispheric dominance, tests such as the block-design task show in **Figure 2** are used. In this test, the subject uses either the right hand or the left hand to arrange the four cubes to match the sample pattern. The performance of each hand is timed separately. Depending on which brain hemisphere is used, the reaction times of the left hand or the right hand will be significantly better.

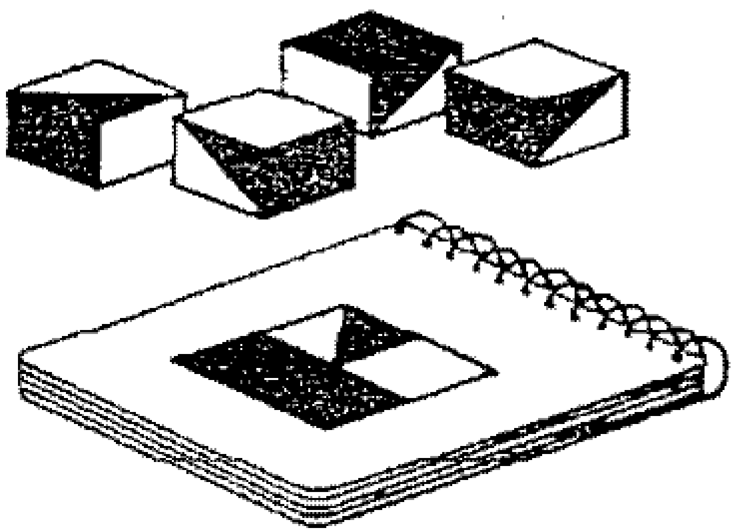

Figure 2 Block Design Task

In studying information processing, it is important not only to think in terms of structural and location differences, but also to consider the bio-chemical and neuro-chemical properties of the brain. An important biochemical reaction in the brain involves the activity of serotonin, a neuro-transmitter which operates at the junction between nerve cells. There appear to be at least five kinds of serotonin receptors in the brain, one of which is serotonin 2, which is found in good supply in the frontal lobe. The activity of serotonin 2 appears to relate to behavioral inhibition in the frontal lobe. If one is low in serotonin 2 activity, this person generally lacks behavioral inhibition. This person would be more inclined to impulsive behavior.

Use of "personality theories" to categorize human behavior also has given us insight into impulsiveness. Those who study personality believe that there are possibly five broad personality profiles that can be used to describe different people. These profiles include such items as extrovert versus introvert, neuroticism, social skills, intelligence, and other factors. Within each of the broad or higher-order personality profiles, there are more specific first order traits. One of the first-order factors is impulsiveness.

Impulsiveness appears to consist of at least three sub-parts; acting without thinking, non-planning, and cognitive impulsiveness. Impulsiveness does not necessarily indicate an abnormal personality. All of us have these traits to some extent. However, those persons with high levels of impulsiveness will often show certain problems with adjusting in a variety of situations. In the laboratory, we have used fifteen to twenty different tests to assess the behavior of those with high impulsiveness. For example, one task is paced tapping or the ability to mark time cognitively. Here there are consistent differences in high versus low impulsiveness with high impulsive subjects being much less accurate in pacing their taps.

Some studies have attempted to identify the extent to which personality traits such as impulsiveness are genetically determined. One such study, conducted recently in Sweden, used monozygotic twins (identical twins), dizygotic twins (fraternal twins), and siblings as subjects. The data from this study clearly showed a genetic predisposition for impulsiveness with the relationship strongest in the monozygotic twins.

Studies such as the above, which show a genetic influence on impulsiveness, and other studies, which indicate a biochemical basis, are providing a more clear picture concerning the basis for behavior and, in turn, the way individuals process information in the world around them. In order to pursue these lines of investigation into impulsiveness, I have been involved for the past three years in studies of members of our prison population as I noted earlier. Certainly, in this population one can find many persons for whom impulsiveness is a key personality trait. In the use of prisoners, all of whom are volunteers, we obtain cognitive psychophysiological data. Twenty-one electrodes are attached to the skull to obtain measures of brain activity. Subjects are then run through a number of laboratory-information processing tasks. As they perform each task, measures of brain activity can be related to the specific demands of the task.

One task used with prisoners is a choice-reaction time test in which the subject watches a screen for a particular stimulus. For example, if the letter "A" appears, the subject pushes with the right hand. If the letter "B" appears, the subject pushes with the left hand. Then we reverse the two letters and the two hands. Then, at random intervals and without the subject's knowledge, other letters appear. On these trials, the subject is not supposed to respond at all and most don't. The objective here is to add an additional feature of uncertainty and to make the task more challenging.

As prisoners accomplish the choice-reaction task, the electrical activity of the brain is recorded through electrodes placed at various sites over the skull. This gives us a very nice topographical map of electrical activity and clearly shows which locations within the cortex are activated and are principally involved in solving the task. We can also see, and this is very important, the correlation of activity between different parts of the brain for different kinds of information processing demands. This information allows us to relate functioning at different parts of the brain to each other.

In our recent research, studies of brain function have been conducted using prisoners, medical students, and controls matched with prisoners for race, socio-economic level, educational level, and other relevant variables. We find that in prisoners the correlation between the simultaneous functioning of frontal brain areas and posterior areas is high. When the frontal areas are working, other areas of the brain are supporting this activity. By contrast, other groups show lower relationships for the same tasks. With these other subjects, the frontal areas appear to operate more independently and do not require support from other brain elements. Prisoners appear to be less efficient in information processing in general because their frontal functions are not functioning independently.

The study of brain functioning in prisoners also has involved the extent to which certain drugs might improve information processing. Phenytoin, a drug used for many years for epilepsy, was chosen because it is generally safe and has the potential for controlling brain activity that we think relates to certain kinds of aggression or violence. The effect of phenytoin on prisoners was to reduce the correlations between anterior and posterior sections of the brain during the performance of tasks. In effect, this drug makes these brain areas function more independently. On the behavioral side, we obtained a significant reduction in the number of aggressive acts committed by prisoners while they were using this particular medication. What we have, then, is a pharmaceutical intervention which can be demonstrated to change the manner in which some individuals process information and also to control undesirable tendencies toward impulsive aggression.

In other studies in which we have worked with children, particularly those who have been classified as hyperactive, we found that drug therapy was useful in reducing tendencies toward impulsiveness. However, we also found that to achieve any lasting benefit, behavioral cognitive therapy had to be used in conjunction with the drug therapy. Now we plan to use the same approach with prisoners. Here we need to identify the proper teaching technique to use with each prisoner as we seek to improve his behavioral problems and to change his methods of information processing.

In summary, the work being done today in clinical neurophysiology, coupled with advances in behavior therapy and training technology, ultimately should allow us to select personnel with cognitive styles and learning skills more consistent with task demands. We also should be able to use our knowledge of the manner in which the brain processes information to develop individualized training programs which will do a better job of bringing young people into the work force. For instance, if we find an individual who scores high on the block design test but low on a verbal comprehension test, we will know that chances are he is more right than left hemisphere dominant. Then we can tailor training materials which provide information more in a spatial and holistic form than through strict reliance on the printed word. Under these circumstances, this individual, rather than being an immediate reject, might develop into a productive member of the work force. There is much to be done before these studies can be put into practical use and the result will never be absolute. Individual differences in cortical structure and in learning styles will make the prediction of success a function of probability. However, a better understanding of the manner in which the brain processes information does offer potential benefits for better training and, in the end, success on the job.

TRAINING FOR VISUAL INSPECTION

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The Human Role in Inspection

To evaluate and improve visual inspection training, we must first understand the inspection job itself. Classic learning texts and practical training practitioners (Goldstein, 1974) agree that a detailed task analysis is the first step in training. Only when we understand the task can we evaluate the person to be trained, to determine what training is needed to bring the person to a high level of performance. Because there are large individual differences in inspection abilities (Wang and Drury, 1989), some form of training is indeed required to produce consistent inspection performance.

A task description of aircraft inspection (Drury, 1989) is shown in **Table 1**, which gives examples from both visual and NDI tasks. This can form the basis of the task analysis required for training. Tasks 1 through 5 represent the basic inspection process and can be classified into two categories:

Manual Tasks: Initiate, Access, Respond

Cognitive Tasks: Search, Decision Making.

Table 1
Generic Task Description of Incoming Inspection,
with Examples from Visual and NDT Inspection

Task Description	Visual Example	NDT Example
1. Initiate	Get workcard, read and understand area to be covered	Get workcard and eddy current equipment, calibrate
2. Access	Locate area on aircraft, get into correct position	Locate area on aircraft, position self and equipment
3. Search	Move eyes across area systematically. Stop if any indication.	Move probe over each rivet head. Stop if any indication.
4. Decision Making	Examine indication against remembered standards; e.g. for dishing and corrosion.	Re-probe while closely watching eddy current trace.
5. Respond	Mark defect, write up repair sheet or if no defect, return to search.	Mark defect, write up repair sheet, or if no defect, return to search.
6. Repair	Drill out and replace rivet.	Drill out rivet, NDT on rivet hole, drill, out for oversize rivet.
7. Buy-back Inspect	Visually inspect marked area.	Visually inspect marked area.

Training for manual or procedural tasks is relatively straightforward (e.g., Johnson, 1981), but training for cognitive tasks is less well known and so will be treated in more detail in this paper.

The current state of training is that much emphasis is placed on both procedural aspects of the task (e.g., how to set up for an X-ray inspection of an aileron), and on diagnosis of the causes of problems from symptoms (e.g., troubleshooting an elevator control circuit). However, the inspectors we have studied in our task analysis work have been less well trained in the cognitive aspects of visual inspection itself. How do you search an array of rivets -- by columns, by rows, by blocks? How do you judge whether corrosion is severe enough to be reported?

Most inspectors receive their training in these cognitive aspects on the job by working with an experienced inspector. This is highly realistic, but uncontrolled. Our experience in training inspectors in the manufacturing industry (Kleiner, 1983) has shown that a more controlled training environment produces better inspectors. If training is entirely on-the-job, then two of the main determinants of the training program -- what the trainee sees and what feedback is given -- are a matter of chance; i.e., of which particular defects are present in the particular aircraft inspected.

There is a large difference between training and practice. **Figure 1** (Parker and Perry, 1982) shows how the effective discriminability of a target changed between two periods of practice compared with periods before and after training. There was a highly significant improvement with training but not with practice. The challenge is to apply what is known about human learning of cognitive tasks so as to maximize the effectiveness of training for the aviation inspector.

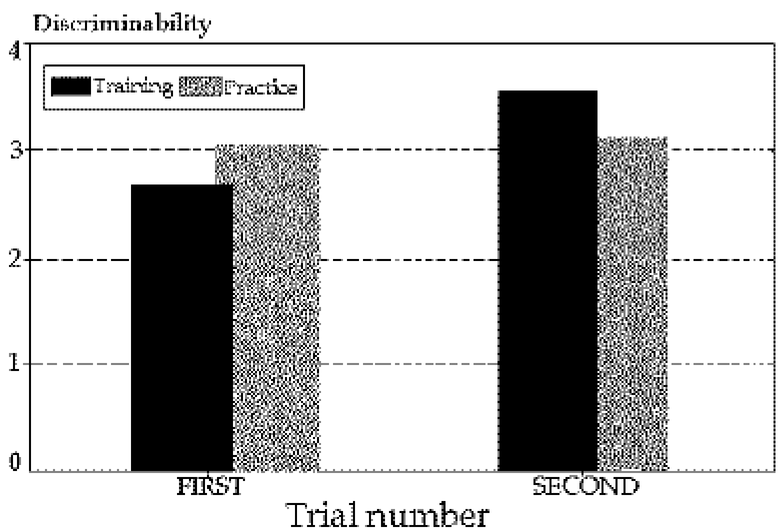

Figure 1 Training vs. Practice

Training Principles

A basic principle of training is to determine whether the activity is indeed trainable. Studies of visual search (Parkes, 1967; Bloomfield, 1975) have shown that both speed and accuracy improve with controlled practice. Embrey(1979) has shown that for decision making, discriminability can be trained. Thus, both of our cognitive factors (Task 3, Task 4) can be trained.

The principles on which training should be based are relatively well known, and can be summarized (Goldstein, 1974):

1. Develop and maintain attention; i.e., focus the trainee.
2. Present expected outcomes; i.e., present objectives.
3. Stimulate recall or prerequisites; i.e., get ready to learn.
4. Present underlying stimuli; i.e., form prototype patterns.

5. Guide the trainee; i.e., build up skills progressively.
6. Give knowledge of results; i.e., rapid feedback.
7. Appraise performance; i.e., test against objectives.
8. Aim for transfer; i.e., help trainee generalize.
9. Aim for retention; i.e., provide regular practice after training.

Control is important. Items 4, 5, and 6 above all require the trainee to receive a carefully tailored experience to obtain maximum benefit. Some particular ways in which these principles have been applied are:

1. Cueing. It is often necessary to cue the trainee as to what to perceive. When a novice first tries to find defective vanes in an engine, the indications are not obvious. The trainee must know what to look for in each X-ray. Many organizations have files of X-ray films with known indications for just this purpose. Specific techniques within cueing include match-to-sample and delayed-match-to-sample.
2. Feedback. The trainee needs rapid, accurate feedback in order to correctly classify a defect or to know whether a search pattern was effective. However, when training is completed, feedback is rare. The training program should start with rapid, frequent feedback and gradually delay this until the "working" level is reached. More feedback beyond the end of the training program will help to keep the inspector calibrated (Drury, 1989).
3. Active Training. In order to keep the trainee involved and aid in internalizing the material, an active approach is preferred (Belbin and Downes, 1964). In this method, the trainee makes an active response after each new piece of material is presented; e.g., naming a fault, weighting a discrepancy card. Czaja and Drury (1981) showed that an active training program was much more effective than the equipment passive program (**Figure 2**) for a complex inspection task.

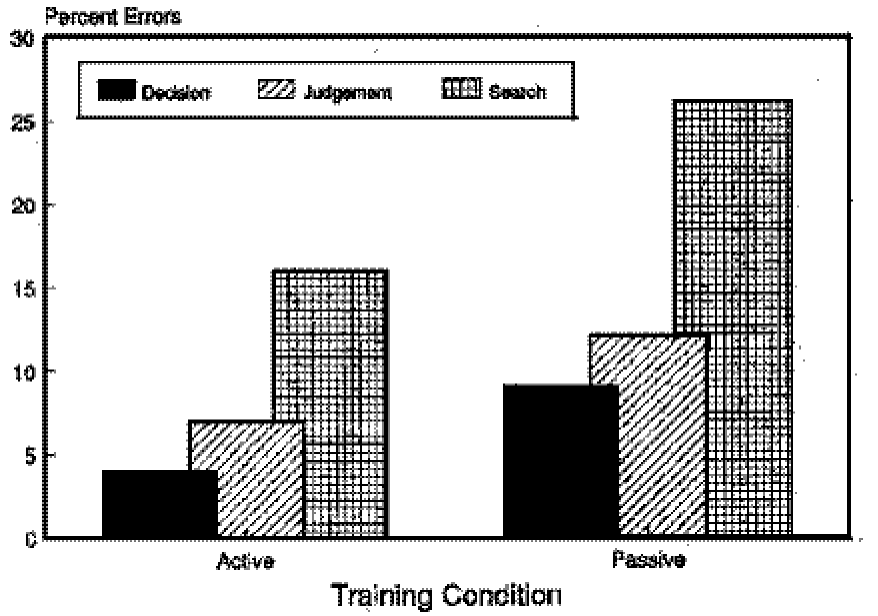

Figure 2 Active vs. Passive Training

4. Progressive Part. A standard methodology in industrial skill training (Salvendy and Seymour, 1973) is to teach parts of the job to criterion, and then successively larger sequences of parts. Thus, if four task elements were E1, E2, E3, and E4, we have:
   - Train E1, E2, E3, E4 separately to criterion.
   - Train E1 and E2, E3 and E4 to criterion.
   - Train E1 and E2 and E3, E2, and E3 and E4 to criterion.
   - Train whole task E1 and E2 and E3 and E4 to criterion.

   This technique enables the trainee to understand task elements separately and also the links between them which represent a higher level of skill. Czaja and Drury (1981) and Kleiner (1981) use progressive part training very effectively.

5. Develop Schema. The trainee must eventually be able to generalize the training experience to new situations. For example, to train for every possible site and extent of corrosion is clearly impossible, so the trainee must be able to detect and classify corrosion wherever it occurs. Here, the trainee will have developed a "schema" for corrosion which will allow the correct response to be made in novel situations which are recognizable instances of the schema. The key to development of schema is to expose the trainee to controlled variability in training (Kleiner and Catalano, 1983).

Not all of these techniques are appropriate to all aspects of training aircraft inspectors. The next section provides some industrial examples of their use, leading to recommendations for aircraft inspection training.

Examples of Inspection Training in Manufacturing

Table 2, modified from Czaja and Drury (1981), shows the results achieved by industrial users of the training principles given above. In each case the inspectors were experienced, but the results from new training programs were dramatic. To provide a flavor of one of these successful programs, the final one by Kleiner will be illustrated.

Table 2. Summary Table of Practical Applications of Inspector Training Programs.

Investigator(s)	Training Technique	Type of Task	Results
Tiffin, J. and Rodgers, H.B. (1941)	Knowledge of results and training sessions which included lectures	Inspection of tin plates	General improvements in inspection performance; greater detection of faults
Evans (1951)	30 min. class instruction; 11 tests with K of R over 2 weeks	Micrometer inspection of gage blocks	50% reduction in average error, but no effect on retention
Martineck, H., & Sadacca, R. (1965)	Knowledge of results using an error key	Photointerpretation	Decrease in errors of commission
Chaney, F.B., & Teel, K.S. (1967)	Four 1-hr. sessions included lectures, demonstrations, and K of R from a Q&A period	Inspection of machine parts	Training resulted in a 32% increase in defects detected
Cockrell, J.T., & Sadacca, R. (1971)	Knowledge of results and group discussion	Photointerpretation	Significant improvement in inspection performance and a decrease in false alarms
Parker, C.G., & Perry, G. (1972)	Demonstrations, use of photographs simulating items and faults, examples of faulty items, practice with K of R	Inspection of glass bowls	50% increase in faulty detection, 50% increase in false rejections
Duncan, K.D., & Gray, M.J. (1975)	Gradual approach to the task (diagnosis of faults then verification) using programmed instruction	Fault detection in a petroleum refinery process	Training resulted in an increase in faults detected, decrease in detection time, and decrease in false rejections
Houghton, S. (1982)	Product knowledge, standards, search training, practice with K of R, progressive part	Solder joint, inspection	Efficiency up from 33-67% to 89-97%
Kleiner (1983)	Progressive part, cueing K of R, active	Aircraft bearing inspection	Rest errors reduced to zero, 50% scrap reduction

The company manufactured precision roller bearings for aircraft, and the training scheme was aimed at improving the performance of the inspection function for the rollers. All inspectors were experienced, from 2 to 14 years, but measurements of performance (Drury and Sinclair,

1983) showed much room for improvement. Based on a detailed task analysis, a two-day training program was developed. Inspectors were taught using a task card-based system (**Figure 3**). Each card had a color-coded task section.

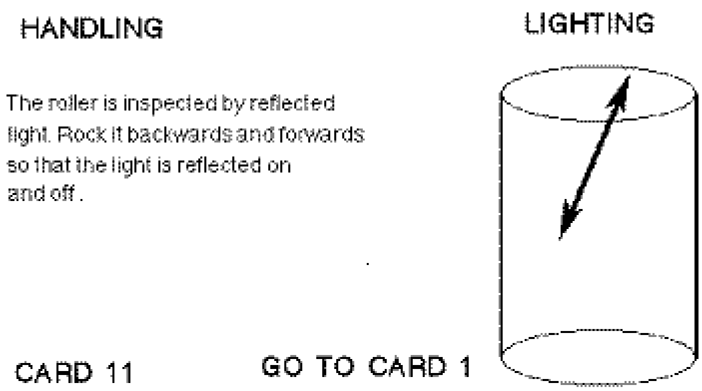

Figure 3

Naming of parts (surfaces)

Naming of defects (flaws)

Handling methods (handling)

Visual search (search)

Decision making (standards, decision making)

Process interface.

For each section, there was a progressive set of cards with information, possible physical examples or test procedures, and a sequence indication. Each card required an active response. **Figures 3**, **4**, and **5** show examples of Handling, Search, and Decision. Note that in each case the next action is to go to the first card in the section to preserve the progressive part structure.

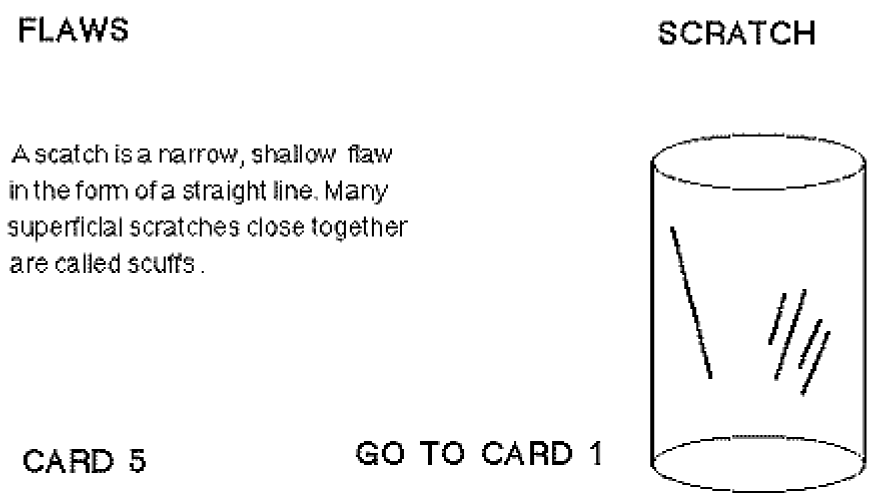

Figure 4

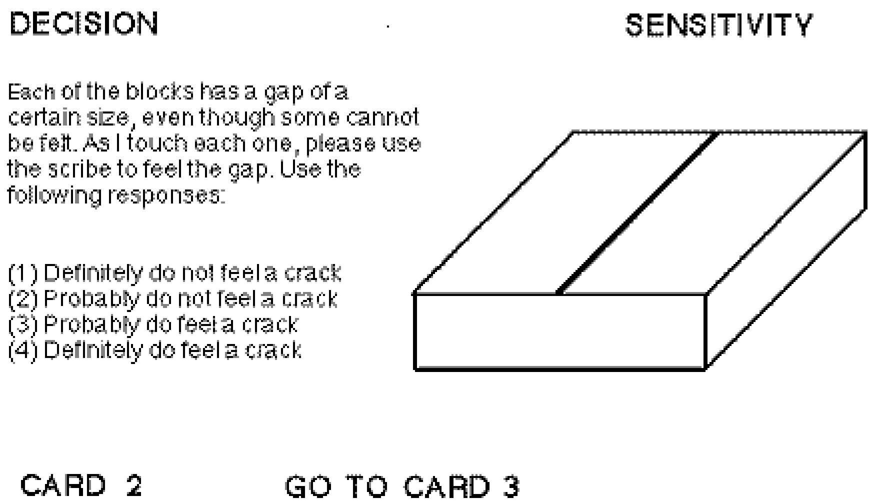

Figure 5

This training program was evaluated in two ways. First, two new recruits were able to achieve perfect scores on the test batch at the completion of the program. Second, the quality of feedback from inspection to manufacturing increased so much that scrap was halved between the six months before the training and the six months after. The whole program was replicated for the inner and outer races of the bearings, entirely by company personnel using the roller training program as an example. Incidentally, subsequent university involvement with turning this company into an acknowledged world-class manufacturer was based on the results achieved in this inspection training program.

Application to Aircraft Inspection

How can these principles and manufacturing examples be applied to aircraft inspection? Obviously, in such a short paper it is not possible to provide more than isolated examples, so the search and decision aspects of visually detecting defective turbine vanes on film will be used as an example. Specifically, this refers to an observed gamma ray inspection of a nozzle guide vane area of a JT9D. The current job card and **NDT** manual lists and illustrates six defects:

1. Trailing edge burning
2. Trailing edge bowing
3. Airfoil bulging
4. Missing vane inner rear foot
5. Broken vane mounting bolt
6. Incorrect vane tilt.

For defects 2, 3, and 6, standards are given, but for others, they are not. There are also defects in the **NDT** manual which are not on the workcard, and differences in terminology between the manual and the workcard. Given that these task design problems can be cured, a training scheme for these defects would proceed as follows:

1. Part naming -- Cueing and active response to the name of each part (inner lug,

mounting bolt, trailing edge, etc.). A physical model should be easily visible and accessible away from the engine. Knowledge of results is given after each response in each step.

2. Transfer to film -- Repeat the part naming on the film to ensure that the three-dimensional concepts have formed a schema which generalizes to a two-dimensional view.
3. Defect naming -- Present large examples of each defect, clearly cued (marked) on a model.
4. Transfer to film -- Repeat the defect naming on film.
5. Search training -- Search for one defect (e.g. bulging airfoil) on different films until the defect can be located accurately. The different films provide the variety needed to develop schema.
6. Search training -- Repeat step 5 for each defect type. Repeat for combinations of defects until complete set can be searched for accurately.
7. Decision training -- Provide the standards for each fault with the measurement procedure. For example, measuring the width of the trailing edge for trailing edge bowing and comparison to standards. Use pre-marked defects to remove any search component. Repeat step for each fault and for combination.
8. Whole task -- Practice both search and decision aspects for each fault separately and for whole set.

Such a training procedure uses the techniques discussed earlier. It is mainly performed off-line in a controlled manner, but the results of the studies quoted in the previous section show that such training successfully transfers to the more complex on-the-job environment. What has really been done is to prepare the trainee carefully to make maximum use of what he/she sees on the job, rather than leaving the learning process to trial and error in an uncontrolled environment. Because the training experience is so controlled, it is concentrated. Trainees can progress to the same level as experienced inspectors (and usually beyond) in days rather than months.

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ORGANIZATIONAL CONTEXT IN AVIATION MAINTENANCE: SOME PRELIMINARY FINDINGS AND TRAINING IMPLICATIONS
Progress of the Human Factors Team National Aging Aircraft Research Program

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Introduction

What I will present today is the report of initial findings from preliminary research on a complex subject. This report describes research on the organizational context of airline hangar maintenance. In line with the topic of this conference, I will draw some implications for maintenance training from those initial findings.

First I must insert a caution that what follows should not be interpreted as criticism of maintenance people or their dedication to air safety. Throughout the course of this study I continue to find well-meaning people everywhere I have visited. These are people who want to do their best for flight safety. In my remarks today I intend to be fair in reporting from my limited sample, but for the purposes of this conference I also intend to emphasize the training needs I have discovered from my interviews.

Background and Purpose of the Study

This study was undertaken to begin the process of obtaining information about human relations and communication in aircraft maintenance work. There is no current public information on the behavior of typical maintenance organizations in the U.S. commercial air transport system. Such information needs to be available from an industry-wide perspective to form a baseline measure. Such a baseline would facilitate developing guidelines for improving error management, improvement of other aspects of maintenance effectiveness (e.g., the speed, flexibility, and cost of maintenance), and improving the quality of working life of all members of the maintenance system. This present study is less ambitious in its scope, but no less so in its intention. It is a rapid observation and diagnostic tool, intended to provide some baseline information quickly to the industry in order to demonstrate the utility of organizational variables in improving maintainer performance, attitudes, and error management.

The full results of this preliminary study will be available to the industry by the Autumn of 1990 to permit a decision on the form and timing of a more extensive, quantified survey study of the organizational context for maintenance.

Design of the Research. A narrow slice of aviation maintenance is investigated in the present study. I have proposed to visit and have discussions with people in ten maintenance facilities in U.S. commercial transport aviation between January and August 1990. These visits involve discussions with aviation maintenance technicians (AMTs), their supervisors and managers. Where possible, the setting is the C-level maintenance check of aging aircraft. All work shifts engaged in the maintenance check are visited, and between 20 and 30 interviews/discussions have been completed at each site.

Progress to Date. Five sites of the ten proposed have been visited. These include Part 121 carriers and Part 145 repair stations. Regional air carriers will be included in the sample, but have not been visited yet. The visits to date have ranged between two and four days and have focused on the activity around a single aircraft.

General Findings

Figure 1 shows what I have seen and heard in the typical evolution of today's maintenance organization. In the late 1960s and early 1970s, the organization of hangar maintenance was guided by the skill and experience of general foremen. To them reported shift foremen and specialist mechanics prepared mainly by their duty tours in military aviation. Also included at that time were schedulers to monitor job assignment documents and instructors to improve and broaden the mechanics' performance and skills.

THE MAINTENANCE ORGANIZATION

1970: The General Foreman

Foremen and specialist mechanics

Schedulers

Instructors

1980: Proven work cards

Experienced foremen and mechanics

Shift foremen and mechanics

Planners

1990: Withdrawal of experienced mechanics

Reduced parts inventories

Older airplanes

Planners/computer experts

Shift Foremen

Instructors

Newer, sheet metal Mechanics

Figure 1

By the late 1970s, the mechanics and their supervisors had reached a high level of competence. Job cards for work assignment had been proven effective and the process of standardizing the work flow in hangar maintenance necessitated the new role of "maintenance planner" to create and manage a work flow system.

Today, in 1990, we find a reduction in the numbers of experienced mechanics and inspectors. This represents, first, the still-lingering effects of AMT layoffs during the dark days of the PATCO strike and our U.S. oil crisis of the early 1980s. A second reason for this reduction in experienced AMTs is the exodus prompted by AMT retirements, promotions, and interdepartment transfers to maintenance shops. Following the general economic recession and airline deregulation, what we find are many indicators of a cost-conscious industry - a most obvious sign of which for the maintenance system is reduced parts inventories. Finally, as we well know now, the fleet of new transport aircraft in 1970 has become "aging aircraft." Together these changes result in the typical hangar maintenance organization guided by shift foremen and/or planners. The latter are increasingly computer-literate and tasked with digitizing the job card and work planning/tracking system. After a decade of absence, maintenance training departments and their instructors are reappearing.

AMT Experience. This current hangar maintenance organization typically has a bimodal experience distribution of 30-plus years and 3 or fewer years. With the increase of aging fuselages, and Airworthiness Directives to attend to them, most demand for new mechanics has been in sheet metal repair. Thus, most sheet metal mechanics are new, and most of these are young. They typically hold an A&P license, but did not enter aviation training directly out of high school. In most cases these new AMTs do not have military experience, and if they do, they are not necessarily immediately qualified for A&P work in a Part 121 carrier or Part 145 repair shop. For instance, experience as a military crew chief provides deep experience in weight and balance but little else, while repair in helicopters provides no understanding of repair on pressure cabins. There are also some AMTs who come into maintenance work after spending time in defense-related and/or aircraft manufacturing. This is also of limited benefit.

Organizational Structure. Structure differed among the sites I visited. The atypical characteristics range from unified systems to separate fiefdoms. The latter are often organized with Maintenance, Materials, Inspection, and Planning/Scheduling Departments, all reporting to separate vice presidents.

In some companies, Scheduling and Maintenance report together at a lower organizational level. In yet others, a materials group reports to the maintenance organization. These differences are usually reflected in the degree of cooperation among the departments and the degree of shared purpose. Several companies I visited had sheet metal departments in heavy maintenance units, separate from and in addition to sheet metal shops.

Different structures can act to vest authority in some departments (e.g., Planning), consequently eliminating or reducing authority in another department (e.g., Maintenance). In these cases, Planning usually reports up a separate chain of command from Maintenance.

For instance, in one company, high control of repair by Planning through restricting access to job card racks diminished the sense of control that mechanics, inspectors and their supervisors felt. Lower control and pride of "ownership" often led to lower care/attention to work performed.

Differences in norms between departments, or less developed norms in an inexperienced workforce, lead to decisions to control work which have widespread effect. In one instance, Inspection took control of routine job cards "opening up" access for preliminary inspection, based on a mistrust of inexperienced mechanics "closing up" access before inspection had been completed. They did this by issuing a "non-routine" job to open-up, and another to close the job after inspection. The resulting lack of control of initial work planning by maintenance foremen and scheduling supervisors created confusion and frustration.

Expectations. I often heard reports of errors involving miscommunication. A new employee and an experienced boss usually means deference of the former to the latter - the former is expected to be learning the ropes, after all. Such subordinates will not often voice uncertainty or their lack of experience when assigned to a job. There may also be a failure to report problems if they occur. Relatively inexperienced employees are thus assigned to work beyond their abilities with ensuing repair errors. In those companies where there are strong sanctions (expectations) against remaining quiet and no punishment for speaking up, these errors are reported much less frequently.

Attitudes and Opinions. Despite these differences among companies, there were similarities in how AMTs saw things and felt about them. **Figure 2** lists the common categories of current attitudes.

Organizational Purpose and Mission. In all sites, a typical statement was, "everybody wants quick turnaround." Whether this was cause for AMT's pride or frustration or stoicism depended on the degree to which they saw this as realistic and relevant. AMTs consciously accepting safe, fast turnaround as realistic and relevant is an operational definition of purpose or mission. Most C-check sites I visited, however, had no apparent mission, either espoused or enacted. In these places, AMTs were willing to do their best in what seemed to them to be impossible circumstances. Only one of the sites visited revealed a strategy of maintenance which was both acknowledged and successfully pursued by AMTs. This site took pride in airworthy repairs and fast turnaround of the aircraft. In this site, foremen routinely held meetings with AMTs at the beginning of shifts to emphasize the joint purpose and their performance in its pursuit. In the other sites, confusion and crisis were the trend, typically with a willingness of AMTs to respond if they were led.

THE MAINTENANCE ORGANIZATION

Typical Experiences in C-Check

- "Everybody wants quick turnaround."
- "Folks are uncertain about what a flaw is, or what to do about it."
- "Those (new/young) folks don't love airplanes like we do, they aren't loyal to the company, and they don't have that old hustle."
- "Computers are coming in, and we're not certain who's in charge -- maintenance, or planning, or the computer?"

Figure 2

Work assignment was seen as disorganized in two sites, with mechanics milling around at first of shift at the card racks until jobs were passed out. Once in receipt of job assignments, AMTs go to the job location and begin work or wait to get advice from leads and supervisors. In another case, Planning controls the job cards and passes them through the window to mechanics and inspectors without comment.

AMT Experience. Inexperience typically elicits similar reactions throughout the maintenance organization. Inspectors are expected (by themselves and others) to be confident of their decisions. These decisions often go beyond the identification of a flaw and include the required repair as well. Often relatively inexperienced inspectors (or inspectors with experience limited to systems, engines, and flight surfaces) will prescribe sheet metal repairs which are at variance with mechanics and their supervisors. These frequent differences are usually resolved between inspection supervisors and their counterparts in Maintenance.

Thus, AMTs are wary of one another's abilities and this includes feelings of mechanics for inspectors as well as vice versa.

Organizational Culture. In the past, the aviation industry could aptly be called "boys' own airplane club," because the people who chose it loved airplanes and flying. It was and still is a **boys'** club, in maintenance at least, because I saw very few women AMTs or managers. The passion, however, has largely gone the way of dope and fabric wings - held by the long-time employees and a few of the newcomers. From the top to the bottom jobs, people today join airlines for many reasons beyond the love of planes. This clear shift, plus changes in the labor force, confounds the long-service employee. Older AMTs are often discouraged with what their companies have become, and they resent the newer mechanics' lack of skills, their laissez faire attitude, and their high turnover. The new mechanics seem to like the work, but are not "excited" about it. The company's reputation is of little concern to younger workers because they are/will move on to other companies or other industries.

Whether or not an organization has a mission or conscious purpose, it can have a clear locus of control. This is sometimes structural combined with behavioral norms, and sometimes the norms themselves, over time, can wrest control in one group over the others. Usually the struggle for control over maintenance work is between Maintenance and Planning - and as computerized planning becomes more common, it can take on a life of its own, seeming to rise above both the Maintenance and Planning people in its rigidity and singular focus.

Training

Figure 3 lists the results to date which bear on training issues.

THE MAINTENANCE ORGANIZATION

Technical Training

Pre-employment preparation

Ab initio training

Recurrent training

On-the-job training (OJT)

Other Training

Safety training

Team building, leadership

Attitudes toward training

Figure 3

Technical Training

Pre-employment Preparation. There is little sheet metal training in A&P schools. Previous aircraft manufacturing experience is usually good for riveting skills.

Ab initio Training. With new mechanics' typical inexperience with Part 121 aircraft and maintenance practices, some vestibule training is provided in most sites observed. This training is intended to provide introduction to Part 121 aircraft through reviewing the AA Chapter categories.

Recurrent Training. Inspectors are faulted for not having much previous sheet metal experience and no training in sheet metal after becoming inspectors.

On-the-Job Training (OJT). On-the-job training (OJT) is performed by young, relatively inexperienced AMTs as often as by the seniors. Despite descriptions of elaborate OJT programs in several companies, little beyond "sit by Joe" was observed.

Attitudes. Younger workers' attitudes toward recurrent training are mixed. In companies where some training is provided they want more, and in those that don't provide much training, AMTs don't complain but they may not realize what it can add.

Other Training

Safety. *Ab initio* orientation training usually covers personal safety. Many companies require periodic (often monthly) safety meetings.

Team Building, Leadership. One company provided shift foremen with training on how to conduct meetings. This company also required them to hold a crew meeting at the start of shift. Some of these foremen used their training well, and others did not. Even when the meetings were less skillfully led, the crews acted with less disorganization than in sites where foremen were neither encouraged nor trained to lead meetings.

Implications for Training

Figure 4 lists implications of these results and the recommendations which follow from them.

IMPLICATIONS FOR TRAINING

Some preliminary thoughts

- Increase and improve OJT
- Improve and expand sheet metal training
- Emphasize and expand teamwork training

Figure 4

Increase and Improve OJT. When OJT is offered it should be conducted by experienced employees, trained in teaching/learning techniques. It should be planned and frequent, with records kept complete and up to date. OJT records should include time spent on the training as well as an evaluation of the learner's knowledge and performance for a complete system or mechanical/electrical module. Ensure that faulty knowledge is not perpetuated from instructor to learner.

Improve and Expand Sheet Metal Training. A&P schools should extend their practical sheet metal repair module and minimize theory. Recurrent training for sheet metal repairmen should include theory as well as technique. Damage tolerance principles as well as the origins of SSIDs and on-condition monitoring should be covered. Sheet metal courses would be an effective addition in the inspectors' recurrent training program as well.

Emphasize and Expand Teamwork Training. Other industries outside aviation have established the effectiveness of brief, frequent and focused meetings between supervisor and subordinates. Where these are very brief but daily start-of-shift safety meetings, lost time accidents and injuries decrease. In the present study, those cases where foremen were observed leading daily, focused shift briefings, their groups were effective in achieving high performance. Where principles learned in leadership and team training were applied by foremen in these briefings, their results were even more positive.

Appendix B: Meeting Agenda

Third Federal Aviation Administration Meeting on Human Factors in Aircraft Maintenance and Inspection
"Training Issues"
12 - 13 June 1990

Tuesday Morning - Marlborough Rooms A/B/C

7:30 a.m. Registration

8:30 a.m. Welcome/Meeting Objectives *William Shepherd, Ph.D.* **Federal Aviation Administration**

9:00 a.m. Keynote Address *Col. Robert R. McMeekin, MC, USA* **Federal Air Surgeon Federal Aviation Administration**

REGULATION AND OVERSIGHT OF MAINTENANCE TRAINING BY THE FAA

9:30 a.m.	FAA's Proposed Revisions to Parts 147 and 65 *Leslie K. Vipond* **Office of Flight Standards Federal Aviation Administration**
10:15 a.m.	Break

TECHNICAL TRAINING (A&P SCHOOLS, MILITARY, ETC.)

10:30 a.m.	U.S. Navy Training for Aircraft Maintenance *Captain James Qurollo, USN* **Naval Air Maintenance Training Group**
11:15 a.m.	Training Within the Industry *David Wadsworth* **President, Professional Aviation Maintenance Association**
12:00 noon	Lunch

Tuesday Afternoon - Marlborough Rooms A/B/C

TECHNICAL TRAINING (A&P SCHOOLS, MILITARY, ETC.) - Cont'd.

1:00 p.m.	Technical Training Schools *Jack Moore* **President, Aviation Technician Education Council and Professor, Clayton State College**

INDUSTRY TRAINING PROGRAMS-THRUSTS

1:45 p.m.	An Innovative Approach to Training **NDT** Inspectors at Boeing *Diane Walter* **Boeing Commercial Airplanes**
2:30 p.m.	Break
2:45 p.m.	Development of Maintenance Training for a New Aircraft - Commercial Tilt Rotor Program *Thomas Cooper* **Bell Helicopter**
3:30 p.m.	Maintenance Training - A View from the Floor *John Goglia* **International Association of Machinists and Aerospace Workers (IAM&AW)**
4:15 p.m.	Adjourn

Wednesday Morning - Marlborough Rooms A/B/C

INDUSTRY TRAINING PROGRAMS-THRUSTS - Cont'd.

8:30 a.m.	Airline Maintenance Training - Experimental Training Systems *Kenneth Govaerts, Ph.D.* **AMR Technical Training** and *Andrew Gibbons, Ph.D.* **WICAT**
9:15 a.m.	Introducing CRM into Maintenance Training *William R. Taggart* **Resource Management Associates/Pan Am**
10:00 a.m.	Break
10:15 a.m.	Training at the Repair Station *Michael Rose* **Lockheed Aeromod**

ADVANCE TRAINING TECHNOLOGY

11:00 a.m.	New Training Technology for Maintenance *William Johnson, Ph.D.* **Galaxy Scientific Corporation**

11:45 a.m. Lunch

Wednesday Afternoon - Marlborough Rooms A/B/C

ADVANCE TRAINING TECHNOLOGY - Cont'd.

12:45 p.m. Use of 3-D Presentations in Maintenance Training *James Rice, Ed.D.* **Rice Aviation**

1:30 p.m. How the Brain Processes Information *Ernest S. Barratt, Ph.D.* **University of Texas, Galveston**

PANEL PRESENTATION

2:15 p.m. Progress of FAA Human Factors Team *Colin G. Drury, Ph.D.* **SUNY Buffalo** and *James C. Taylor, Ph.D.* **University of Southern California**

MEETING RECOMMENDATIONS AND CONCLUSIONS

3:00 p.m. *William T. Shepherd, Ph.D.* **Federal Aviation Administration** and *James F. Parker, Jr., Ph.D.* **BioTechnology, Inc.**

3:30 p.m. Adjourn

Appendix C: Meeting Attendees

Third Federal Aviation Administration Meeting on Human Factors Issues in Aircraft Maintenance and Inspection
12 - 13 June 1990

TRAINING ISSUES

MEETING ATTENDEES

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