

**Meeting 10: Maintenance Performance Enhancement  
and Technician Resource Management (1996)**

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

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# INTRODUCTION

**William T. Shepherd, Ph.D.**

*Federal Aviation Administration  
Office of Aviation Medicine*

## WELCOME

Welcome to the tenth meeting in our continuing series of *Human Factors in Aviation Maintenance and Inspection* workshops. This meeting shall focus on maintenance performance enhancement and technician resource management. We trust that you will find the workshop to be interesting and valuable.

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

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

The first result is that meeting attendance has increased by over 400%. There is definitely a growing aviation industry awareness of human factors in maintenance. The topic has been a significant item of discussion at both 1995 Safety Summits, held by the US Department of Transportation.

A second result is information dissemination. Our research team has produced over 200 reports, publishing over three thousand pages in hard copy and on four CD-ROMs. We have distributed these publications widely.

A third important obvious result is The *Human Factors Guide for Aviation Maintenance*, now available through the US Government Printing Office. The *Guide* has set the standard for maintenance human factors information. The CD-ROM version of the *Guide* extends beyond the hard copy to provide a variety of multimedia information.

Fourth, and hardly last, we have conceptualized, created, and evaluated numerous advanced technology training and job-aiding systems. The Portable Performance Support System, the Boeing 767 environmental control system tutor, the Ergonomics Audit software, and the Coordinating Agency for Supplier Evaluation software are only a few of the other tangible results produced by our team.

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

Sincerely,

William T. Shepherd, Ph.D.  
Manager

Biomedical and Behavioral Sciences Branch  
FAA Office of Aviation Medicine

# Keynote Address

## 10th Meeting on Human Factors in Aviation Maintenance and Inspection

### Plan for Maintenance Human Factors

**Fred Leonelli**

*Manager, Aircraft Maintenance Division  
FAA Flight Standards Service*

#### INTRODUCTION

Good morning, everyone. Welcome to the Tenth FAA sponsored meeting on Human Factors in Aviation Maintenance and Inspection. My presentation today is in three parts. First, I will present a brief, oral history lesson, recalling the first successful identification and solution to a World War II aviation maintenance human factors problem. This will be followed by Part 2 which will be a briefing of FAA's action plan titled: Total Optimization of Performance in Aviation Maintenance, or TOP-AM for short. Then in Part 3 of this presentation, I will share with you a couple of personal observations on possible changes the FAA could experience in the near future-- and the impact of those changes on maintenance human performance research efforts. I will finish with a personal request to the aviation maintenance industry.

#### PART 1

Almost every one agrees that the "modern" science of human factors began over 50 years ago during World War II. When World War II broke out, the -- then -- brand new field of human performance research concentrated primarily upon eliminating certain common accidents related to cockpit design and aircrew performance under stress. Research papers on pilot fatigue, cockpit lighting, and similar aircrew-cockpit interface subjects continued to be published by scholars long after the war, giving rise to the new discipline of aviation psychology.

Regrettably, little was published dealing with specific aviation maintenance human factors problems. This doesn't mean that important work in addressing maintenance human factors problems wasn't being accomplished during the World War II years - it was!

Allow me to share with you a story told to me by Mr. Chuck Shaffer, a retired FAA airworthiness inspector. Chuck was one of those lucky individuals who personally participated in one of those first, but undocumented, "successes" in aviation maintenance human factors and performance. Back in 1942, Chuck was based at an Army Air Corps training field a little south of Midland, Texas. He was a B-24 flight engineer in training, who was also required to work part-time as a mechanic to keep his aircraft flying when he was not scheduled for classes. Along with this dual workload, his training unit was experiencing a high number of maintenance personnel accidents.

His company commander's leadership response to this loss of manpower and intolerably high accident rate was to get everybody up at 5 am, six days a week, for 1-1/2 hours of close order drill and intensive calisthenics using the 9-1/2 pound, M-1 Garand rifle.

While in today's society, the company commander's approach to a human factors problem seemed a little Draconian, the fix worked! In less than three weeks, the accident rate dropped below the Army

Air Corps' average for B-24 maintenance personnel. Incredibly it continued to decline up until the day Chuck and his fellow trainees were shipped to their overseas units.

On the day before Chuck was shipped out, the company commander posted a letter on the company's bulletin board. His letter, in the form of a poorly veiled apology, explained his rationale for instituting the dreaded 1-1/2 hours a day exercise routine.

He narrated that when he first examined the company's lists of accident related injuries he found the vast majority of them were upper-body injuries, such as broken arms, sprained shoulders and wrists, and lower back injuries.

He then spent some time watching the men work and observed that most of his trainee flight engineers and mechanics were not physically strong enough in their arms and back to maintain 10 hour work days, 6 days a week. So the men got tired, sloppy, and hurt - in that order.

Briefly put, the company commander's human factors problem-solving process went like this:

1. Our accidents are caused by fatigue and lack of upper body strength.
2. The workload will remain the same or expand, so my men need stronger upper body muscles to cope.
3. I know exercise improves endurance and makes muscles stronger.
4. Solution: make these men exercise their upper body muscles with a readily available 9-1/2 pound weight and monitor results.

I think we can agree that the company commander's approach was a simple, perhaps crude, but nevertheless effective approach to solve one maintenance human factors problem. To the best of my knowledge and Chuck's, this solution was never published, never studied, and never implemented at any other Army Air Corps bases. Why not? My best guess, with the confusion of running a two-theater war notwithstanding, would be that "maintenance," even aviation maintenance, is falsely perceived as a kind of a dry and colorless subject. Not at all the kind of research material that an aspiring Ph.D. or General would find interesting enough to explore.

So for almost 42 years after the end of WW-II, we mechanics did not share in anywhere close to the attention, notoriety, or veneration that is heaped upon our flying brethren by both academia and the media. But if the truth be known, we in the aviation maintenance community quietly enjoyed the anonymity.

Regrettably, that all changed on April 28, 1988, when on a routine flight between the Hawaiian Islands of Hilo and Honolulu, a Boeing 737-200, suddenly lost 20 feet off the top of its main cabin section, terrifying the passengers and resulting in the tragic death of a flight attendant. From that day forward, maintenance human factors was no longer dry and colorless. Scientists and the Federal Government began to direct more of their attention to solving these kinds of problems, and the research and development into aviation maintenance human factors and performance was accelerated.

From the beginning, the FAA's Aircraft Maintenance Division has supported research into human factors programs. We were here at the first maintenance human factors workshop, and every year since. In 1991 we participated in the development of the Aviation Medicine Human Factors Handbook. It's a very important document that addresses everything a repair station or an air carrier needs to know about creating the ideal work environment for maintenance technicians. We continue to support Aviation Medicine's research programs in maintenance human factors.

In 1991 and 1994 we started working on two major human factors and performance initiatives: the Maintenance Job Task Analysis, and AD Communication. "Job Task Analysis Project" was created in 1991 and is being worked by Northwestern University of Chicago. They will identify each task a maintenance technician performs and identify the scope and detail of the training for each of those

tasks. The job task analysis is scheduled to be completed by the end of this year and, once completed, it will be used to develop state-of-the-art Federal Aviation Regulations for maintenance technician training.

In 1994, Northwestern University was also tasked with developing a project that will take the "confusion" out of airworthiness directives. The project is designed to improve AD readability and overall level of compliance. The "AD Communications Project" is scheduled to be completed by mid-1997.

## PART 2

One year ago, as a result of a less than auspicious safety record in 1994, over 900 aviation industry, government and union aviation officials participated in an aviation safety workshop here in Washington, DC. From that January 95 meeting, the concept of "Shared Responsibility" was born. Shared responsibility means that both industry and the FAA are responsible for finding and solving aviation safety-related problems.

The published goal of this concept is "zero accidents." To help meet that clearly defined end, the maintenance workshop participants recommended: "that FAA Flight Standards Service should devote additional research effort toward human factors and performance for aviation maintenance, and focus the research on error-detection and prevention." The FAA's flight standards service responded to this specific industry's workshop recommendation by assigning the aircraft maintenance division as the lead organization to pursue that goal of zero accidents in the maintenance human factor area.

As manager of the aircraft maintenance division, I tasked two elements of the FAA's internal research community, the FAA's Tech Center's maintenance, inspection and repair section (AAR-433) and the Office of Aviation Medicine's research and special project staff, (AAM-240) to develop and implement an appropriate action plan. Their action plan is titled "The Total Optimization of Performance in Aviation Maintenance or TOP-AM" for short. It is a systematic, integrated FAA action plan for enhancing maintenance personnel performance by improving error-detection and prevention--- by applying human factors and performance principles.

Our TOP-AM plan addresses the following areas: work structure and function, equipment, job system design and development, and training and information delivery. The rationale behind the development of TOP-AM focuses on:

- Part 121 and Part 135 operators
- Maintenance, how it is tracked, how to enhance it, and how to insure a level of human performance which promotes our zero accident mandate
- How to enhance professionalism in maintenance performance
- New initiatives designed for short term implementation
- Prompt evaluation of the results of new initiatives
- And finally, directing limited FAA resources to areas that can be significantly improved.

Since TOP-AM is designed with the concept of shared responsibility, the two user groups -- FAA and industry -- will participate together in the TOP-AM committee. The TOP-AM committee was formed in April of 1995 and includes members from Flight Standards Service, Aircraft Certification,

FAA Medical, and representatives of large and small air carriers.

The basic tenets under which the committee operates are:

1. The FAA's Aircraft Maintenance Division role in this partnership is the mentor and overseer of the TOP-AM action plan. We are responsible for all decisions on maintenance human factors and performance projects, and the accountability for ensuring that current and planned work meets industry and Flight Standards Service requirements. FAA's AAR-400 at our technical center in Atlantic City and Aviation Medicine will provide the majority of the research and development funds, and manage certain research tasks.
2. The FAA's Office of Aviation Medicine research and special projects staff will also administer research and development tasks and provide funding for these projects.
3. Air carrier representatives are responsible for a ruthlessly honest review of the TOP-AM plan and for providing the FAA with their expertise, coordination, and participation in current programs, as well as developing future maintenance human factors and performance initiatives.

### Three Parts of the TOP-AM Action Plan

The first part is the executive summary handout, which is an overview of my briefing today and also includes a list of projects we are currently working on.

The second part is a strategic plan of action. This Part 2 of the TOP-AM Action Plan shows our overall objectives for improving human performance for the next five years. It is more cerebral in nature because it identifies broad research areas, the intelligence gathering methods to be used, and limits, if any, on the products or data produced.

The third part of the action plan will be what I call the Maintenance Human Factors and Performance Tactical Plan. For me it will be the most useful, because it will identify the current projects, the responsible organizations, the products to be delivered, and the project's milestones. This tactical approach is useful for two important reasons:

1. The TOP-AM plan stays flexible, current, and responsive to the plan's users, the industry and the FAA
2. I have just one document to review, to track the status of each human factors project and I will know immediately if I should hand out a bunch of "atta-boys," or dust off some M-1 Garand rifles.

So far I have briefly described the plan, its beginning, its design, the players and their responsibilities. But all this background information begs the question "What have we been doing since last January?" Again, as I mentioned before, in Appendix II of the TOP-AM Part I handout, you will find an overview of current and future human factor initiatives that the FAA and the TOP-AM committee has initiated in the past year.

## PART 3

As promised, I will now close with some personal observations and comments. In October of this year, the FAA may be forced to go on a "SlimFast" budget! Current FY '97 budget projections estimate a 1.3 billion dollar cut from fiscal year 1996 allotment. Such a dramatic cut will have across-the-board cuts, and maintenance human factors' research may be adversely affected.

At this point in time, it is still too early to know how much, or in what areas of maintenance human

factors and performance research will be impacted. I expect to work closely with the TOP-AM steering group over the next six months to make the potential budget cuts as painless as possible.

There are two major bills, that are FAA-specific, presently being worked in both Houses of Congress. One bill, HR 2276 addresses FAA re-organization, and the other concerns itself with the separation of the FAA from DOT.

We should know something concrete on, or before, the end of April; after both Houses meet in Committee and either agree to work out a compromise or agree to table both bills. If the FAA is re-organized or moved, the aviation industry will have to understand that some research projects presently in work, will be delayed, or canceled even if they were lucky enough to be funded in the 96 fiscal year budget. Part of this painful process of change is that existing manpower and resources will have to be juggled to meet the demands of the new working environment. No one is exempt from this process, including me.

## CONCLUSION

My final comment takes the form of a request. In the past year I have reviewed a great number of maintenance human factors reports and proposals. It appears to me that in our 10 years of formalized research we have evolved to a point that we tend to place more emphasis and funding on major factors, bigger processes, and complex procedures and forgetting, or at least delegating, to second place, the immediate, limited, but no less important needs of the men and women on the hangar floor. Therefore, today I am asking industry to do all of us a real service. For the next 12 months, at every air carrier line station, repair station, and maintenance facility, I am requesting that each manager, supervisor, and technician concentrate on finding and fixing 100 small human factors problems that bedevil mechanics and technicians every day on the hangar floor.

I am convinced that if we get into the habit of concentrating on correcting all the small, myriad problems that plague our industry, the outcome would be that the big and ugly maintenance related human factor problems will be far fewer in number, and decades apart.

# Keeping Quality in Focus During Restructuring

**Donnacha Hurley**

*Chief Executive  
TEAM Aer Lingus*

## INTRODUCTION

Good morning ladies and gentlemen. And sure it is a nice mild morning unlike the "snow-in" that you experienced here last week.

As you can probably gather from my brogue, I am Irish, which for many of you is synonymous with green, shamrock, Guinness and Blarney stone; but most of all rain - and we sure do get a lot of that.

For those of you who experienced the "snow-in" of last week, I am sure it's of little consolation to you that my kids look at these scenes on the TV news and feel deprived since they haven't had the privilege of playing in the snow! Perhaps we can have a deal here - we'll give you some rain in exchange of snow! On second thought, let's leave well enough alone - I couldn't sell that - since you probably would not want our summer rains.

I am indeed glad to be here today to make a presentation at this 10th conference on Human Factors in Aircraft Maintenance. I hope that you will all be able to understand my Irish brogue. I will answer any questions later.

The topic I am going to speak on this morning is: "Keeping Quality In Focus During Restructuring" - emphasizing the restructuring journey and importance of Quality.

TEAM Aer Lingus embarked on its restructuring journey in late 1993, and it is still on-going. Over the past 7-8 years, I have attended many presentations by the gurus and consultants who were always at pains to emphasize that world class, total quality, employee involvement, call it what you may, was a "Journey", not a project. I always subscribed to the view, but perhaps thought it was a project. Having been living with it at TEAM for the last 18 months, I can assure you that it is a journey and can confirm similar sentiments from my previous employment.

It takes a lot of hard work and commitment to ensure that you stay on track. It's not just good enough to get on the track. That's the easy part. Once on the track you must keep up the continuous improvement momentum because, as Will Rodgers said, "If you rest on the right track you will get run over by the guy coming along from behind."

## A little bit about TEAM Aer Lingus

We are based in Dublin, Ireland -- at the center of the universe! We are in the Aircraft Engineering and Maintenance business.

The services we provide can be broadly categorized as follows:

- | Aircraft Overhaul
- | Component Overhaul
- | World-wide Materials support (Aer Spares/Rotables/Leasing/AOG support)
- | Technical support (Engineering, Planning, Quality, Technical Training)

We are part of the Aer Lingus group of companies employing 1700 people in TEAM. Aer Lingus is the state-owned national airline of Ireland. The current group structure:

- | Maintenance
- | Airlines
- | Services

It is a much slimmed down Group which previously had diversified into hotels, computers, etc. but has now restructured back to its core business strength.

The Maintenance section has:

- | TEAM
- | Airmotive, which is also in Dublin and in the engine overhaul business
- | Shannon Repair Services, which is a single bay airframe overhaul facility based at Shannon airport

The Airlines consist of:

- | Aer Lingus main airline
- | Aer Lingus Commuter, which is regional carrier in Ireland and UK
- | Futura is a charter company based in Palma, Spain
- | Galileo is a reservations system

The Services section wraps up the other companies of the Group.

The Group turnover is £1.3bn and the airline operates a fleet of 32 modern 737 [EFIS](#)/Airbus 330s.

## **So why did TEAM Aer Lingus restructure?**

Very simply, TEAM was losing money and was likely to continue doing so unless something was done with its costs base, as there was no sound basis for expecting an improvement in the yield which is the only other way of "squaring the circle." Such a loss-making situation was unacceptable to the shareholders. Accordingly, TEAM developed a plan which would return it to profitability within the stipulated five-year time frame.

## **Why was TEAM losing money?**

The reasons can be categorized into:

- | External Reasons
- | Internal Reasons

## **The External Reasons**

First, similar to most industries, the competition upped the ante. Secondly, this competition was fueled by enormous over-capacity currently estimated and growing through new entrants and efficiency generated capacity. Thirdly, OEM chain started to target the after-market which had not

really been their stomping ground in the past.

Might I also say that by comparison to other industries in which I worked, I believe that the OEM's performance is a significant barrier to progress in our industry since they do not measure up to the best in class practices on:

- | Cost
- | Service
- | Lead-time

## Turning to the Internal Reasons

Our costs structure was far too high, which was being impacted greatly by:

- | Out-of-date work practices (i.e., demarcation)
- | Work patterns which meant we did not have flexibility to have our resource available when customer demand dictated. We had to address the peaks with overtime/more people and we had to pay people to sit around during the valley period

We had management issues:

- | People
- | Processes

Things have changed right around the world. All suppliers must focus on Customer priorities and provide them with what they want and this industry has now got to face up to the fact that we must focus on customers needs and it is a buyers market.

In a buyers market, regardless of the fact that different companies place differing weightings on the individual elements of the Total Cost Equation, each vendor must be able to deliver upon the world class measures of:

- | Lowest cost
- | Highest quality
- | Superior customer service

In the cases of Quality and Customer Service, it is necessary to deliver on both the:

- | Hard and definitive elements (technical quality, OTD) as well as the
- | Softer issues - a word that now becoming more widely used in "Perceived"
  - | Perceived "Quality"
  - | Perceived Customer Service

This is the challenge.

In this industry we are having to play catch-up with what the Japanese have done in most other industries in terms of Quality, along with Deming. In fact, it is no longer true solely with the Japanese, the Quality concept is everywhere.

In my view, we are laggards in facing up to the realities of life which practically all other industries have had to face up to and did so long before us. We must, if we want to survive, be World Class. World Class is the highest standards in everything we do, as measured by the customer.

For many years this industry considered itself unique and convinced itself it didn't have to take on these principles. I worked in other industries that could equally have been defined as unique and they had to embrace these concepts. Those who didn't are going/have gone to extinction.

TEAM Aer Lingus has decided -- and perhaps we had no other option -- that we need to embrace World Class standards of performance, if we are going to survive in a highly competitive over-capacity industry.

Survive is the operative word since we are in an industry that has rates of \$30/hour +/- . We all know that your local mechanic charges that or more, and are in this highly regulated industry where our people:

- | Are highly trained with lots of experience
- | Carry a huge responsibility on their shoulders -- that of safety for the flying public -- not to be taken lightly.

One could ask the question, "Are we selling ourselves short?" I can say, "yes" and could support it, "but that's all the customer will pay." So we have to accept the reality.

One could expect and accept that everything will be cut to the bone to operate in this environment, perhaps even to the extent of cutting corners. Someone might ask, "Will quality be compromised?" At TEAM Aer Lingus the answer is a resounding, "NO." Our logo, the Shamrock, our heritage, our people, our conscience and our values will never allow that to happen. In a small country and in a small local community with 1700 livelihoods dependent on the well-being of TEAM, we cannot and will not compromise on Quality, not only for the sake of TEAM, but also for the sake of the Airline.

Each company has to honestly and responsibly answer the question, "So what have we done?" Well, we went through 12 months of negotiations to reach agreement on restructuring, which involved 1300 people being laid-off and Chapter 11 bankruptcy before reaching an agreement. That will give you a flavor of the confrontation and "them" and "us" attitude that prevailed.

There was a complete mistrust and breakdown of communication between worker and management. In fact workers had taken away the consent to manage.

Our priority was to right our costs, which involved addressing both direct cost issues and management issues.

The direct costs included:

- | Payroll
- | Work practices
- | Work patterns
- | Non payroll overheads
- | Purchasing

The management issues tackled where structure and processes. These were the tangible/hard and perhaps easy issues to address. That in itself would not have been sufficient if we were serious about change and viability since TEAM had come from the cost center mentality and had to come to grips with the commercial realities of profits and viability.

Perhaps this is hard for many of you to understand. It was for me also when I joined 18 months ago.

But when you are in a "cost" environment (a protected species for 25/30 years) where profits were not a measure of success, then you can begin to understand the difficulties involved in the Paradigm Cultural change.

There are consultants who sell their services on the implementation of World Class and Total Quality programs which are after launched in a blaze of glory. We all know and perhaps we experienced how quickly some of these initiatives failed. At TEAM we did not choose "big bang" approach - why? TEAM had tried a Total Quality program in 1992/93, before restructuring, and it did not work.

As happens in many organizations, for these initiations there is a Project Manager appointed and plans are set down and it is never integrated into day-to-day management and, therefore, takes second priority to the day job.

The same thing happened in TEAM and responsibility was passed down the line.

Senior management personnel were too busy with their day jobs. They delegated and abdicated. So we weren't going to fail a second time.

However, the senior management team and I mapped out a 4 year program of change:

- | Reframing
- | Pathfinding
- | Revitalizing
- | Renewal

We set out where we were going. We were targeting World Class. We know we are on a journey and want to have arrived with success under our belts so as to win back credibility before we beat the drums again.

This is our second year, and maybe in 12 - 18 months time we will give the program more publicity. Having worked in an organization which had a high profile project, I can honestly say that the progress on this less public program is every bit as significant. As I said, we have been through Phase 1/Year 1.

First phase priorities were:

- | Get management to manage.
- | Reassess costs.
- | Move to being output driven, rather than input driven.
- | Focus on the basics.
- | Support these initiatives with appropriate training. This is not only Management development, but also skills of Performance Appraisals, Presentation Skills, Commercial Awareness, etc.

The "Basics", as we refer to them, were the key issues we had to get managers to take on board in terms of being output driven and being focused on profitability in the medium term. To many of you this is perhaps straight forward and a "given"; to others maybe not.

We are aiming to have these basics almost as day-to-day values, not high-powered values, but honest-to-goodness building blocks for the future.

In fact, sometimes organizations miss the point completely when starting out on this type of journey.

This focus manifested itself right across the organization. Specifically dealing with quality

assurance, we targeted:

- | Moving away from a policeman role to a pro-active role. Build quality upfront.
- | We set a vision of where we wanted to get to in terms of QA. We targeted ISO 9000 as an external accreditation of our standards. In your terms, it would be the equivalent of Malcolm Baldrige.
- | As I have already said, we wanted managers to be accountable for Quality Assurance, not just those in the quality department
- | And above all, we led by example by getting senior management more actively supporting this.

In more specific terms, some of the things we are at are:

- | Refresher Courses
- | Standards management
- | Standard Operating Procedure
- | Reminder cards
- | Customer complaints
- | Auditing with follow-up to completion
- | Self auditing
- | Perceived Quality
- | Supplier and sub-contractor approvals
- | We have improved our communications process so that everyone is informed. Difficult as it is, we have to break away from the mold of "information = power". I have addressed all 1700 people in group of 30 - 60 twice in 1995.
- | Management commitment and support
- | Visibility of management - MBWA
- | Performance expectation for departments

As you know, success only comes before work in the dictionary. The journey continues:

The hard work - we are not finished.

- | We have started to get employee support, trust and credibility.
- | In 1996 we will focus on the employee.
- | Gold standard - provided you pay
- | Competitive Price - not necessarily at \$30/hour
- | On Time - everything
- | Continuous Improvement - continuous re-engineering. BPR is good buzz word. We are doing it, but again without the drum beating.
- | Stick to the knitting, and be profitable.
- | New IT systems - at a cost of almost five million dollars.

- | TEAM, in-house to make it happen and externally to keep customer satisfied.

In a word:

- | Openness
- | Clear objectives
- | Unrelenting/intolerance of less than 100% input

Thank you very much.

# Panel Presentation on Airline Maintenance Human Factors - Goglia

**The Honorable John Goglia**

*National Transportation Safety Board (NTSB)*

## INTRODUCTION

Good Morning. It really is a pleasure to be here today. I think this is either the third or the fourth time I've addressed this group, and I've enjoyed it every time.

## SAFETY SUMMIT

Before I start into the Human Factors presentation that we've prepared, I'd like to talk about the safety summit for a minute. It was a year ago January that about a thousand folks met here in Washington and heard the secretary announce zero accidents. I know I for one, and a lot of other people, looked at that with a very jaundiced eye. Because it's really an elusive goal. In fact, one that probably can't be met. But the effort to get there and the drive to have zero accidents or minimal accidents is in fact obtainable. After that meeting we all walked away and nothing went on. It looked initially like we were going to have a typical politician's announcement of the program -- all the fluff, we walk away -- it just sort of dies a quiet death and nobody mentions it anymore. But, this time something was different. And the difference was that the industry picked-up the mantle, not the government. And they have carried forward a number of programs, more than I'm involved with or aware of their presence. But, they have been carrying forth and doing yeoman's duty towards that goal of zero accidents.

When you look at the just the effort that has been undertaken within the ATA towards that goal, I don't know how much of their resources are devoted to it, but it's considerable. And most of the resources are also the industry resources that come to it. If you look at the talent the industry has put in place to address the specific problems or issue areas, some of the best talent this industry has to offer has been put in place to deal with it.

## NOW IS THE TIME FOR CHANGE

I would bet five years ago, you could have probably gotten a million to one odds in ATA leading the charge. They actually want to use this data to better the system. Just amazing is an understatement. We see this throughout the industry, where people are really pulling together to try to reach a better accident rate. It really is an exciting time. Today is probably the most exciting time in aviation, in the entire history of aviation. Because never have we had so many diverse groups going in the same general direction. Never. Never have we had the level of cooperation. Before I took on this NTSB job, I could walk into the ATA and walk upstairs and walk into offices and talk with people openly. Just a few years ago that was impossible. It is a different era in aviation today than has ever before existed. We have cooperative efforts on all the major carriers between their workforces, even in the unionized workforce. You would expect that on Delta or other carriers that don't have union participation, but I'm talking about Uniteds and USAirs and Northwests. There is unprecedented involvement in trying to make our product better. This effort collectively by everybody can only lead to a lowering of the accident rate. Maybe we will never get to zero, but we're going to get better than we have been in the past. We all deserve a tip of a hat to ourselves.

## HUMAN FACTORS

Human Factors can lead to improvements in our area. For the benefit of those in the back room, I was pinned moments ago by someone. It says: "Aviation mechanics keep pilots up". I think that's very true; if it wasn't for maintenance airplanes wouldn't fly. We in this industry fit together like a glove and a hand. Everyone of us is dependent upon somebody else. That's people-to-people skills, whether it be communications or working. Actually, there is usually more than one person working on accomplishing a task those are important. These people have not received the level of attention I think that they have needed in the past. When I look back on my many years in the industry, too many, as I hear Bill rattling off all those things, I was feeling older and older. But, when I look back and think how many times I've seen maintenance problems and then I've seen them repeated and repeated and repeated because we never fix them. We may have disciplined somebody -- given them a kick in the butt and sent them home without pay or whatever -- but we never fixed the problem. It was only in the last few years we finally started to focus in on fixing the problem, never mind what the individual did. In fact in many cases when we have some big mess ups, we are better off not even addressing what the individual did, but addressing the systemic problems that led up to it, so we can prevent it from reoccurring. Before I came to the Board, I was involved with an effort on USAir looking at aircraft damage. USAir, like every other carrier, experiences a fair amount of air craft damage on the ground -- people driving tugs going through the airplane, FOD -- I mean the whole litany of things or hazards that the airplanes encounter on the ground. All of those are generated by people. I bet this industry spends in direct cost three hundred million dollars a year in the aircraft damage, and there is indirect cost that come with that probably \$4 to 6 for every direct dollar. We are talking maybe over a billion dollars in cost that we have been unable to get a good handle on. These are people problems; these are human factors in the broadest sense that we need to address. Fortunately some programs are addressing that. I have totally deviated from what I was going to say today. But, all those areas are now finally coming to the top; we are finally looking at them in a different light and we are finally going to find ways to address them permanently. Not with a Band-Aid approach.

## SAFETY IS FOREMOST

Risking being redundant, I'll go through what I have written. Since taking my seat in the actual transportation safety board the question has arisen -- what my agenda will be. The first answer, of course, is transportation safety. Now some may say that isn't everybody's in this industry's agenda. Most certainly it is the agenda of everyone with whom I associate. Having been involved with more accident investigation that I care to recall, I found that experience means nothing if it is not a learning experience. Therefore, my agenda with the board will be to tackle those issues which I believe, based upon my experience, are the biggest threats to transportation safety. Human error in maintenance is just beginning to receive the attention it deserves Air safety statistics frequently list maintenance as a minor casual factor in the airline or transport accidents Not addressed in any of these statistics is the cost to the industry in delayed, diverted or turn around flights. The UKCAA reported that in a three year period some of the recurring maintenance problems included incorrect component installations, electrical wiring discrepancies including cross circuits, cross connects, loose objects, including tools, cowling in the access panels not secured -- those were in the top eight. Not exactly exciting stuff, but certainly items that could cause serious problems in the right (or wrong) scenario. Closer to home, Boeing conducted a study of safety issues involved in aviation incidents between '82 and '91. The number one issue came up to be control flight into terrain -- not surprising -- but the number two item came up as being maintenance and inspection. Now by this stroke count they had 2100-odd control flights in the terrain; they had 1481 maintenance issues, and further down on their list was another 200 or so uncontained engine failures. That moves maintenance right to the forefront, yet it hasn't received the attention nor the resources that controls flight into terrain have received.

Soon after my arrival at the NTSB I requested copies of any accident report that indicated involvement in maintenance in the cause. This sounds like an easy request but I found out otherwise. First off, accident reports are not categorized that way, and we had to go back through report after report after report trying to find it. We are still working on it. I think so far, we have identified eight or ten and have requested reprints of all of them. It's a chore to try to pull that data out. However, let me talk about a few of those incidents.

## THE HUMAN + MAINTENANCE PROCEDURE EQUATION

Maintenance personnel are called upon to solve a diverse range of problems. Diagnosing a problem on a basis of a sketchy report by a pilot can call for creative thinking and experience, but creative thinking can sometimes create new and unexpected problems. In June 1990, the windscreen of a British Airways BAC111 blew out as the aircraft climbed through 17000 ft. The accident was traced to incorrect installation of the new windscreen during the night shift before the flight. The windscreen had been installed by maintenance with the wrong screws. I think most of you remember the pictures that were distributed world-wide with the captain hanging over the windshield while the aircraft was landing. That incident report is nothing more than a list. Since the aircraft didn't crash there was no major investigation and the report contains nothing more than a physical description of what happened. None of which assisted in our understanding of why those events occurred.

Closer to home, in May 1979 an American Airlines DC10 crashed shortly after take-off from Chicago killing 271 people. At rotation the one engine on pylon broke away from the wing severing the hydraulic lines as the aircraft climbed away. Hydraulic fluid was lost and the outward flap retracted on the left wing while the right wing flap remained extended. The aircraft rolled to the left and crashed into the ground. The engine pylon had failed as a result of a fracture that was attributed to maintenance practices at the airline. Although the manufacturer specified that the engine and pylon should be removed separately, the airline had developed a one-step maintenance procedure in which the engine and pylon were removed as one unit. This not only saved about 200 person hours of labor but also it was considered safer as it reduced the number of fuel lines, hydraulic lines and wires which needed to be disconnected. The procedure adopted by the airline involves support of the engine with the use of a fork lift.

The safe completion of the procedure relied upon the accurate movement of the fork lift to avoid damage to the pylon and its attached points. Unfortunately, the engineers who wrote the procedure were not aware that the fork lift could not be controlled with sufficient accuracy. The engineers never observed the entire process being performed by maintenance personnel and were not aware that the procedure was more difficult than planned. Not surprising, in the year before the accident, another airline using the same procedure had damaged an engine pylon, yet the damage had been blamed on a maintenance error. The cause of the problem was not fully investigated and the damage was not reported to the FAA. Given that time frame, I don't think that even if it had been reported to the FAA that they had the wherewithal to distribute that information to the industry so that we all could have benefited from it.

## BY THE BOOK ISN'T ENOUGH

Many maintenance tasks are too large to be completed in a single shift and the result is a human factor typo; the result in the significant challenge to job quality. Paper work generally ensures a seamless continuity of work tasks, however, misunderstandings can still occur. Eagle Lake. Texas Continental Express. I am sure that anybody in here that has anything to do with maintenance remembers these incidents. I have a copy of the report, but essentially turn over procedures were the cause. What's really scary is that six months later the same airline and the same shift turn over procedures resulted in a near duplication of the accident. The plane didn't crash, the people didn't die, so we didn't get all the press coverage, but two incidents in the same operation in six months. It even

gets scarier as I look this document. I just talked to the investigator in charge about that accident, many of the processes that we use for the turn over at the Express Carrier are used today in everyone of our airlines.

Nobody has benefited from the lesson of these two incidents, at least not in the large enough scale for it to be noticeable from the outside. We still conduct business the same way; we still have lousy shift turnovers. Those are people-to-people problems -- those are human factors problems. Maintenance merely driven by paper work. Although the maintenance menu and task cards specify that the procedures to be followed, specify that the procedures ought to be followed, there is a potential for divergence between procedures on the paper work and the way the job is actually performed. Reducing the gap between procedures and practices is not just a matter of making the workers do the work by the book, it also is necessary to ensure that procedures are realistic and as convenient as possible. In formal work practices on norms as Dr. Taylor has taught me to say -- "Often replace cumbersome, workable standard procedures because norms are not documented and rely upon assumptions about the way we do things around here." Deviation from an accepted norm can be as dangerous as deviation from a formal procedure. There is no simple way of ensuring that maintenance errors will not occur. However, an important step towards maintenance safety is the recognition that maintenance incidents may be indicators of wider organizational problems. Industry has and is aware of these problems and is working towards these solutions to the people issues.

## SLOW BUT STEADY START

It is tough to broadly characterize the work that has been done, but in general it has not really jumped into the pool of people. However several carriers have started programs that have begun to address the issues. Five years ago almost to the day is the anniversary of Desert Storm. I was in Washington then and I was surrounded by a bunch of pilots. It was the National Aerospace Plan and for hours I listened to them. The recurrent thought that kept coming to me was "Why don't we have a similar program in maintenance?" Many of the techniques that they were and talking about we could benefit from in maintenance, but we didn't have such a program. We sat there for the better part of the day and into the night actually. I was doing what I do best -- thinking in a classy place -- thinking about the whole issue of CRM.

I went back and decided I'd like to try that with my employer, US Air. We can start taking a bite of that elephant. We have a labor organization; just try asking labor unions to do something pro-active - - the entire leadership in labor organizations is reactive. When companies do something they react, that's 99.9% of what they do. That guy from Boston is going to show up and ask them to take pro-active (I am in trouble here). But after a while I tried to do it and I was successful. I got them to agree to let us try a program in USAir. I had to go to Phase 2 now and to sell the plan to the company. I was blessed to have a VP in maintenance who was looking ahead. Fred Cocker presented it to him and he thought it was worthwhile to pursue. Now we had to do something that was out of the norm for everybody. In order for a program like this to succeed we need to have the FAA involved.

## WORKING WITHOUT A NET

Throughout my working career, the FAA was never really noted for forward thinking and if it isn't in the book it doesn't exist. But we needed it. It wouldn't work without truly getting everybody together. So I had the honor of approaching Vince Laperra and if you know Vince, or have talked to him you would not think that this guy was a forward thinker. We got Clay Fuchey whom many of you know is the FAA human factors guru back a few years ago. He came in and gave us some guidance. By this point our little circle had expanded and I picked up Joe Kania and Dave Driscoll, who have done yeoman's duty and deserve a lot of credit for the success of the program. We were off and running. It was a rocky and sometimes tedious task to put a program in place where one had never existed

before. There were no guidelines to follow; there was nothing. We wrote as we went. We were fortunate that Clay Fuchey recommended Jim Taylor to us, who we did not know at that time, who had done a little bit of similar work for Continental Air Lines. Their program was aimed at their management folks; US Air's program was aimed at the guy on the floor, the technician. We visited Continental. As a matter of fact John Stelley, who is here was very open and honest. They shared with us what they were doing, their successes and their failures. As a result, our program is built on Continental's program. I am going to bring up Joe Kania who is going to describe the maintenance resource management program here in just a couple of seconds, but I want to touch upon something I just picked up a few minutes ago in the schedule of today's events.

## **MAINTENANCE = CREW-ACCOMPLISHED TASK**

We talked about someplace's maintenance resources management and someplace's technician resource management and to most that would seem rather transparent, but I think that we need to be a little careful. In today's environment when you talk about technician management you are giving the impression of talking about the individual, the singular person. Maintenance today, particularly in large maintenance organizations, is no longer a singular event; it is a crew-accomplished task. I think that maybe we should consider if we are going to put a tag on any of this activity that we call maintenance we should put our arms around the whole group and not give the perception that we are only going to talk about the individual. The individual may be perceived as being blamed or found to be at fault, when experience has shown that the fault is systemic. Right now the airline industry is expanding its people work in human factors. Northwest Airlines is going in this direction; I know that Dr. Trashier is in the audience and he has a lot to do with their work. United Airlines is moving down the path to a very exciting program for a number of reasons. I'll just mention two that I believe are the primary ones.

## **THE UNITED PLAN**

The first is the stepping off in many ways from the USAir program so they have the benefit of the successful areas that US Air has worked in. And secondly, they have actually devoted some money, training money up front for cultural change. We encounter this in our shop or workplace wherever a "mechanic is a mechanic is a mechanic" is often heard. But mechanics training has changed; I went to school long time ago -- it was 1962 and it's a long time ago -- my training is different from the mechanics that have come out in the middle 1980s. My work experiences have been different. Some of the training takes the form of osmosis; it may be accurate and proper and it may not be. When we get on-the-job training we pick up the other guy's good habits as well as his bad so its a problem. United's approach has been up front -- to train everybody. They are going to bring everybody up to a standard whatever that standard is. This is probably the first time this has ever been done in this industry. Then they are going to step off from that point. I tell you this going to lead to numerous successes. I am very excited about what United has to do. I am not going to steal any more thunder from Darryl, but I think you all will agree with me after you hear it that it clearly is going to raise the level for maintenance technicians and raise the professionalism that they so deserve and desire.

## Panel Presentation on Airline Maintenance Human Factors - Kania

**Joe Kania**

*Senior Director of Quality and Safety  
USAir*

### INTRODUCTION

Thank you, John. I appreciate your comments. John was very complimentary to a lot of people, but I got to tell you that if it wasn't for John, we probably wouldn't be here today for USAir telling you about our experiences because we really did start this up. Hopefully what you are going to hear from us today is a description of a living partnership program in action focusing on human factors. The partners are the FAA, labor and management. We feel it is an honest, no-holds-barred approach to improving safety and compliance. We call it MRM at USAir. I don't know if we are going to change that; we may find some type of little catchy word that we want to use like the "team concept", but right now its MRM.

### RECRUITING THE TEAM

MRM was created in USAir in 1992 to enhance the safety, quality, reliability and efficiency of the company's maintenance and inspection program. As John pointed out, the union and the FAA came to us; it wasn't our program. It's a spin off from crew resource management, and it enlists the cooperation and open communication between management, AIM and the FAA. It embodies the intent of compliance through cooperation and partnership. The program is unique because of the FAA's role of support and encouragement among the parties versus enforcement. Keep in mind that in 1992 the partnership wasn't alive and well; it has come a long way since then.

### DEVELOPING A GAME PLAN

Our initial objective back in 1992 was a project to conduct research into the causal factors which result in human error and maintenance paperwork. Why did we pick maintenance paperwork? We thought long and hard on this. There are a lot of areas we could have focused on as a team and tried to resolve the problems, but the FAA is obligated to take certain steps if there is a serious violation. We thought if we focused on paperwork -- the airplane is normally safe; it's normally air worthy; it's simply a paperwork error that was admitted -- we could resolve and identify some problems if we focused on that one area. That's what we did. We tried to develop a strategy supported by management, labor and the FAA that strives to eliminate paperwork errors and other issues that surfaced. We developed a means whereby the results of this research can be used to enhance the safety, improve maintenance training and quality control programs related to paperwork errors. We begin a process of open, honest communications among management, the IAM and the FAA which is this partnership.

This approach is not typical. Usually you throw all of your problems into a funnel and your work goes out and your result comes out of the funnel and that's what you focus on. Here we start at the bottom of the funnel with just paperwork we are trying to see what would come out of the top. We knew we were going to see other problems in addition to paperwork problems. The perceived benefits for the FAA -- decreased number of enforcement actions against mechanics and the company through increased compliance with FAR enforcement action -- in my opinion (a lot of this is my opinion) is a pain in the butt for the FAA just as it is for the carrier or the mechanic.

Enforcement action, again in my opinion, does not promote compliance or safety. I'll speak to that in a little bit more in-depth in a minute. The benefits for the company -- increased safety, compliance in productivity as a result of lowering errors and approving maintenance quality -- this is what it's all about. This is what we want. This is, of course, what you some of you as our customers want for the mechanics -- reduction of enforcement action by the company and the FAA a result of improved compliance.

Enforcement action against the mechanic is extremely traumatic. I'd venture to say it borders on being unsafe. When a mechanic is going through the process of enforcement he or she is totally preoccupied with what's going to happen to him or her. However, if a mechanic knows he or she will receive amnesty for an honest mistake that person becomes a safe, productive employee immediately. Consider the three or four months or whatever it takes for the mechanic to resolve the problem he is having. He is worried about losing his license; how much time; how much money he is going to pay. He is not a very good employee during that period of time. With this program we think we eliminate all of that.

I mentioned earlier about the enforcement action from the FAA. For example, let's compare a letter of investigation with a self disclosure -- I hope that you all are familiar with those two programs. When we receive a letter of investigation from the FAA we answer that letter assuming that we are going to end up in court. We don't put all of our cards on the table. We are not entirely up front with them. We don't lie of course, but we don't tell them everything. Why can't we tell them everything? If we tell them everything it may cost us money; we may get a bad reputation. So we hide things. The FAA, on the other hand, does the same thing -- there is absolutely no communication other than "we will see you at the informal hearing, or we will see you in court." That is not a very productive exercise to go through. On the other hand, in self disclosure -- keeping in mind it means just that -- the airline found it, the mistake, before the FAA found it. Is that right? I don't think it is right, but that's the way it is today. So you are looking at timing here. Self disclosure versus letter of investigation. In self disclosure we tell the FAA that we found the mistake. We work together with the FAA to resolve this mistake. All the cards are on the table; you cannot put a comprehensive fix in place unless the FAA agrees to it.

## **TEAM WORK, TEAM WORK, TEAM WORK**

Now, it doesn't take a rocket scientist to know which one of these two exercises gives us better safety better compliance and a better relationship. Every project has to have a steering committee, and we have one too from the USAir management side. It was myself and Dave Driscoll, Dave is right here in front; we are still involved. From the IAM side it was John Goglia who we said earlier introduced it, and now Terry Clizere is picking up for him. Terry is right over here. We mentioned the managers. Without the managers -- Vince Laperra and Al Zito -- we couldn't have done this either. Dave Cann started it and Jim Balock, who is also here today, is picking up on it. Our program facilitator evaluator was Dr. Jim Taylor whom John mentioned earlier. That was our team, and we got along really well.

Our initial approach was to conduct focus group meetings before we could fix a problem. We certainly had to understand what the problem was. We had 160 lead mechanics, inspectors mechanics and foreman involved in 28 separate sessions in seven stations. We averaged about six employees per meeting. All of this was conducted by our independent facilitator, Jim Taylor. Sessions were conducted as brain storming sessions to list paperwork errors and their causes and to develop a set of possible solutions. It is kind of interesting how Jim approached this. It was all new to us. I am sure for some of you who have done this before it isn't new, but Jim got the people in the room to put the butcher paper up all around the wall and just listened the first half of the meeting to whatever the employees were having problems with, what don't they like about management. He kept it directed toward paperwork, allowing them to get off paperwork just a little bit just to let them vent a little. About half way through the meeting he cut it off and he said "OK folks you gave me all your problems. Now your task is to give me the solutions." This is where the butcher paper came in.

Writing on the wall worked really well.

The next step then was to summarize all of these comments and suggestions. We didn't yet analyze them; we simply summarized them. If three or four focus groups gave us the same problem we would just lump that into one problem. We classified the data into categories, and we established a corrective action plan. What we can do immediately and what we can do long term. One of the things we realized we could do immediately came out when we started conducting crew meetings. We heard the message that we don't communicate very well, so we started conducting crew meetings. We initiated a maintenance newspaper. It dramatically reduced the calls to the FAA. The mechanics were giving us a chance to resolve the problems before they went to the FAA. When they go to the FAA, and this is for the FAA people that are in here, you know you have a formal procedure you have to use for the hot lines and it's no fun either. An example of this is the log book redesign after we merged with Piedmont Airlines.

We had two log books. We had a wide bodied log book for [ETOPS](#) airplanes. We had a narrow bodied log book, and it worked O.K. But we felt we were at a point after a couple of years after the merger that we could reduce this to one log book so we went to La Guardia. We said "La Guardia you said you wanted to help, help us redesign this log book." Dave Driscoll handled it personally; they wouldn't even talk to him. They said "Get out of here this is just a one shot deal. You are really not interested in redesigning the log book." Dave was persistent. He kept going in. It wasn't too much longer after that they were calling Dave up to get his butt up to La Guardia. They redesigned the log book 100%. The mechanics redesigned the log book. Of course, they consulted with maintenance; they consulted with management, but it was their log book. In previous log books, the edition that we put out for USAir for 33 years, there was always something wrong with them. You know what usually happens if you don't have a part in it -- Ah! you should have done this, you should have done that. There was absolutely no criticism of this log book, no suggestions to improve it after the mechanics improved it. We are very proud of that.

Take our general maintenance manual. To the airline people in the audience, if you are anything like USAir 40 years ago we had a policy manual. It's our general maintenance manual. We put all our policies in there and it hasn't changed since. The only thing we kept doing was adding policy, adding policy. We asked Jim Taylor to look at our general maintenance manual when we first started working with USAir to see if he could interpret anything or understand our policy, and his response was "No, I can't." But we expected the mechanic to comply with the policy that's in the GMM after about 40 years of evolution. We had such a success with the log books that we decided to let the mechanics, the labor group, rewrite our GMM. We did it and it was a great success. Dave and Charlie from the IAM headed that up. Their first step was to take that manual and go through every page and put it into a certain section. Maybe one section would be all deferred maintenance. another section would be time cards or whatever. They sent those sections out to various stations and said "here folks you wanted to do it, reformat it so that it is user friendly send it back to us."

Now I'll be a little honest with you, we didn't trust them totally. We thought they are going to slide something in on us, so that they get more money, easier work rules, stuff like that. So we had to review this. I have to tell you we did not find one incident of that, not one. The book was reformatted. It's becoming more user friendly and it was totally done by the work force. Again we are proud of that. On December 21, 1994 Dr. Taylor sent a report to Galaxy basically summarizing a lot of the things that we just discussed here and another thing that we had done. Let me tell you about that.

## DEVELOPING NEW STRATEGY

Dr. Drury, who is also in the audience today, worked with USAir on our formatting of our paperwork -- how we write the paperwork. The typical scenario is that the engineer who writes the paper work sends it down to the floor. Then he gets upset because the mechanic doesn't follow what he is trying to say. He should take the paper work down on the floor and work with the mechanic for

the first time to prototype it and then produce a much, much better document, Dr. Drury also looked at the way we lay out our job procedure cards, the sequence -- check the tire pressure, go in and check the cabin lights, come back out and check the brakes, then go and check the tail, those types of things. Dr. Drury helped us tremendously with that. It is now our pride and joy. Our pride and joy is our round table meeting. Our round table is nothing more than our name for a group of people getting together to analyze, to understand why a person made a mistake. John alluded to this earlier. If we bring this mechanic in we can really, really learn something from him.

We have had 15 round table discussions. Let me tell you a little bit about the process. Round table meetings provide forums for addressing human factor related errors that have occurred in USAir's work place. Error discussions are conducted in a problem solving, non-accusatory approach to resolution. The IAM has agreed to accept management's decision on errors to receive a round table approach. In other words, if the person did something and it's gross negligence we are not going to bring him into the round table and waste our time there. It's the honest mistakes we want, and the IAM has agreed to let management make those decisions. The round table working board consists of representatives from the IAM, the FAA and USAir management. I think No. 3 is very important. If FAA enforcement action is contemplated, the FAA round table working board member serves as a chairman and has sole authority for final determination in accordance with the FAR. We don't know where the discussion is going to lead whenever we bring everybody around the table to discuss the error, so we have to give the FAA that flexibility if something serious comes up they certainly have their guidance to react to that.

As I said, we have done about 15 round tables. What we do is ask the mechanic: "You made a mistake. You have total amnesty from the company. We are not a 100% sure what the FAA is going to do. You may end up with a letter, you may end up with something more serious, but we want everybody to learn from your mistake, and most of all we want to learn from your mistake. Why did it happen? What were you thinking about? What paperwork didn't you have? What tooling didn't you have?"

That person comes to that table very, very apprehensive. There are usually two FAA people on the table, two management people and two IAM people. We allow people to sit in, but we don't allow them to talk, unless they raise their hand, or we ask them something because then it would get kind of confusing. It's not a formal hearing. Our first task is putting the mechanic at ease because he is very, very apprehensive. But I can tell you, the ones that I sat in on, and, as I said, Dave handled about 15 of them, everyone of the mechanics came out of there thanking us. Each one became an ambassador for the program and ambassador for the partnership, and he left there with a feeling that he had accomplished something. We were definitely sure that he went back as a better person. This approach versus the previous method of giving him three days off or 30 days off depending upon the severity of the mistake, and the FAA coming down and the mechanic having to go through all of that. We know that we are really accomplishing something, so when I say this is our pride and joy it really is; we are really proud of it.

This new approach not only improves the relationship between the three parties -- the IAM, the FAA and management -- but also, more importantly, enhances safety. We learn from all of this. We've had some incidents where a mechanic cut a tube a little bit too short. We sat down around the round table and talked about it and he showed us an engineering diagram that he was using. The thing was handwritten. The engineer thought he was doing his job, but this mechanic is looking at this with all the handwriting on it. I turned out that there were six tubes in this one case that we are looking at, five of the tubes had fixtures. The mechanic puts the tube in the fixture, and he cuts it off. This particular tube didn't have a fixture. Maybe he told somebody in management about it, maybe he didn't. We immediately got him a fixture. Now this is the type of stuff we can share outside of USAir; it doesn't have to stay in USAir. We can share throughout the industry; the rest of the industry people who have problems like this can share with us. So again, as I say, we are very proud of that program.

I told you earlier that we are tracking paperwork errors. I'll go through this very quickly quick, only one time. This is the monthly paperwork discrepancies summary for August 1993. It speaks to

engineering orders, job procedure cards, not all of them just the ones that are production and control items -- log sheets, tags, which are our return to service tags. The total accomplished in this case was 41,000. Incorrect or incomplete total is 774, that percentage was 1.86%. Missing paperwork 78, that percentage was 19%. Obsolete paper work is 4, percentage was 0.01%. Total discrepancies out of 41,000 were 856, for a percentage of 2.6%.

Component removal request -- if we have paper work, if we had scheduled a component removal and the paperwork doesn't verify that it was done we will change the unit. Again, if we can't get the paperwork corrected, we reschedule tasks, inspection tests, those types of things. Again, if we can't verify it by the paperwork, we reschedule it. For the month of August we had 13 and 15 there respectively. Now we jump to August 1994, we went from 2.06% in 1993, to 1.59% in 1994. In August 1995 we went from 1.59% in 1994 to 1.36% in 1995. The most current one we have is November of 1995, and we are all the way down to 0.93%, so it is a significant difference. We break these down by stations, and we further break them down by the EOS. It is probably a 15 or 20 page report. This is only the summary, so we have had some successes with improving our paperwork.

I also mentioned the round table. This is simply a round table group in discussion -- the FAA, the IAM, Management and the person who made the error. We usually meet in the FAA office; they have the nicest facility. Again, my point is that bringing that mechanic to the FAA office is very tough on him or her. These discussions usually last a couple of hours and are very, very productive. Other than that there are some action items. We don't just find out what the error is and walk away. Everyone has some action item. Maybe the FAA has to interpret an FAR or some guidance that they are giving us. Maybe the company has to rewrite job procedure manuals or fixtures as I mentioned earlier. Maybe the person doesn't have enough help. There are always action items. They are always documented. They are always followed up.

We also give that erring person, the mechanic, an action item. It's usually different action items. I've brought two with me here, this is out of that faces and places magazine. I am not going to let you read it. We brought a couple of hundred here; we'll put them across the room if you are interested in taking them. It is really a chore for the mechanic to write an article on the error that he or she made. The one you are looking at up here concerns a sheet metal repair on the airplane. We had to take the ADC's out to repair it, gave the mechanic the job to close it back up again, before he had it closed up his lead mechanic came and asked him to help on an engine. He went and helped on the engine, he had not as yet connected the static lines. When he came back to the job, the panel was closed, and he assumed that the static lines were closed up. The airplane took off and returned. We had to hook up the static lines. This gives you some idea what he went through. John, or somebody, mentioned earlier about turn overs, obviously, this wasn't a very good turn over. It was just his explanation of what happened.

This story goes out to all of the maintenance people throughout the company and to the flight people. We just lay this in different areas and people pick it up, and as you can see, the other articles there are the social articles. I would recommend that if any of you are going to develop a paper, put those social articles in there. People don't tend to pick up the purely technical information. They like to see that social information in there and that drives them into the other issues. Such as this one: "The lift that let me down". The mechanic, I believe, was in La Guardia. He was going to change a fuel control underneath the U part. The lift truck was underneath the airplane, he removed the fuel control and went in to see where his new fuel control was. While he was in there, lift truck went up by itself and damaged the airplane. The lift truck was tagged that the lift wasn't working only in the down position. The mechanic assumed it was working in the up position. It malfunctioned and went up under the airplane and damaged the airplane. We have a policy in the manual that says you do not leave equipment running around the airplane. The mechanic did not follow the manual because he did not understand the manual. Now we send this message out to the entire field about running equipment and what this mechanic's mistake was.

## THE NEXT MOVE

Where do we go from here? We definitely want to continue the round tables. We are having a lot of success with the round table. We want to expand the program to encompass all of the benefits derived from the human factors programs, which is one of the reasons we are here. We want continued communications mechanic involvement, and we want to develop a partnership with the other carriers and the industry. As I said earlier, there is no reason why this should stay within USAir. There is no reason why the Continental program should stay within Continental. The Northwest program, the United program, we should share this and be able to bring you up to date on their programs what they are doing right now and also what the industry is doing.

## Panel Presentation on Airline Maintenance Human Factors - Mortensen

### Dal Mortensen

*Senior Staff Executive  
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### INTRODUCTION

Good Morning, it certainly is a pleasure to be here and share with you the evolution and the experience of United Airlines with human performance in aviation maintenance. It looks like we are a little short on time, so I'll try to keep this within 10 or 15 minutes. For those that need to be advised of the acronym that's used in United Airlines -- MOD is the Maintenance Operation Division. This is our division's response to human performance initiatives.

### SCOUTING THE FIELD

The first thing, of course, you have to do anytime you are going to initiate a plan is to develop a steering committee. The steering committee was initially set up by the senior executives of the maintenance division to set our performance policy, oversee the integration of human performance and related initiatives into the MOD. I have the privilege of heading that steering committee. Because our initial thrust in the education and work in this arena is going to be in line maintenance, the sponsor is Ron Utech who happens to be the Vice President of line maintenance. Very importantly, early on we recognized the need to develop a partnership with our friends in flight operations who have spent years working in the area of human performance in flight operations. Cal Hutchins is my advisor from the flight training organization and he also manages the training program for United Airline pilots. The membership, most importantly, includes members from the IAM -- Andy Buttafuccho, who is the Assistant General Chairman and Director of flight safety of District 141 and the flight safety coordinators, Michael Pete, Tom Rollin and Wayne Gallimore. Some of these gentlemen are in the audience today; as are important members of quality assurance. We are also fortunate to have Ken Highlander, Carl Pape, the education, development and training organization and our People Services, or personnel, on the team.

### THE WIND-UP

In United we have a real opportunity because of our ESOP company, to really perform somewhat of a miracle in getting a partnership with all three participants that can play a role in the development of these programs. The first thing we did was to establish our objective. This was "to eliminate the causes", and I emphasize causes, "of maintenance-related error events to enhance safety and advance the professionalism of the MOD employees". We say maintenance-related because it is not just the mechanics that do the work and pull the wrenches that can be a participant in maintenance-related error. So we emphasize that; we also emphasize the issue of professionalism. We heard earlier today what that is really about. For those of us that are licensed mechanics, there is a very strong need for us to continue and evolve our profession.

The strategies that came out of the committee were to do these four things:

1. Create a division steering committee -- of course, we did that right away.

2. Create awareness -- awareness has got to go all the way to the top of the organization. Certainly one of the human factors in errors that occur can very well be the organization itself, the leadership and management -- the tone that is set by that organization.
3. To develop and deliver the learning -- decide what it is and how we are going to approach this in the way of educational activities.
4. To implement an analysis process of maintenance-related error occurrences.

It does not mean that for years we haven't had a strong investigative process within our division, it's just that we had to develop some new ways of approaching investigation and data gathering to put it into a form that we can analyze.

## THE PITCH

I'm going to talk a little bit about the individual strategies to create the awareness. In September of last year we had a leadership conference which focused on maintenance-related errors and human performance. Among others we had John Goglia, who joined us as one of the keynote speakers to kick this off. We had about 200 manager-level and above employees in the division. IAM leadership, we had a contingent from USAir (they are from the IAM), We spent a day and a half with them talking about human factors -- what is it? what is going on in the industry?, some insight as to what's going in the FAA and NTSB activities that John brought to us. It was a very, very intense session on getting everybody up to speed on what it is we were dealing with. We needed, of course, the use of additional communication vehicles. Joe mentioned earlier the need to give some wide publicity to the error events that go on within your company. For those of you who can look back ten, twelve years ago in the flight Ops arena, who ever would have thought that you would pick up a company document where pilots would openly talk about busting an attitude, wrong heading, etc. Where they can come out in a company publication that clearly describes and discusses the details of what went wrong. We see that today.

We need to do that in the maintenance arena, and for the last two or three years, in the line maintenance area particularly, we have a quality bulletin that goes out quarterly that talks about these events and captures, and discusses why things went wrong. We need to also look into the area of the support organizations that contribute the product which we use to perform maintenance. To that extent, the Director of Engineering and I spent about three weeks conducting human performance in engineering discussions, talking about the products they turn out, the job cards, the drawings, the engineering variations, etc. To make sure that they understood the product that they put out can either enhance or create safety, or be a contributing factor in maintenance-related error events.

## THE DELIVERY

In our learning effort we wanted to develop a human performance introductory workshop. Members of my steering committee traveled around the country, and even made some foreign travel, to talk to carriers that had been involved in human factor and human performance training. One of the best programs that we've seen in our travels and studies is one that's put together in Canada, by Gordon DuPont, of the Canadian Ministry of Transport who is in the audience today. That program, I believe, really captures the essence of what we need to do in the way of technician training programs.

When we examine our training effort, we need to integrate the human performance, human factor information into all of our technical training. Again, if you talk to the people in flight operations human factors, you will find that any training that occurs within our company has an element in it of the human factor aspect of the training that's going on. That's one of our main objectives -- to integrate human factors into all technical training and make it an integral part of the training. We

also need to have an annual recurring learning opportunity. This may be in the form of a video or what have you, but that's something to plan for the future. The event-driven recurring learning is something that we will need to use when we have a maintenance-related error and we have an investigation that needs to, among other things, make people go back and redo the human factor training element that probably touched on the issue that was found to be in error. Lastly, we need to address the delivery of our training, which will be a two-day workshop. We call it a workshop because it really has to be the type of environment where people get involved. The workshop will be delivered by members of the IAM as well as our education and training staff; that is a team of people who will deliver this training program.

## THE FOLLOW THROUGH

This is a very ambitious schedule for us. We are targeting the line maintenance organization, and for us that's over 4000 mechanics around the world, who in 1996 will sit through a two-day workshop session. We think we can do it; we have the commitment. The main thing now is to get this product together, which we will have by the middle of February, develop a couple of prototypes, have them critiqued and get everything ready to be put into place.

Finally, I'd like to talk a little bit about MEDA. I believe Jerry Allen is here from Boeing and he is going to talk later in the program about MEDA. I would just like to give a strong support and a pitch and say that this effort is something that really has focused the need in an investigative process not only to have a disciplined, consistent way we look at maintenance error events, but also it will lead us eventually to a database where we can all share our information, our chain of events, our root causes. All of this so we can take the event apart and look at it to improve upon our future training activity. MEDA, of course, is a pioneer program that Boeing put together some two and half years ago. We were one of the carriers that was involved in initial development. It went through a number of critique sessions to create improvements in the process, in the investigative form and so forth, so it really is a very good program. I know it's not the only one; there's other companies now that are coming out with similar systems. But it's exactly the sort of thing that we need so that we can gather this information.

## NEXT UP

In closing, let me just say that on a personal note, that for the last 25 years in my career, I have had the privilege of being the head of QA at two different airlines. During that time, we had literally hundreds of events of maintenance-related error occurrences, and it seemed like we were always on the defensive. An event would occur; we'd react; we would try to do a good analysis. To me, this program is the first thing that we've really seen that allows us to get on the offensive. I believe our training program reaches our objective; that it will not only define what "human factors" is, but also it will remind the people of their responsibility as mechanics in terms of abiding by the FARs. Earlier we heard mentioned the old shift change job turnover problem. It has plagued us for years and years. Many of the FARs need to be revisited to reinforce the idea that those regulations which have been in place for 30, 40, 50 years were put in there for a darn good reason. We really have to do our best to abide by them, and eliminate future maintenance errors.

# Communication in the Maintenance Work Environment

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## INTRODUCTION

At a time when organizations increasingly expect employees to work with minimal supervision and to show more initiative, competent communication skills are becoming a must. The American Society for Training and Development (ASTD) surveyed its members who are training practitioners, managers, administrators, educators, and human resource developers. They found that the foundation skill upon which all other skills are based is learning to learn. Technical competence requires reading, writing, and computation. The results of this survey suggest that skills that enable people to communicate effectively on the job are oral communication and listening.

This presentation will provide a discussion of communication within organizations and will develop an understanding of the problems that can arise for the aviation industry. Areas to be discussed include the communication process, language usage, verbal and nonverbal communication, listening behaviors, teamwork, conflict management, how to make meetings work, and written communication. Strategies for fostering competent communication behaviors will be included.

## COMMUNICATION

Communication does not involve merely sending a message back and forth to another person like a ping-pong ball. Instead, communication is a transaction in which everyone participates, continually offering definitions of themselves and responding to definitions of perceived others. It is a process that occurs between people, rather than a static entity. Communication reveals the dynamic nature of relationships and organizations. In effect, it reflects the notion that nothing stands still.

### Definition

There have been hundreds of definitions of communication developed over 25 centuries. For our purposes, "communication is the dynamic and irreversible process by which we engage and interpret messages within a given situation or context." It is "dynamic" since it is constantly in motion and changing and "irreversible" in that nothing we say can ever be completely retracted. For example, if you have a hostile exchange with a coworker and make a statement in anger, only to realize later that your comments were inappropriate, there is no erasing this exchange from the record, even through an apology. Instead, hurt feelings that accompany these sorts of exchanges can have a lasting impact on the other person. As a consequence, we must be diligent in our efforts to be responsible communicators.

Communication is a "process" because it is a specific, continuous series of actions directed toward some end, which is the exchange and interpretation of messages. In order for communication to have occurred, the sender's message, whether verbal or nonverbal, must be interpreted by the person receiving the message. Thus, communication can be viewed as being subject to individual perception of what has transpired. Often, people's retelling of past events does not necessarily coincide. Instead, widely varied stories surface that reflect the subjective interpretation of each of the participants.

The final component of communication is the presence of a "situation or context." Messages cannot be accurately exchanged and interpreted without knowledge of the complete situation in which they

were stated. Likewise, without a context in which to place a given message, meanings may be misconstrued or misinterpreted. If a coworker shares information with a supervisor about another worker and does not include the individual's entire circumstances, inaccurate inferences may be drawn. Similarly, if only portions of a conversation are overheard, any meaning assigned to what has transpired will likely be inaccurate.

## Competent Communicators Qualities

Unfortunately, communication does not always run smoothly. Inevitably, misunderstandings or conflict will occur. If you have ever unintentionally insulted someone or blurted out something thoughtlessly, you can appreciate the need for competent communication skills. [Communication competency](#) is the ability to achieve your communication goals. It is the ability to communicate in a personally effective and socially appropriate manner.

## COMMUNICATION ISSUES

Various problems can be the result of a lack of effective communication skills in the workplace. These problems can be attributable to a vast array of issues that pervade the organization. Some factors that contribute to major communication problems include the following:

### Language Usage Barriers

Language is becoming an increasingly sensitive concern in the workplace. There are several problems that contribute to [barriers to effective language usage](#). These include:

### Team Characteristics

Group and teamwork will not only be important, but unavoidable in twenty-first century life. Either you love or hate working in groups. This process can be rather time consuming and difficult. Conversely, it can be both rewarding and productive provided it occurs under conditions conducive to the efficient conduct of business.

### Conflict Causes

Conflict is a social interaction between people involving a struggle over claims to resources, power and status, beliefs, and other preferences and desires. There are constructive purposes served by conflict. It can enhance understanding and identification of problems, while increasing alternatives and worker interaction. Conflict stimulates interest, creativity, commitment, and quality in the workplace.

### Listening

More time is spent listening than in any other form of communication. Therefore it would seem to be the 'linchpin' method for enhancing an individual's overall communication skills, whether they be written or oral, verbal or nonverbal, alone or in small groups. In essence, listening is hearing with selective attention. There are a variety of different methods that can be used to enhance listening behaviors. The following checklists of behaviors to improve listening effectiveness will facilitate this process:

- [Listener Checklist](#)
- [Language Suggestions](#)

- Successful Culture Characteristics
- Communication Flow Solutions

## Leadership Skills

Leadership skills are a critical quality in determining managerial effectiveness. Included within these skills is the ability to plan and [conduct meetings](#) and [develop effective teamwork](#).

There are several strategies that can be used in managing conflict. These include:

- Conflict Resolution Strategies
- Effective Communicator Guidelines

## SUMMARY

In summary, communication is an ongoing, dynamic, and complex process. It requires a high level of sensitivity and awareness on one's own part in order to effectively monitor one's own verbal and nonverbal behaviors so as to enhance the likelihood of achieving communication competence. The benefits for the individual and the organization are limitless.

## APPENDIX

### COMPETENT COMMUNICATOR QUALITIES

1. *They are appropriate.*

They follow the rules that guide interactions in a given context. What may be appropriate in one situation may not be appropriate in another.

2. *They are effective.*

They communicate in ways that help them achieve their goals. Effective communicators set goals related to their needs, wants, and desires. Their personal communication style facilitates the accomplishment of these goals.

3. *They are adaptable.*

They recognize the requirements of a situation and adjust their communication to the situation. An unwillingness to adapt may make it more difficult to accomplish goals.

4. *They recognize roadblocks to effective communication.*

They note potential obstacles and work to overcome them. These obstacles may include ineffective language usage, unintentional body language signals, as well as contextual and situational factors.

5. *They understand that competency is a matter of degree.*

They realize that a given act of communication is rarely completely competent or incompetent, but probably somewhere in between. Each component of competency can be considered as occurring "more" or "less."

6. *They are ethical.*

They adhere to standards of right and wrong based on their background, point of view, and circumstances. Because the range of factors that distinguish right from wrong vary considerably, there are few absolutes when it comes to ethical communication.

## COMMON LANGUAGE USAGE PROBLEMS

1. *Allness*

We perceive only a small portion of the world around us. Whenever we talk or write, we usually omit more than we can say. The "allness illness" entails forgetting about this selection process and the notion that certain things are always omitted in communication.

People who have the allness illness tend to be intolerant of others' viewpoints. Instead, they mistakenly believe that they know all there is to know about something. There is a corresponding tendency to ignore information that could change an outcome. Instead, people may be judged based upon a single incident or event.

2. *The Word Is Not The Thing*

Bypassing is used to describe miscommunication patterns that occur when senders and receivers of messages "misconnect" with each other in terms of the meanings of words being used. Supervisors and subordinates can use the same words, but the intent of their communication can fail because they each attribute different meanings to the specific words.

3. *Incompleteness*

To some extent, words are the map of the territory that we want to share with others. Just like a geographical map is scaled down to size and does not accurately reflect details, so, too, is the case with words. They do not necessarily accurately represent objects, events, feelings, and ideas. In short, words do not depict everything there is to say about some event or phenomenon.

A map cannot provide a complete and comprehensive representation of a geographic area. Correspondingly, words do not provide an exhaustive view of reality. Since language seldom conforms to the reality of a situation, it is important to keep in mind that there is always more to be said about everything.

4. *Levels of Abstraction*

It is impossible for human beings to take in everything that occurs in the surrounding environment. We must abstract certain details and omit a seemingly endless number of others. How readily we can perceive the limitless possibilities of a word's meaning will determine the extent to which we understand and then communicate accurately our messages to others.

Supervisors must be sensitive and aware of this tendency since any particular object or event has multiple levels of meaning. In communicating with others, the manager must mentally define words based upon the other person's level of abstraction which will ultimately determine the meaning of the word.

### 5. *Inference Versus Facts*

Often times, we will draw inferences regarding contextual factors before we have all the necessary facts. Inferences are constructed so rapidly that we rarely reflect on whether they accurately represent something as we would like them to be.

Declarative statements are made in the business context on a regular basis. This would include statements such as, "She didn't return the file" or "The work was not completed because he's lazy." These sentences provide no means of verification as to whether they are factual or inferred.

## TEAM CHARACTERISTICS

### 1. *They are a diverse group of people.*

Each individual provides specific and varying resources and abilities that provide constructive input into the team process.

### 2. *Responsibilities are shared among members.*

Everyone facilitates team activities and discussions. All members are, in effect, equal participants in the team process.

### 3. *There is a team identity.*

It has a particular identity, personality, self-image and sense of cohesiveness.

### 4. *Its efforts are interconnected.*

The team constantly weaves and coordinates the contributions of each member in order to develop a tighter energy and focus.

### 5. *Members strive for mutually defined goals.*

There is intense and open communication designed to develop group consensus. There is usually a clear and elevating goal that motivates its members.

### 6. *A team works within the context of other groups and systems.*

A team affects and is affected by the context and situation. It does not function in isolation or in a vacuum.

## CONFLICT CAUSES

### 1. *Organizational structure.*

Can pit departments or people within the organization against each other. Causes include unclear goals or power building. If two units see their roles overlapping or striving for similar objectives, they tend to be placed in direct competition with each other.

## 2. *Performance measures.*

If not clearly stated in terms of expectations, the employee will fill in the gaps. If the manager bases rewards or punishments on behaviors that are unrelated to the job itself, the employee's behavior may pattern itself to receive the rewards.

## 3. *Unclear job roles.*

Competition may result if members of the organization pursue the same goals. Conflict will likely continue until the job roles are clarified.

## 4. *Conflicting reality perceptions.*

Each of us defines our own reality based on our individual perception of the context or situation. When these do not coincide with reality perceptions developed by others, conflict inevitably occurs.

## 5. *Organizational ambiguity.*

Included in this category are: multiple direct bosses; unclear instructions; personality conflicts; poor attitudes; lack of authority; supervisor's lack of experience or understanding; differing standards of behavior amongst organizational members.

## **LISTENER'S CHECKLIST**

### 1. *Establish an interest in the topic.*

Brainstorm within yourself the reasons why you might benefit from listening to the other person with whom you are communicating. In doing so, you will afford yourself the opportunity to have an open mind toward what is being discussed.

### 2. *Tolerate distractions.*

Noise can serve as interference in our efforts to listen to someone else. Office equipment, low-flying aircraft, radio, televisions, and other people can serve to divert our attention away from the person to whom we are listening. Even our mood or uncomfortable room temperature can serve as distractions. The key is to listen through the distractions and to focus on the other person and the messages they are transmitting.

### 3. *Select an appropriate time and place for listening.*

The context should be conducive to effective listening behaviors. For some people, the best time of day is first thing in the morning. For others, it is later in the day. Similarly, sometimes it is most appropriate to meet with someone else in his/her office or at a "neutral site."

### 4. *Stop talking.*

If you know you talk too much, curb your comments. The more time spent talking, the less time we have available to actually listen to what the other person is saying.

### 5. *Be prepared to listen.*

Understand your own emotions and feelings. Try to perceive other people as they perceive themselves. Be sure that other things on your mind do not distract you. In particular, be sure you are physically and mentally ready to listen.

6. *Look at the other person.*

This confirms their existence; it lets them know that you are actually interested in what they are saying. If looking at their eyes is difficult, look at their hairline, mouth, forehead, or cheek area. Eye contact is a nonverbal message that says, "You have my undivided attention."

7. *Listen to what is said and what is not said.*

Words can tell us what other people are thinking. Often times, we can infer more meaning from what they do not say rather than what they do say. For example, if issues are repeated, this might indicate an emphasis on those concerns.

8. *Overcome prejudices and biases.*

If you enter into a conversation with your mind already made up, then you will likely miss most of what is being communicated to you. Maintain an open mind at all times by listening rather than judging. In short, suspend judgment.

9. *Actively listen and establish clarity checks.*

Restate or paraphrase what the other person is saying. This not only provides clarification, but can also assist in determining the accuracy of what has been heard in the discussion. Focus on both verbal and nonverbal feedback from the other person. Factors such as their body position or posture, tone of voice, and physical appearance.

10. *Ask questions.*

In doing so, you indicate an interest in what the other person is saying. It also helps you to better understand what they have communicated to you. Ask questions in an open ended way so that the person does not become defensive. For example, "what are your thoughts pertaining to that matter" or "describe what occurred" provides for more disclosure on the part of the other person.

11. *Avoid the "hair-trigger" syndrome.*

Do not react too quickly. Instead, be patient. Try not to complete the other person's statements for him/her until he/she has fully completed what he/she is saying. This is especially true during conflict or in controversial contexts. Similarly, restrain yourself from the impulse to ask question prematurely until the other person has fully expressed his/her thoughts.

## **SUGGESTIONS FOR EFFECTIVE LANGUAGE USAGE**

1. *Be accurate.*

Verify word definitions and meanings whether direct or implied.

2. *Be clear.*

Strive to convey a sense of shared meaning in word imagery being transmitted to others.

3. *Limit jargon.*

Avoid the overusage of technical terms, buzzwords, acronyms or abbreviations.

4. *Avoid cliches.*

Limit commonly overused phrases, words or examples.

5. *Avoid slang or offensive terms.*

These can become obstacles to achieving communication goals and objectives and usually result in misunderstandings.

6. *Be concrete.*

Using abstract terms makes it difficult to create shared meaning.

7. *Avoid ambiguity.*

Verify that your words are being understood by the people with whom you interact.

8. *Be concise.*

Present your message in a simple, focused manner avoiding any unnecessary digressions or tangents.

9. *Be descriptive.*

Use vivid language to represent what you are communicating.

10. *Establish Your Credibility.*

Language usage will contribute toward the overall presentation of your believability and competency to others.

## **CHARACTERISTICS OF A SUCCESSFUL ORGANIZATION'S CULTURE**

1. *There is a clearly worded and communicated overall philosophy.*

This should reflect the organization's vision for itself, its products, and its services. This vision is then transformed into a mission statement, which includes goals and objectives. Strong organizations are able to reach consensus regarding this philosophy.

2. *The components of the organization philosophy are understood and shared.*

This includes guidelines pertaining to what is and is not acceptable or appropriate for workers in the organization. Performance standards are a critical component since people see firsthand the ways in which quality and other related factors are achieved and maintained.

3. *Shared rites and rituals are practiced.*

Rituals reinforce an organization's values and standards. When employees attain these standards, they should receive appropriate recognition. Rituals and rites include factors such as promotions, transfers, training programs, achievements and retirement.

4. *A special feeling or climate exists.*

This sense is conveyed through communication networks and patterns, as well as physical layouts and arrangements. The physical arrangement of an open versus closed office enhances or inhibits interaction.

5. *There is a concern for people.*

Truly successful organizations display a genuine, heartfelt concern for employees. This may entail a simple "thank you" for a job well done or providing for a system of employee recognitions/awards or added benefits.

6. *Open communication prevails.*

Communication is the most important component of an organization. All the other factors rely on communication for their success. In vibrant organizations, communication tends to be open, free, spontaneous, adequate and feedback-oriented.

## **SOLUTIONS TO COMMUNICATION FLOW PROBLEMS**

1. *Strive towards improving communication techniques.*

Plan meetings and organize thoughts in advance. Ensure accuracy in written and oral communication transmission and reception. Provide timely responses. Be precise.

2. *Make sure that messages are targeted to the correct person.*

Be certain that messages transmitted are, in fact, received. If they are not, identify why and implement corrective measures. In particular, copy written communication to the appropriate individuals.

3. *Indicate the timeliness of expected responses to messages transmitted.*

Perhaps your priorities are not those of the other person's. Try to organize and word the message in such a way that it does not require an inordinate amount of time to read and respond to.

4. *Consider the communication objectives.*

What do you intend to accomplish? How do you intend to achieve this desired outcome? In what communication context is it most desirable to convey the information? In writing? In a one-on-one meeting? Or in a group or committee context?

5. *Maintain accurate documentation.*

It is especially beneficial to maintain written minutes for all meetings that occur and to have those minutes approved by those in attendance.

## PREPARATION STEPS FOR CONDUCTING MEETINGS

1. *Determine the purpose of the meeting.*
  - | Is the meeting necessary?
  - | What are the goals and objectives of the meeting?
2. *Determine the audience.*
  - | Who should attend?
  - | What should participants bring to the meeting?
  - | What is each person's range of contributions?
  - | Are there any hidden agendas?
3. *Make initial preparations.*
  - | Who is responsible for each portion of the meeting?
  - | Has everyone who should attend been contacted?
  - | Have room arrangements been made?
  - | Is there written verification of the meeting and its arrangements?
  - | Is there a written agenda? Has it been sent out to participants in a timely manner in advance of the meeting?
  - | Will breaks be necessary?
  - | Are there any special equipment needs? What about hand-outs?
4. *Prepare the meeting room.*
  - | Is the room of sufficient size for the meeting? It is comfortable and well ventilated?
  - | Are there any distractions in the room?
  - | Are there sufficient electrical outlets available for special equipment needs? Will a lectern be needed?
  - | Will there be a need to supply notepads, writing implements, refreshments, name cards/tags, etc.?

## Meeting Facilitator's Responsibilities

1. *Establish an open and comfortable communication context.*
  - | Arrive early and check arrangements.
  - | Greet participants as they arrive prior to the meeting.
  - | Make certain that everyone has been introduced to each other.

2. *Direct the flow of communication during the meeting.*
  - | Start the meeting promptly.
  - | State the purpose and objectives of the meeting.
  - | -Use the agenda as a means of guiding the direction of the meeting.
  - | Facilitate equitable participation amongst the members.
  - | Ask questions in order to keep the discussion focused.
3. *Present final comments.*
  - | Ask for consensus or call for a vote on issues when appropriate.
  - | Summarize discussions and decisions.
  - | Provide task assignments and appropriate follow-up.
4. *Provide follow-up to the meeting.*
  - | Summarize agreements, assignments, and deadlines.
  - | Make sure that there are accurate written minutes that are distributed and approved by the participants.
  - | Anticipate and facilitate potential problem areas prior to the next meeting.

## **GUIDELINES FOR TEAM DEVELOPMENT**

1. *Determine the purpose of the meeting.*
  - | Who are the team members?
  - | What is the demographic composition of the team? including age, gender, socioeconomic status, etc.?
  - | What experiences do these people bring to the team?
  - | What attributes does each individual have to offer the team?
2. *Seek ways to connect team members.*
  - | Identify areas of common ground or past experiences.
  - | Indicate what members can do in order to achieve a sense of pleasure from the other team members.
  - | Identify ways in which team members can support each other.
3. *Develop a team vision.*
  - | What are the team's goals and objectives?
  - | What are the desirable outcomes?
  - | How does all of this interconnect with the team decision making process?

4. *Develop a group character.*

- | What norms and expectations will foster a strong, positive climate?
- | How can the positive attributes of the team and its members be reinforced?
- | How can the team and its members be made to feel special and unique?
- | What are the team's code of ethics and standards?

5. *Create a context that is safe for team participation.*

- | What can members do to maximize their diversity?
- | How can team members identify shared values and orientations?
- | How can the team develop strategies for managing conflict?
- | In what ways can each team member share in leadership?

6. *Discuss each of the phases of team development as they occur.*

- | How can these phases be identified?
- | How will the team react to a lack of progress?
- | How will the team deal constructively when crises and conflicts occur?

7. *Develop task processes.*

- | Find ways of maintaining open, clear, and supportive communication.
- | Develop strong analytical team processes.

8. *Establish mechanisms for team self-assessment and improvement.*

- | How will feedback be incorporated into the team process?
- | How will the team obtain feedback from both team members and non-members?

9. *Find ways to celebrate the team and its accomplishments.*

- | How will the team accomplish its vision?
- | How will the team accomplish its goals and objectives?
- | What can the team do to recognize and reinforce its achievements?

## **CONFLICT RESOLUTION STRATEGIES**

1. *Identify problems and intentions.*

Stop and think before speaking. consider your goals and objectives; what you wish to accomplish. Once these items are clarified, you may be better prepared to state your comments in a more positive and constructive manner.

2. *Describe the problem and state your desires.*

If you disagree with someone, they cannot work through the conflict unless you communicate your concerns to them. It is your responsibility to describe the situation as concretely as possible. In doing so, the other person has the opportunity to understand your position.

3. *Avoid creating defensive reactions in others.*

Strive towards depersonalizing conflict so that it will not directly impact personally. Stick to the facts without criticizing others.

4. *Listen actively.*

Attend to the feelings and emotional tone of the message, as well as the content of what others are saying. Be supportive by providing encouragement. Realize that understanding the needs and desires of others is necessary to the reduction of conflict.

5. *Persuade others of the value of conflict.*

If a person views conflict as something to be avoided, they may respond defensively. They need to understand that avoiding conflict may be a short term solution that only delays the inevitable.

6. *Develop intragroup trust.*

Conflict is not a win/lose proposition. Nor is it a place for personal vendettas. Instead, conflict involves cooperative problem solving. The degree of trust established will directly impact the ability to manage conflict constructively.

7. *Do not take disagreement as personal rejection.*

Instead, focus on the content of the discussion, rather than the personal relationship itself. Respect each person's right to disagree. Do not allow egos to interfere with achieving the group's goals and objectives.

8. *Demonstrate cooperativeness if your plan is rejected.*

Cooperativeness is essential. In essence, the good of the collective whole will then outweigh individual gain and become the top priority for everyone.

9. *Clarify the Issues.*

In doing so, individuals will be able to identify, define, and sharpen the issues. Once this task is accomplished, there will be a clear and accurate picture of the areas of conflict and the consequences of the conflict. This requires flexibility and creativity.

10. *Allow the other person to save face.*

When people engage in face-saving communication, they are able to protect their image and personal identity. This is especially the case during times of conflict since in conflict situations, people are exposing their opinions and attitudes. This makes them feel vulnerable to personal criticism and the loss of esteem from others. In short, conflict can threaten one's identity.

## CHARACTERISTICS OF THE EFFECTIVE COMMUNICATOR

1. *The effective communicator is perceived as being adept at creating messages. That is, messages are perceived as:*

- | semantically sane.
- | reveling something about the communicator.
- | demonstrating that the communicator knows what he or she is talking about.
- | are clear and coherent.
- | make sense.
- | coming from someone who knows what they are doing.
- | being developed and presented in an open and positive manner.

2. *The effective communicator is perceived as being similar to the receiver in a variety of ways. That is, messages are perceived as coming from someone:*

- | with a similar background to the receiver.
- | who has interests similar to those of the receiver.
- | who has attitudes which are similar to those of the receiver.
- | who has opinions similar to those of the receiver.
- | who is liked by the receiver and others.
- | who is physically and psychologically attractive to the receiver.
- | who understands things through the other person's point-of-view.
- | who is genuine and sincere.

3. *The effective communicator is perceived as able to appropriately adapt communication to changing situations and contexts. That is, messages are perceived as:*

- | coming from someone who is aware of the impact of the messages.
- | being appropriate to the purpose of the communication.
- | coming from someone who is able to adapt his/her communication behavior to the situation at hand.
- | coming from someone who is able to adapt to the prescribed role in the situation.
- | coming from someone who has an extensive repertoire of verbal and nonverbal behaviors.
- | coming from someone who uses language appropriate to the receiver.
- | being responsive to others.

4. *The effective communicator is perceived as committed to others. That is, messages are perceived as coming from someone who demonstrates:*

- | concern that the interaction be mutually beneficial.
- | reliability and dependability.

- | supportiveness for others.
- | concern for the needs and wants of others.
- | adapts to others.
- | respect and acceptance of others.
- | avoids immediate value judgments, but, instead, suspends judgment.

5. *The effective communicator is perceived as adept at receiving messages. That is, messages are perceived as coming from someone who:*

- | is an effective listener.
- | is sensitive to verbal and nonverbal messages.
- | is interested in listening to what others have to say.
- | can distinguish between the roles of the source and the message within the communication context.
- | can say the right thing at the right time.
- | is sincere and poised.
- | tolerates and adjusts to distractions.

# Maintenance Human Factors at Northwest Airlines

**Billy G. Cunningham**

*Director, Quality Assurance  
Northwest Airlines*

## INTRODUCTION

First, I would like to express my appreciation to our hosts, the FAA and Galaxy Scientific for providing us, as professionals concerned with the maintenance of aircraft, a forum in which to share our ideas and approaches to the complex and challenging endeavor of researching and applying human factors to aircraft maintenance. I welcome this opportunity to update all of you on the progress we at Northwest Airlines are making in using human factors to increase the safety and reliability of our aircraft. As the Director of Technical Operations Training and the Acting Director of Quality Assurance, I am directly responsible for managing and supporting all of our initiatives in human factors.

Before I begin this presentation, however, I want to say a few words about our approach to human factors: we believe that the introduction of a human factors focus in the workplace needs to be an evolutionary--not revolutionary--one. We are starting small, limiting our scope of impact, trying systems and processes out in only one hangar first and with just one group of employees. As we proceed, we will evaluate and re-evaluate our systems and continually modify them to work for us.

## OVERVIEW

I would like to begin by telling you about our human factors goal at Northwest and explaining our organizational structure. Then we can look back at what we have already accomplished, where we are now, and where we are headed.

### Human Factors Goal at NWA

Our number one goal at Northwest has always been and will always be safety. This isn't going to change. What has changed is that we now view the attainment of our goal through a wider lens, a lens that encompasses the human element. We will now use human factors as a means of achieving our goal and supporting our mission: "to consistently provide safe, clean, technically sound aircraft to support the on-time operation of Northwest Airlines."

All other departments within Northwest view human factors as a means of achieving "zero accidents" as well. Our pilots in Flight Operations use Crew Resource Management in Line Oriented Flight Training and Debriefing (LOFT). In-Flight, which is the flight attendant division, provides general training on Crew Resource Management, and for the past two years has teamed up with pilot Annual Recurrent Training to conduct joint pilot-flight attendant training focused on a specific subject within crew resource management.

Last year all dispatchers and maintenance control staff completed a culture survey, received Awareness Training as part of their annual refresher training, and developed a behavioral model.

Ground Services has taken a different tack: they are conducting Aircraft Damage Investigations (ADIT) to help determine contributing factors to ground aircraft damage and develop corrective actions.

In Technical Operations, we have accomplished a culture survey, developed a behavioral model and implemented an automated maintenance mishap management system. The focus of my talk will be on Technical Operations, but if you have questions about other areas, I will try to answer them.

## Human Factors Organizational Structure

The Tech Ops Human Factors Steering Committee ([Figure 5-1, appendix](#)) is headed by our Senior Vice President and includes representation from all departments within Technical Operations. Also on the committee are the president of IAM District 143, Marv Sandrin; Boeing's VP and General Manager of Customer Services Division, Fred Mitchell; and the Vice President of Flight Operations and a pioneer in the field of human factors, Dr. Clayton Foushee. The Planning Group ([Figure 5-1, appendix](#)), in effect, carries out the directives from the Steering Committee and includes representatives from Flight Operations and the IAM as well.

## Maintenance Error Decision Aid (MEDA)

Looking back on what we accomplished last year in maintenance human factors, I am pleased with the quality of our work and the issues we elected to focus on. But intuitively, I believe we could have made greater strides. One drawback of a more cautious, evolutionary approach is that progress is slower and harder to measure.

Northwest was one of the airlines that participated in the MEDA field test effort. Our personnel completed MEDA training in early January, 1995, and investigated 44 incidents between January and August of last year.

Our approach was to start small and restrict the investigations to the Boeing 747 hangar in Minneapolis. This seemed an appropriate place to start because, as you may recall, in March of 1993 a 747 engine disengaged from the wing as the aircraft landed at Narita, Tokyo's airport, causing the airport to shut down for several hours. One of the NTSB's findings pointed to a lack of human factors engineering principles in the mechanic's job instruction cards. Although not all incidents investigated were as severe as that one (and thank goodness, we haven't had any more serious than that!), the tendency was to use MEDA for major errors.

## MEDA Results

The MEDA investigations revealed that the kinds of errors we at Northwest were experiencing were similar to those of other airlines and to the industry as a whole ([Figure 5-2, appendix](#)). The three major contributors to maintenance errors were information, communication and job instructions.

## HUMAN FACTORS QUESTIONNAIRE - TECH OPS

Concurrent with our MEDA efforts last year, we surveyed our culture. With the help of the experts from NASA/UT and Dr. Bob Helmreich, the Flight Management Attitudes Questionnaire was modified and adapted for maintenance technicians. The questionnaire was issued to the 496 maintenance technicians in the 747 hangar in Minneapolis. We had a return rate of almost 85% with over 700 written suggestions and 66% of the respondents providing at least one written comment. The primary areas of concern were ranked in this order: communication, safety, accountability, and technology.

## TECH OPS RESOURCE MANAGEMENT

These areas of concern were kept in mind as we worked on developing a model for Technical

Operations Human Factors. We wanted our model to complement those already built for Flight Operations, In-flight and the SOC. They were, after all, based on the work of the experts at NASA/UT. Using the pilot model of CRM, we recruited several maintenance technicians to review the model and suggest how it might be tailored to work in the hangars, on the line and in the shops. The result was a set of human factors skills which we want to see used in all areas of Tech Ops and practiced when interacting with other Northwest departments as well as agencies external to Northwest, including the FAA, security, and our alliance partners.

Each human factors skill, which we call "performance indicator", is a clearly defined behavior which can be observed in training and practiced on the job. The performance indicators are divided into four general categories, or "clusters": Communication, Crew Development, Workload Management, and Technical Proficiency.

## Communication

The Communication Cluster describes the model behaviors for crews to use in their communications and involves both the clarity of communication and appropriate techniques.

### **1. Actively participates in shift turnover briefing.**

The shift turnover briefing includes all information pertinent to completing aircraft repair or maintenance. It addresses status of work done, problems encountered and potential problems. The current shift crew may also recommend solutions or procedures.

Both the current and relief shift crews are responsible for ensuring that all necessary information is obtained for an orderly transfer of responsibilities.

### **2. Seeks information and direction from others when necessary.**

Crew members ask questions and seek information from each other, supervisors, or other Technical Operations personnel about maintenance issues and decisions made. The flight crew, other NWA departments or agencies outside NWA are consulted when appropriate.

Crewmembers recognize personal limitations, such as limited experience on a particular aircraft or aircraft system and actively seek direction or advice on maintenance issues when necessary.

### **3. Clearly communicates decisions about maintenance or repair done on the aircraft.**

Crewmembers clearly communicate information regarding tasks accomplished or in-progress or troubleshooting done. Communication may be done orally or in writing using appropriate documentation. If communication is accomplished orally, crewmembers must also document accomplishment of tasks in the logbook, on the job instruction cards (CITEXT) or in the computer system (SCEPTRE). Communication should include other NWA departments as well as agencies outside NWA when appropriate.

This communication level should be complete enough and provide sufficient detail to allow co-workers and other departments to be proactive in solving problems as opposed to continually playing "catch up" and to eliminate redundancy.

### **4. Asserts with the appropriate level of persistence to maintain safety and aircraft airworthiness.**

Crewmembers state their own ideas, opinions and recommendations. They assert themselves and defend their point of view. Crewmembers use appropriate levels of assertiveness, as required, to maintain safety and aircraft airworthiness. This may extend to other NWA

departments or agencies outside NWA.

## **5. Critiques self and co-workers when appropriate.**

Crew members continually assess their own and others' performance to improve operation efficiency and safety. Feedback may be of a positive or negative nature and should be focused on improving the action without attacking the actor. It is specific, based on observation and provided for the purpose of maximizing crew effectiveness.

## **Crew Development**

This cluster describes behavior relating to group interaction and how well the crew works together to ensure operational safety and aircraft airworthiness.

### **1. Involves crewmembers in decision making process.**

Decisions are made in a timely manner taking into consideration all facts available and are conveyed to other crewmembers when appropriate.

Crewmembers participate in the decision-making process, when necessary, to increase the likelihood of making the most appropriate decision.

### **2. Exercises confident authority.**

The supervisor uses authority in a confident and competent manner, without being autocratic, and acts decisively when the situation dictates.

Other crewmembers exercise the authority vested in their respective positions, as required to perform their duties.

### **3. Copes effectively with operational stress.**

Crewmembers cope effectively with operational stress and remain calm in critical and high workload situations. Crewmembers recognize the signs of stress in themselves and co-workers and communicate observations to others when safety or operational efficiency is compromised.

When resources are available, crewmembers seek help in coping with or alleviating stress. They cope with or remove themselves from situations in which stress from a non-operational origin may negatively affect job performance.

### **4. Uses appropriate techniques to manage interpersonal and operational conflict.**

Crewmembers assess underlying problems, identify operational goals, and suggest solutions to lessen interpersonal or operational conflict.

Crewmembers respect another's viewpoint and use a method of conflict resolution appropriate for the nature and criticality of the problem. They look for jointly determined solutions whenever possible.

### **5. Adapts to co-worker interpersonal differences.**

Crewmembers demonstrate an ability to adapt to different personalities and characteristics.

Crewmembers are respectful of different backgrounds and belief systems. Crew members identify and establish common characteristics as a basis for building an effective work group.

## Workload Management

This cluster describes factors in managing workload in order to accomplish needed tasks without compromising safety.

### 1. **Prioritizes tasks to accomplish in timely and effective manner.**

Crewmembers clearly prioritize operational tasks. Primary tasks such as an expiring MEL status on an aircraft are allocated sufficient resources before duties such as routine maintenance are addressed. Low priority or non-essential activities such as social interaction do not interfere with more important tasks.

### 2. **Utilizes tools and resources to maximize efficiency and minimize errors.**

Crewmembers procure and organize tools and consult appropriate technical manuals or computer systems to perform necessary tasks with the maximum efficiency and safety.

### 3. **Monitors all relevant operational factors to maintain safety.**

Crewmembers are constantly monitoring proper use of tools and materials, movement and position of equipment and other operational factors that may compromise safety. The crew uses the information to determine changes in operations and to report them to other co-workers.

### 4. **Manages time to accomplish tasks.**

Crewmembers plan sufficient time to accomplish duties. They recognize that time requirements vary by task and allocate accordingly. Flexibility is maintained to allow for handling possible abnormal or irregular operations.

### 5. **Distributes tasks to maximize efficiency.**

The crew distributes the workload so that everyone is utilized, while no one is overworked. Each crewmember recognizes and reports work overload in self and other crewmembers.

## Technical Proficiency

This cluster describes the technical performance of crewmembers with regard to policies, regulations and the use of tools and resources available.

### 1. **Demonstrates technical skills.**

Crewmembers demonstrate proficiency in use of tools, equipment, troubleshooting skills and other processes.

### 2. **Demonstrates knowledge of aircraft systems.**

Crewmembers demonstrate working knowledge of applicable aircraft systems and consult technical manuals or co-workers when needed. Crewmembers recognize any personal limitations in performing assigned tasks and procure assistance when necessary.

Whenever sufficient time and resources have been allocated, crewmembers will update and improve skills as needed to perform their job effectively.

### 3. **Adheres to company policies and government regulations.**

Crewmembers comply with all company policies and applicable government regulations in regard to both technical and safety issues. Crewmembers demonstrate watchfulness in maintaining compliance among co-workers.

#### **4. Demonstrates knowledge of computer system and manuals.**

Crewmembers know how to enter and access data in the computer system (SCEPTRE) and other computer systems. They consult relevant technical manuals and the General Engineering and Maintenance Manual (GEMM) as necessary.

### **Human Factors Awareness Training**

The focus of the Awareness Training module will be on understanding and applying the performance indicators I just described. The four areas of concern identified in our culture survey (Communication, Safety, Accountability and Technology), will receive special emphasis when we introduce the model. We plan to tap the "Liveware" data from the Mishap Management System (more about that in a moment) and our MEDA investigations to cull real-life examples of errors caused by a lack of specific human factors behaviors and use them in our training.

We are working with Flight Operations to complete the Awareness Training module by the end of the first quarter of this year and look forward to implementing the prototype in the 747 hangar in the second quarter.

### **Task Analytic Training System (TATS)**

TATS has been a real success story in our shops. We began using TATS last year and expect the TATS process to continue into the future. Diane Walter from Boeing has been a key driver and supporter of TATS at Northwest and I see from the agenda that Diane follows this presentation. The work force to which TATS has been introduced has received it well. As of today, over 100 TATS modules have been completed in our APU shop, the JT9D shop, the hydraulic shop, the machine shop and the plating shop. As one process which encourages open communication, crew development, workload management and technical proficiency, TATS has proven to be a successful human factors initiative.

### **Aurora Mishap Management System (AMMS)**

In late September of last year, we were provided with a demonstration of the Aurora Mishap Management System (AMMS). The functionality displayed by the system closely coincided with our needs for an automated data collection system. We were favorably impressed with the AMMS for a number of reasons. Primary among those reasons was the fact that AMMS basically incorporates much of the "goodness" designed into MEDA, and expands that basic concept into a very user-friendly tool. Among its uses are the ability to collect data on-line and analyze it automatically; the capability to identify systemic problems; and a feature which assists in developing intervention strategies.

### **AMMS at Northwest Airlines**

AMMS was implemented here at Northwest on 2 October 1995. The Steering Committee directed that its use be restricted to the Boeing 747 hangars in Minneapolis until our processes, policies and infrastructure are fully developed and fine-tuned.

Eighteen investigators, which included representatives from management and IAM labor, were trained on the use of the AMMS laptop PC-based system. The intent was to use AMMS to investigate all mishaps in the Boeing 747 hangars. Some of the mishaps investigated included shift

turn-over problems, On-the-job injuries, reworks, late delivery of parts, critical path task scheduling, and job instruction cards. In approximately two months, 116 mishaps were investigated. This fell short of the projected number, but was a marked increase over the number of MEDA investigations.

The collection of error data from these investigations has definitely helped to identify the economic impact of mishaps in our maintenance operation, and has also helped to create a higher level of safety awareness.

## Mishap Management System Functionality

One feature of AMMS is the Maintenance Investigator. The Investigator provides a means to conduct new investigations as well as update or view completed investigations. The Investigator also houses the prevention strategy analysis module.

Another feature of AMMS, which we heavily rely on and value, is the INFO base. The INFO base enables us to search on narrative data in the error investigation database and turn this narrative data into statistical graphs. In this way, we can identify systemic problems and begin zeroing in on effective intervention strategies.

The INFO base also contains excellent reference material, such as ICAO Human Factors. We foresee our company policies (such as GEMM) and aircraft/engine maintenance manuals being added to the INFO base for easy reference.

## Quick Look Reports

The next several slides reflect the types of AMMS output available and provide a good idea of the system's capabilities for reporting. One caveat before we proceed: the data reflected in these reports is not conclusive; it is used only to indicate areas that should undergo additional analysis. In order, we will view 1) the costs of mishaps; 2) mishaps sorted by functional area responsible; 3) mishaps sorted by the types of task being accomplished at the time of error; and 4) mishaps sorted by contributing software, hardware, environment and liveware (people) factors. The acronym for these factors is "SHEL".

## Cost of Maintenance Mishaps

Of the total 116 mishaps investigated, approximately 75% of them have some economic value assigned to them. Several investigations did not have dollar values assigned because the mishaps occurred outside of the target area of investigation. If values *were* assigned to those mishaps, the total would be in excess of \$1,000,000. ([Figure 5-3, appendix](#))

As this report indicates, mishaps involving parts is our biggest driver for data collected thus far, with impact on operations running a close second. Mishaps involving parts included parts not arriving on time, wrong parts being delivered, and parts which were out of stock. Dollar values associated with operations are usually calculated on the impact of delayed or canceled flights because the aircraft was late coming out of its check. Although it is not shown here, another module in the AMMS provides a Return on Investment (ROI) for the proposed intervention.

## Mishaps by Functional Area

Another way to view the collected data is reflected in this report. Depicted here are the areas or specialties involved in the investigated mishap. From this graph ([Figure 5-4, appendix](#)), it may appear that the hydraulic and cabin groups create the most mishaps. We are not, however, jumping to that conclusion. The high numbers from these two groups might be because they have more tasks to accomplish, or it might be because they are more prone to come forward and admit that an error occurred. We intend to follow-up on this type of data and determine the causes.

## Mishaps by Task Classification

This report breaks down investigations by the type of task that was being performed when the mishap occurred. Although caution must still be exercised when attempting to draw conclusions from this graph ([Figure 5-5, appendix](#)), it does tend to support other data indicators from the perspective of reliability. For example, we have a higher probability of inducing errors in hardware when we are accomplishing removals and replacement of parts and when we are performing check outs of a system.

## Mishaps Identifying SHEL Factors

The SHEL factors are part of the Investigator feature of the system. You will recall that SHEL is the acronym for software, hardware, environment, and liveware. In general terms, software is defined as the availability, adequacy, and appropriateness of information. Hardware refers to availability, adequacy and function of aircraft, parts, tools and equipment. Environment refers to availability, adequacy and appropriateness of the maintenance facility or the structure's inside working conditions. Liveware refers to physical, mental, or emotional factors and includes relationships with other persons or organizations.

From this report ([Figure 5-6, appendix](#)), hardware and software appear to be areas which merit further investigation. It should be noted, however, that only 40% of the investigations conducted had some type of SHEL response that could be considered a contributing factor. We expect this number to rise as we educate our employees on identifying human factors skills and recognizing them (or the lack of them!) in the workplace.

## TECH OPS HUMAN FACTORS - FUTURE

I want to close by talking a little about the future of human factors in maintenance.

I will begin by saying: The future begins today.

- | We have a human factors specialist hired who will start work this week. She will begin by observing and absorbing our operations in the 747 hangars.
- | We will be expanding the use of AMMS in to other areas of Tech Ops. As needs dictate, the tool will be modified. The Steering Committee has already requested, for example, that a feedback mechanism be built in to the system, so that as data is collected, the responsible parties are automatically pulled in to the loop.
- | The use of TATS will also continue to expand. Some of our other shops have requested assistance in building TATS modules.
- | Awareness Training will eventually be delivered to all maintenance technicians, support staff, managers and executive management.
- | As we revise and create new training programs, human factors issues will be included in them. In the future, human factors will not stand out as a separate focus; we hope to see it become integrated throughout Tech Operations; it will become a seamless part of our culture.

### **We have begun, BUT we still have a long way to go---**

I would like to conclude by saying that while we are proud of how far we have come in such a short time, we still have a long way to go. Some of the issues we will struggle with this next year include:

- | Moving our culture from a 'blame and train' one to one which embraces open communication and disclosure of problems and errors.

- | Educating our Tech Ops managers and crew chiefs to adopt a more consensual, consultive leadership style and abandon autocratic ones.
- | Improving the quality and scope of our investigations to determine "root cause."
- | And in today's fiscally constrained environment, articulating the need to our controllers for continued financial support. They, like us, need to keep in mind, that as long as the human element is involved, mistakes are going to be made. Our job has to be to manage those mistakes, learning from them to prevent their reoccurrence and improving our operation to remain competitive.

## APPENDIX



**Figure 5-1** Steering Committee and Planning Group



**Figure 5-2** MEDA Results



**Figure 5-3** Cost of Maintenance Mishaps



**Figure 5-4** Mishaps by Functional Area



**Figure 5-5** Mishaps by Task Classification



**Figure 5-6** Mishaps Identifying SHEL Factor

# A Human Factors Approach to Aviation Maintenance and Inspection Training: The Task Analytic Training System

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## ABSTRACT

Most aviation maintenance environments rely on a form of on-the-job training which is actually a degenerating buddy system. Training is generally the responsibility of the lead mechanic who may or may not be the most knowledgeable or experienced person and who may or may not want to be involved with training. The Task Analytic Training System (TATS) provides a highly structured, performance-based model that involves full workforce participation in the design, development and implementation of the training. Through incorporation of basic human factors principles such as decision making, communication, team building, and work management, either directly or as a function of the techniques involved, the TATS process results not only in better training and procedures, but an overall improvement of attitude and morale. The theoretical background of the model is addressed by illustrating how proven training methodologies are blended with human factors principles resulting in a unique, team-driven approach to training. The paper discusses major elements of the model including needs identification, outlining targeted jobs, writing and verifying training procedures, an approval system, sequencing of training, certifying trainers, implementing, employing tracking mechanisms, evaluating, and establishing a maintenance/audit plan.

## BACKGROUND AND INTRODUCTION

The Task Analytic Training System (TATS) is a training model uniquely combining proven training methodologies of job task analysis and job instruction training with human factors principles resulting in a highly disciplined, interactive approach to training. This generic model was implemented in the non-destructive testing areas of the Boeing Commercial Airplane Group to address on-the-job training. New and experienced inspectors needed an on-going comprehensive, structured training system designed to continuously improve the quality and reliability of inspections. They needed a system that would provide first-time, remedial and recurrent training. Subsequently a modified version of the same model was employed in designing and developing the Crew Resource Management (CRM) course for Boeing's instructor pilots, test pilots, and ground school instructors. The Task Analytic Training System has been incorporated as part of the Boeing Maintenance Error Management program to be implemented in Boeing factories and customer airlines.

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 human factors principles ([Figure 6-1, appendix](#)). 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 various clients) first appeared before World War II. The human performance-based approach is founded on basic human factors principles.

Skill and knowledge alone are not sufficient to ensure a well-trained and productive employee. An attitude which 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 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.

Another feature is the heavy reliance on people resources and the value of crew coordination. In complex systems where the work of many people combines into a single flow or outcome, or when tasks require group efforts, skills such as communication, decision making, problem solving, conflict resolution and work management may become critical elements for task completion. When activities require more than a single individual, the Task Analytic Training System incorporates "Team Task Analysis".

## 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 of 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 training programs get put on the shelf and are forgotten. There is no follow-up or evaluation of the programs.

Fifth, most airline maintenance environments rely on a form of on-the-job training which is actually a degenerating buddy system. Training is generally the responsibility of the lead mechanic who may or may not be the most knowledgeable or experienced person and who may or may not want to be involved with training. The result is that-- (1) valuable details are left out of procedures, (2) mistakes are perpetuated, (3) there is a lack of consistency from one person to another, one shift to another, etc., and (4) shortcuts are developed due to lack of understanding as to why things are done the way they are.

A sixth problem is that traditional training focuses on tasks in a generic "context-free" setting. There are many local features of the work environment that contribute to the success of the training such as:

1. Task completion may be hindered by the need to "unlearn" old methods.
2. Task completion may need to accommodate frequent personnel shifts or shift changes.
3. Task completion may require the availability of information resources, equipment, etc. which are beyond the typical task description.
4. Task completion may run up against cross organizational conflicts (e.g., incompatibility of procedures, terminology).
5. Task completion may be hindered by physical aspects of the workplace (inadequate space, environmental and safety conditions).

## WHAT, WHY, HOW, WHERE, WHEN

## WHAT is the Task Analytic Training System?

The training system is a generic process, a performance based, hands-on approach applicable to any job and organizational style. It provides comprehensive, structured, on-the-job training. The model can be used effectively for both technical and "soft skills" training. Human factors principles such as decision making, communication, team building, and work management are either built directly into the model or are present as a function of the techniques involved. In general the process enhances mutual respect and trust, goal-directed behavior, self-esteem, and responsiveness to new ideas and contributions.

## WHY was the training system developed?

1. To provide new workers with structured on-the-job training.
2. To provide recurrent and remedial training to experienced workers.
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.
7. To incorporate aspects of crew coordination into task analyses as required, supported by the relevant team skills training.

## 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 include 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 knowledgeable workers, key supervisors, and technical experts. They review and approve all modules for accuracy and completeness, and for compatibility with current procedures and policies. In addition, they determine the administrative requirements for the implementation of any changes.

The facilitator functions as a progress expert and is present at all design team meetings to keep the team on track, help handle disagreements, and coordinate all activities. Strengthening communication links to avoid misunderstandings is a constant task for the TATS facilitator.

Although not a job expert, the facilitator contributes expertise in guiding the team through the task analysis and the eight implementation steps.

### **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 workers are very quickly trained in new skills with minimum disruption of the day-to-day 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 work force. 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 on-going. Modules are written and used as needs arise -- new materials, new equipment changes in processes, etc. The flexibility of the modules, or short procedures, allows for individual training plans. Due to prior experience, everyone will not need training in all areas.

## **HUMAN FACTORS PRINCIPLES of the TASK ANALYTIC TRAINING SYSTEM**

The Task Analytical Training System is based on human factors principles which are, in turn, based on present day social psychology, organizational and management theories. On the basis of these principles, there are five assumptions which are reflected in the training program.

The first assumption is that human behavior is goal directed. We assume that in the workplace, a person's primary goal is to make a contribution both as an individual and as a significant member of his or her work group. It is through this active contribution to the work process that individuals feel job satisfaction, and work groups sustain high morale. The achievement of these goals is the basis for building a motivated workforce in which workers are productive, responsible and cooperative. When workers are not given the chance to contribute, or when their work is undermined, an unmotivated workforce may develop in which individuals become counterproductive and less caring about their work.

The second assumption is that people resources can improve performance and the work processes. This is, in part, because people are active problem solvers, creative decision makers and holders of critical knowledge, skills and experience which can generate new ideas and solutions for problems. Furthermore, having an active role in solving problems is a hallmark of job satisfaction. People who are encouraged to be creative and active participants feel they can make a difference and have an impact on the work environment. The Task Analytic Training System uses work groups to generate solutions by having them ask questions such as, "What is the best way to do this job?"

The third assumption is that work is performed in a social context. People do not operate in isolation. Everything we do, as individuals or in groups, relates in some way to other people (e.g., members of your own work group, your work group's prior or later shift, supervisors, instructors, other related work units). Most problems cannot be solved by one person in isolation. Rather, cooperation and the

contribution of the people resources around us solve problems. The study of human error has paid little attention to the fact that behavior is not solitary, In fact, the social dynamics of the work environment, including management styles have a tremendous effect on error rates.

Fourth, use is more important than possession. The skills and knowledge a person has do not count unless they are put to use. In order for TATS to succeed, workers and management must commit to an attitude that values work, worker participation, and job satisfaction over and above the possession of the skills and knowledge requirements alone.

The fifth assumption is that people and organizations produce synergy; that is, the whole is greater than the sum of its separate parts. The Task Analytic Training System is based on maximizing the benefits of using people resources. The quality and quantity of individuals' independent work is not as effective as the same work accomplished cooperatively. Similarly, crews may work independently within a larger organizational system, but their work will be more effective if their respective jobs are designed, analyzed and trained within a systems perspective.

## 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 ([Figure 6-2, appendix](#)).

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.

Much of the success of the Task Analytical Training System is due to the process itself. The eight step process guarantees employee ownership of the program. A description of the process follows:

### 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. During this initial phase, the teams must be established and the roles and responsibilities set up. On the basis of the needs identified, this is also a good time to begin defining the measurable objectives of the program. These may include overall performance and training goals, as well as specific performance standards associated with particular tasks.

### 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)? and (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 task breakdown continues until the tasks take no more than one-half hour to teach and learn ([Figure 6-3, appendix](#)). One-half hour segments:

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 change.
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 team designs 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. Depending on the program objectives defined, the project plan may include systematic data collection in order to track specific performance and training goals. 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 strengthen management involvement and commitment.

### **Write The Training Modules - 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 which is cumbersome and difficult to modify. Generally, writers include enough material to serve as memory joggers for an instructor experienced doing the job. The easy-to-read-and-use format promotes workforce acceptance and increases the likelihood of the modules being used for quick task references. Each module has a cover sheet ([Figure 6-4, appendix](#)) which prepares the instructor and trainee to try out the tasks written in the modules. It is critical that the objective defined for each module be able to serve as a measurable, and standard criterion for a trainee's task performance.

During the writing phase, the team engages in various activities: meeting other teams in different areas; discussion, 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.

### **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: who needs training in which modules and by what dates, who will do the training, and how results of training will be measured. A person is assigned to prepare individual plans, taking into consideration prior skills and knowledge brought to the job by trainees and a logical sequence for presenting the modules.

## Tryout, Evaluate, and Modify - Step 6

Important with the first, and subsequent use(s) of the training modules 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 ([Figure 6-5, appendix](#)). Anyone may suggest changes, including the trainees. This is also the time to make sure that the performance standards are adequate and that both instructors and trainees share a clear understanding of what counts as "successful task completion".

## 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: signs of program obsolescence, identification of new training needs, opportunities to streamline the process to make it more cost-effective, and organizational changes that impact training.

## Start Training - Step 8

The Task Analytic Training System incorporates traditional job instruction 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. Third, 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 about the training and content, as well as training implementation, as possible.

## SUMMARY

The Task Analytic Training System is uniquely based on three interacting components: (1) job task analysis, (2) job instruction training, and (3) human factors principles. 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 highly structured and disciplined on-the-job training program that is on-going. By the nature of its design, it addresses remedial, recurrent and first time training. When successful task completion involves more than one person or more than one team, the system is adapted to incorporate team task analysis into training modules. The Task Analytic Training System produces a trained workforce whose performance can be observed and measured against carefully identified standards. In addition, the system can provide overall performance and training enhancements that can be tracked as an integral part of the initial project plan and the continuing maintenance and audit plans ([Figure 6-6, appendix](#)).

The critical role of 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.

## APPENDIX



**Figure 6-1** Three Components of Task Analytic Training System



**Figure 6-2** The Working Elements of TATS



**Figure 6-3** The Job Task Analysis Breakdown



**Figure 6-4** Training Module Cover Sheet



**Figure 6-5** Module Development Process



**Figure 6-6** Summary

# Crew Coordination Training: It Isn't Just For Aircrew Anymore

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## ABSTRACT

Crew Resource Management (CRM) was developed by the airlines in the late 1970's to address mishaps linked to crew coordination breakdowns. The military services adopted CRM in the early 80's and modified it to meet their needs. Subsequent research conducted by the Navy identified seven common behavioral skills that, when not used, lead to flight mishaps: Communication, Assertiveness, Mission Analysis, Decision Making, Situational Awareness, Adaptability / Flexibility and Leadership. Recently, the Naval Safety Center determined that many aviation ground mishaps result from a breakdown in the crew concept and a lack of the same behavioral skills. Consequently, a Groundcrew Coordination Training (GCT) program is being developed by the Naval Safety Center for U.S. Navy and U.S. Marine Corps aircraft maintenance and line personnel.

## INTRODUCTION

### General Background

All designated Naval Aircrew are required to take both initial and refresher Aircrew Coordination Training or "ACT." ACT as a program has gone through an evolutionary process over the years. The first ACT program was a direct adaptation of the Cockpit Resource Management (CRM) course developed by the commercial airlines in the late 1970's to attack a growing problem of mishaps linked to crew coordination breakdowns, crew size reductions, greater workload and new technology. The Navy-Marine Corps Aviation Team and the other military services modified the CRM program during the early 1980's to meet their needs. Subsequently, many Naval Aviation communities, such as the A-6 *Intruder* and the CH-53 *Sea Stallion*, tailored ACT to be more platform and mission specific. ACT was also expanded to include cabin personnel and is now being integrated into all phases of flight training and standardization evaluation. Overall, the dramatic decline in Class A Flight Mishaps in recent years has been attributed in part to the development, implementation, and enculturation of ACT in the Fleet.

Research conducted by the Naval Safety Center in conjunction with the then Naval Training Systems Center identified seven common "Behavioral Skills" that, when not used, lead to Flight and Flight Related Mishaps. They are: Communication, Assertiveness, Mission Analysis, Decision Making, Situational Awareness, Adaptability / Flexibility, and Leadership. These behavioral skills are the cornerstone of the Naval ACT program. Recently, a Naval Safety Center analysis of Aviation Ground Mishaps, those mishaps where there is no intent for flight, determined that the majority depict a lack of behavioral skill use by maintainers and linemen and a breakdown in crew coordination. As a result, a Groundcrew Coordination Training (GCT) program is now being developed for U.S. Navy and U.S. Marine Corps aircraft maintainers and line personnel.

## OBJECTIVE STATEMENT

The purpose of this effort is to observe the need for GCT in Naval Aviation. The objective is to suggest a plausible course of action for addressing it.

## PREVIOUS INITIATIVES

Before outlining the scope of the Naval Safety Center's GCT program, it is appropriate to acknowledge the ground breaking work underway in the commercial airline industry. In *Maintenance Resource Management*, [Bradley \(1995\)](#) stated "The push for applying resource management training to (maintainers) is almost entirely industry driven." Given the competitive nature of commercial airlines to meet schedules, provide safe and reliable service, and keep operation costs down this it is not surprising. However, it is also important to note that the Federal Aviation Administration's National Plan for Civil Aviation Human Factors and Human Factors in Aircraft Maintenance and Inspection program has fostered much interest in such human factors efforts.

Continental Airlines' Crew Coordination Concepts (CCC) program, initiated in 1991, is recognized as the pioneering effort to apply CRM in aviation maintenance ([Bradley, 1995](#)). According to [Taylor and Robertson \(1994\)](#) its charter is: "to equip all maintenance personnel with the skill to use all resources to improve safety and efficiency." Originally designed for supervisory personnel, CCC is now mandated for all staff levels and consists of a interactive two day workshop that includes lectures, case studies, videos, and exercises. The course is facilitated by a human factors expert and technical maintenance representative, and its objectives are to diagnose organizational norms and impacts on safety, promote assertive behavior, evaluate individual leadership styles, understand and manage stress, enhance rational problem solving and decision making skills and develop interpersonal skills. The results reported by [Stelly and Taylor \(1992\)](#) after the first year of CCC at Continental Airlines were remarkable:

- | 1200 total out of the targeted 1800 personnel were trained
- | Cost of repair maintenance caused ground damage was down 68%
- | Maintenance caused ground damage incidents were down 34%
- | Occupational injury hours paid are down 27% and medical paid are down 12%

[Taylor and Robertson \(1993\)](#) state the strengths of CCC program were: timing and content was well received by participants; training produced improvements in most attitudes measured; performance appeared to improve due to CRM training and specific attitude changes may cause specific performance changes. It also was contended that CCC creates an atmosphere of active change and continuous improvement. They recommend helping participants plan for using their new skills at work, focusing directly on assertiveness skill training and widely publicizing CRM training. In a final report on Continental's CCC program after three years of experience, [Taylor and Robertson \(1995\)](#) found attitudes improved following training as well as in the months that followed, participants reported shifting from passive to active job behaviors and CRM skills were clearly linked to improved safety, efficiency, and dependability performance.

## GROUNDCREW COORDINATION TRAINING

### *Overview*

The Groundcrew Coordination Training or "GCT" format and content is based on the P-3 *Orion* ACT syllabus and the author's experience as an ACT instructor. It includes an introduction to the crew coordination concept, coverage of the seven behavioral skills, their importance and barriers to their use (with illustrative examples) and a number of case examples for discussion.

## *Introduction to GCT*

Naval Aviation has developed and implemented several programs to reduce Class A Flight Mishaps over the past 50 years ([Figure 7-1, appendix](#)). Notable efforts include establishing the Naval Aviation Safety Center (NASC), implementing the Naval Aviation Maintenance Program, developing the Replacement Air Group (RAG) concept, initiating the Naval Aviation Training and Operations Standardization (NATOPS) program, starting the Squadron Safety Program and most recently the Aircrew Coordination Training (ACT) program. ACT has been attributed as being a major factor that has led to the dramatic reduction in Class A Flight Mishaps over the past decade.

Crew Resource Management (CRM) was developed by the airlines in the late 1970's to attack a growing problem of mishaps linked to crew coordination breakdowns. The Navy-Marine Corps team and the other military services modified the program during the 80's to meet their needs. Several communities (i.e., A-6, CH-53, etc.) tailored the program to be more platform specific. Research subsequently identified seven common behavioral skills that, when not used, are ties to aviation mishaps. Recent Naval Safety Center analysis has determined that many Aviation Ground Mishaps also show a lack of skill use and poor crew coordination. Approximately one third of the Class C Aviation Ground Mishaps (those costing over \$10,000, but under \$100,000 and/or involve serious personal injury) each year for the last 10 years involved a breakdown of the crew concept as outlined in the Naval ACT program.

Clearly, there is a need to develop and foster the crew concept among aircraft maintainers and line personnel if the Naval Aviation Safety Program is to further increase its effectiveness in reducing mishaps. So it can now be said about Crew Coordination that "Its Not Just for Aircrew Anymore!"

*What is Crew Coordination?* It is the process of coordinated action among crew members which enables them to interact effectively while performing mission tasks. Many times aircraft maintainers and line personnel approach their tasks as individuals and not part of a team. They may look out for themselves, but not for those around them (e.g., a wingwalker crouched in front of a mainmount to block the wind was crushed when movement started). Many people have paid dearly for someone not being part of the team (e.g., a maintainer working on the main rotor head spun it, mangling the hand of another working on the tail rotor linkage). The key is that in many instances effective crew coordination would prevent such mishaps from occurring.

*Why is Crew Coordination important?* Good Crew Coordination can increase mission effectiveness by minimizing crew error, maximizing crew resources and optimizing risk management. It minimizes crew error and maximizes crew resources by bringing to bear all the sensory, attentional, perceptual, cognitive, decision making, problem solving, etc. capabilities that are available in a group. In other words, the eyes/ears, minds, knowledge and experiences of all the team members can be used to prevent error(s) that lead to mishaps (e.g., while towing an aircraft wingwalkers must maintain a sharp lookout, yet there are collisions with hangars, aircraft, etc.). Resources that prevent errors and increase effectiveness are also essential to manage risk. Generally, military activities have risk and associated hazards; if they are accidentally or intentionally ignored the outcomes can be quite disastrous (e.g., maintainers climbing on aircraft are required to wear "cranials," yet individuals fall from aircraft in front of peers without them). So there is a clear need for crew coordination, what constitutes it?

## *Seven Behavioral Skills*

As was mentioned earlier, research conducted by the Naval Safety Center, in conjunction with the then Naval Training Systems Center, identified seven behavioral skills that were common themes in mishaps involving aircrew error: Communication, Assertiveness, Mission Analysis, Decision Making, Situational Awareness, Adaptability / Flexibility and Leadership. Each has its own operational definition, stated importance, and associated barriers. This discussion covers each using "interesting" examples.

*Communication* - the ability to clearly/accurately send and acknowledge timely information,

instructions, or commands and provide useful feedback. This skill is important as it helps aircraft maintainers and line personnel perform tasks effectively, avoid error and prevent accidents as well as facilitate timely dissemination of data/information and maintain group situational awareness. Known barriers include passive listening, no/poor feedback, non-standard terms and inappropriate method.

*Example* - Carrier flight deck crew moved an aircraft to be refueled. Later the sailor operating the fuel hose walked away, thinking refueling was completed the crew moved the aircraft. The attached line was ripped out and spewed fuel into the aircraft, damaging it and onto the deck, fouling it. Was there a breakdown in communication in this mishap scenario? Could communication prevent this from happening again?

*Assertiveness* - the ability, willingness, and readiness to take action: making decisions, displaying initiative and maintaining position until convinced by the facts. It is important as it encourages aircraft maintainers and line personnel to provide relevant data, raise timely issues, make suggestions, confront ambiguities, maintain position when challenged, give position on decisions and refuse inappropriate requests. Known barriers to assertiveness include rank gradient, position power, inexperience and personal coercion.

*Example* - Two maintainers in completing a maintenance task were securing a wire bundle in the nose landing gear compartment. The senior marine wanted to move part of the gear assembly and disregarded warnings to use a required jack. When the part was removed the nose landing gear immediately collapsed on the maintainer, killing him. Should the junior marine have been more assertive in this mishap scenario? Could assertiveness prevent this from happening again?

*Mission Analysis* - the ability to effectively coordinate, allocate, and monitor all crew resources, organize/plan tasks, monitor situations and provide feedback on what was done. It is important for aircraft maintainers and line personnel to develop a good plan and revise it as the situation changes to prevent mission failure or a mishap; it establishes mission requirements/constraints, specifies plans/expectations and critiques/updates existing plans. Known barriers include high operations tempo, time pressure, and personal coercion.

*Example* - Ordinanceman was tasked to retrieve additional sonobuoys by the mission commander. He drove a panel truck into the hangar by the storage locker. While backing up, he hit the nose of a nearby parked aircraft. Should the mission commander have made an analysis to determine how many personnel were required in this mishap scenario? Could mission analysis prevent this from happening again?

*Decision Making* - the ability to use logical and sound judgment based on the data/information available This ability includes: assessing the problem, verifying information, identifying solutions, anticipating consequences, explaining rationale and evaluating the situation. It is important for aircraft maintainers and line personnel to make good decisions that minimize error and optimize risk management as poor judgment is a leading cause of mission failure and mishaps. Known barriers include inaccurate and ambiguous information, pressure to perform and rank differences.

*Example* - A sailor walked into the paraloft from the line shack with a lit cigarette. Entering the room he was told to "put it out." He instantly responded by putting it in the closest thing that looked like an ashtray -the "expended" rocket motor of a salvaged ejection seat. This ignited the solid propellant residue and the seat fired, killing one and maiming another. Should the lineman have taken some time to consider the available information in making a decision in this mishap scenario? Could decision making prevent this from happening again?

*Situational Awareness* - the ability to identify the source/nature of problems, extract/interpret essential data, maintain accurate perception and detect any conditions requiring action. It is important for aircraft maintainers and line personnel to detect/appraise deviations, identify potential problems and show awareness of task status. Known barriers include insufficient communication, fatigue/stress, task over/under load, group mind-set, "press-on" attitude and degraded conditions.

*Example* - Civil servant was moving some maintenance ladders out to the flight line and drove through the hangar bay. He took great care to avoid the aircraft and drove under the tail of one to

ensure he had clearance. Unfortunately, the driver forgot that the ladders combined with the truck height were taller than bottom of the aircraft. This aircraft had to be taken off the schedule due to the damage it sustained. Should the driver have observed the situation before proceeding in this mishap scenario? Could situational awareness prevent this from happening again?

*Adaptability /Flexibility* - the ability to alter one's course of action contingent on or a function of another's action or as the situation changes. It is important for aircraft maintainers and line personnel to alter behavior to properly address the situation, remain open to other ideas, assist others, keep cool under pressure, and adapt to change; it is especially useful if unplanned events come up, emergencies arise, or the crew is shorthanded. Known barriers include confusion, lack of information, time pressure and new unfamiliar situations.

*Example* - The airframers decided to stop drill the a fatigue crack on an aircraft to keep it from propagating. The drilled crack looked "bad" and it was elected to put a plate over it. The quality assurance personnel removed the plate and seeing the crack "hard downed" the aircraft. Should the airframers have been more flexible and adapted to the situation in this mishap scenario? Could adaptability/flexibility prevent this from happening again?

*Leadership* - the ability to direct crew member activities and get them to work together as a team. It is important for aircraft maintainers and line personnel to inspire crews to work together. The leader directs, coordinates, and delegates tasks, ensures all know objectives, focuses on critical issues and is informed, gathers relevant data, gives feedback, and creates a professional atmosphere. Known barriers include micromanagement, poor interpersonal skills, inexperience, time pressure and new unfamiliar situations.

*Example* - Mechanic was sent to do a final check on an engine prior to a functional check flight. Instead of using a ladder to reach the engine compartment, the sailor elected to drive a tow tractor next to the aircraft. After completing the check he started for the hangar, but unfortunately he hit a snag, the propeller. He hoped the 4" chunk missing from the blade would not be noticed. Luckily the aircrew did a good preflight. Should the sailor have shown more leadership by owning up to the mistake? Could leadership prevent this from happening again?

**Note.** All the behavioral skills are key ingredients to developing, fostering and maintaining the crew concept for aircraft maintenance and line personnel. Further, all seven behavioral skills are intertwined and must be part of any crew activity.

### Case Examples

Here are a few Aviation Ground Mishaps from the past few years. Can you pick out the breakdown in crew concept and what behavioral skill(s) could have been used to prevent these scenarios?

| Maintainer was told to retrieve a forklift from the other side of hangar. The supervisor was not in visual contact during move and the forklift struck a parked aircraft.  
(*Mission Analysis, Decision Making, & Situational Awareness*)

| Lineman waiting for crew members started the tow tractor and inadvertently released the brakes. The vehicle jumped forward and struck a parked aircraft.  
(*Decision Making, Adaptability/Flexibility, & Leadership*)

| Checker's view of crew position on the flight deck was obscured by catapult steam. During aircraft spotting a member's ankle was pinned by a main gear.  
(*Communication, Situational Awareness, & Adaptability/Flexibility*)

| Tow director pushing back an aircraft did not maintain proper clearance and the wingwalker did not signal to stop move. The towed aircraft struck a parked one.  
(*Communication, Assertiveness, & Situational Awareness*)

| Maintainer, without supervision, loosened aircraft jacks for removal. The loosened side slipped, the aircraft shifted, and it rolled onto its side.

*(Mission Analysis, Decision Making, & Situational Awareness)*

1 Fuel truck was en route to transient line. Driver moved out to negotiate around a parked aircraft and stuck another waiting for clearance.

*(Mission Analysis, Situational Awareness, & Adaptability/Flexibility)*

**Note.** Clearly there is more than one behavioral skill involved in each of these cases.

## SUMMARY AND CONCLUSION

Despite GCT being develop in "isolation," without knowledge of Continental's CCC program, it is clear that the two efforts parallel each other and emphasize the development and nurturing of the same team building behaviors and skills. As the GCT program evolves, complimentary features of the CCC program will be incorporated and lessons learned followed. Currently, the GCT brief is highly requested by the Fleet and has been given to over 50 active and reserve operational squadrons and maintenance units. Generally, aircraft maintainers and line personnel, ranging from fairly junior airmen to mustang maintenance officers, see the merits of this initiative and want more. The full course will be completed later this spring, and after formal review, made available throughout the Fleet. Finally, there is an ongoing analysis of all Aviation Ground Mishaps and Personnel Injury Reports for the past ten years to assess the magnitude of the crew coordination problem and its associated costs. The results will be used to develop metrics, similar to those used by Continental Airlines, to determine the effectiveness of this new program.

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## APPENDIX



**Figure 7-1** Class A Flight Mishap Rate

# Electronic Ergonomic Audit System for Maintenance and Inspection

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This paper describes an ergonomic auditing software system, one of the tools used for performance enhancement of aircraft inspectors. This tool was developed at Galaxy Scientific Corporation, in cooperation with the State University of New York at Buffalo, for the Federal Aviation Administration (FAA), Office of Aviation Medicine (AAM). The purpose of the development task was to integrate a variety of ergonomic audit tools into a comprehensive package. This ergonomic auditing system called "ERgoNomic Audit Program" (or ERNAP), carries out an ergonomic evaluation for maintenance and inspection operations. The package consists of a user interface, an expert system, a help module, a printing module, and a reference database. The user interface supports user learning, helps guide the user through the steps, describes the less familiar ergonomic principles, allows the user to access on-line help and is simple to use. The expert system evaluates the user inputs based on the reference database and different models of analysis. This package maintains consistency with the *Human Factors Guide for Aviation Maintenance* which is on demonstration during this session.

## INTRODUCTION

The purpose of this development effort was to integrate a variety of ergonomic audit tools that were developed at different universities into a comprehensive software package. The ERgoNomic Audit Program (ERNAP), developed by Galaxy Scientific Corporation, in cooperation with State University of New York at Buffalo, for the Federal Aviation Administration Office of Aviation Medicine, carries out an evaluation audit for maintenance and inspection operations. ERNAP can also be used to guide designers to build ergonomically efficient procedures and systems. ERNAP is simple to use, and it evaluates existing and proposed tasks and setups in the application of Ergonomic principles and suggests ergonomic interventions.

## THE AUDIT PROGRAM

From detailed task descriptions and task analyses of inspection activities, [Drury, Prabhu and Gramopadhye](#) (1990) developed a generic function description which has been used in this audit program. An audit program involves data collection, data analysis, data storage and results presentation. Data can be collected through a series of observations and readings. This collected data can then be analyzed based on guidelines and standards. The analysis is then presented to the user in a suitable/useful format. All the data collected, the data analyses and its results can be saved for later reference if necessary. This entire process can be made using either a manual method or using a computer-based method.

[Meghashyam](#) (1995) does a comparison of manual and computer-based methods of ergonomic analyses in which the computer-based method is found to be superior in performance. [Pusey](#) (1994) does a comparison of ergonomic audits for carpal tunnel syndrome and comes to a similar conclusion. In practice, a combination of both methods is preferred due to hardware constraints.

## Structure of the System

ERNAP was built based on checklists ([Drury, 1994](#)). This program is designed to be run on any IBM/PC with at least an INTEL 486 processor, 4 MB of RAM, DOS 5.0 and Windows 3.1. The program itself occupies 5 MB of hard disk space. ERNAP consists of a data collection module, a file handling module, an expert system module, a printing module, and a help module.

### 1. Data collection module.

The data can be collected directly by using a portable computer, or by using the paper form of the checklists. Data is collected based on the checklists and is classified into three phases:

	Pre-maintenance
	Maintenance
	Post-maintenance.

These modules are also grouped in a classification scheme using four major groupings, following [Prabhu and Drury](#) (1992) and [Latorella and Drury](#) (1992). ([Table 8-1, appendix](#)) shows a clear classification of the data collection modules. As shown in ([Table 8-1, appendix](#)), the Data Collection Module consists of twenty-three checklists. A brief description of each checklist is given below.

#### A. Pre-Maintenance Phase

*Documentation:* Concerns itself with information readability, information content, i.e., text & graphics and information organization.

*Communication:* Between-shift communication and availability of lead mechanics/supervisors for questions and concerns.

*Visual Characteristics:* Overall lighting characteristics of the hanger, i.e., overhead lighting, condition of overhead lighting, and glare from the daylight.

*Electrical/pneumatic equipment issues:* Evaluation of the equipment which uses controls, i.e., ease of control, intuitiveness of controls, and labeling of controls for consistency and readability.

*Access Equipment:* Evaluation of ladders and scaffold for safety, availability and reliability.

#### B. Maintenance Phase

*Documentation:* Physical handling of documents and the environmental conditions effecting their readability, i.e., weather and light.

*Communication:* Communication issues between coworkers and supervisors, and whether or not suggestions by mechanics are taken into consideration.

*Task lighting:* The overall lighting available to the mechanic for completing the task. Evaluates the points such as light levels, whether personal or portable lighting is used, and whether the lighting equipment is causing interference with the work task.

*Thermal issues:* The current conditions of thermals in the environment in which the task is being performed.

*Operator perception:* Operator perceptions of the work environment at present, during summer and during winter.

*Auditory issues:* Determine if the sound levels in the current work environment will cause hearing loss or interfere with tasks or speech.

*Electric and pneumatic issues:* The availability of any electrical/pneumatic equipment, whether the equipment is working or not, and ease of using the equipment in the work environment.

*Access equipment:* Availability of ladders and scaffolds, whether the equipment is working or not, and ease of using the equipment in the work environment.

*Handtools:* Evaluates the use of hand tools, whether or not the hand tools are designed properly to prevent fatigue and injury, and usability by both left- and right-handed people.

*Force requirements:* Forces exerted by the mechanic while completing a maintenance task. Posture, hand positioning and time duration are all accounted for.

*Manual Material Handling:* Uses [NIOSH](#) 1991 equation to determine if the mechanic is handling loads over the recommended lifting weight.

*Vibration:* Amount of vibration a mechanic encounters for the duration of the task. Determines if there are possible detrimental effects to the mechanic because of the exposure.

*Repetitive motion:* The number and frequency of limb angles deviating from neutral while performing the task. Takes into consideration arm, wrist, shoulder, neck and back positioning.

*Access:* Access to the work environment; whether it is difficult or dangerous, or if there is conflict with other work being performed at the same time.

*Posture:* Evaluates different whole-body postures the mechanic must assume in order to perform the given task.

*Safety:* Examines the safety of the work environment and what the mechanic is doing to make it safer, e.g., meaning of personal protective devices.

*Hazardous material:* Lists the types of chemicals involved in the maintenance process, whether or not the chemicals are being used properly, if disposal guidelines are being followed, and if the company is following current EPA requirements for hazardous material safety equipment.

### C. Post-Maintenance Phase

*Buy-back:* Usefulness of feedback information to the mechanic and whether or not buy-back is from the same individual who assigned the work.

By using separate modules, ERNAP allows the users to make specific or comprehensive audits.

#### *2. File handling module.*

This module consists of a database which stores all the relevant information about the audit, such as the modules selected for audit, the information entered into these modules, audit description, etc.

#### *3. Expert system module.*

This module analyzes all the information entered by the user and is based on a rule-based expert system, CLIPS. After analysis, this module presents the analysis and suggestions in a suitable format.

#### *4. Printing module.*

This module caters to the printing requirements. The user can either print the modules themselves or the analyses.

#### *5. Help module.*

This module provides an on-line help to the user. Hot words on the checklists are linked to the help topics within the help module. The help module can also be referred to in its entirety. A glossary of terms is also provided to help the users better understand the terminology.

## Description of the System

On starting ERNAP, the first screen comes up showing information about ERNAP. Following this the next screen comes up as shown in ([Figure 8-1, appendix](#)). The user has the option to either select begin a "New" or "Open" an existing Audit. Selecting "Cancel" shall bring the user to the main screen of ERNAP as shown in ([Figure 8-2, appendix](#)). ERNAP then waits on the user to either begin a "New" ergonomic audit or "Open" a saved ergonomic audit. By selecting "Open", the user can revisit earlier audits. Selecting "Begin a New Evaluation" starts a completely new ergonomic audit and selecting "Open an Existing Audit" starts a previously conducted audit.

These options are available to the user in the "pull-down" menus. Selecting either of these (Open or New), shows the different modules of ergonomic evaluation. The user at this point can select any or all of the ergonomic audits. This can be done by selecting the check boxes provided against each audit, as shown in ([Figure 8-3, appendix](#)).

ERNAP will step through only those modules that are selected by the user, thus allowing a partial audit. Once the user has started the audits, ERNAP starts with the first module and presents the user with specific questions related to the operation being audited. ([Figure 8-4, appendix](#)) shows an example. ERNAP uses a simple user interface for the input of information related to the operation under audit. The user interface has been developed based on the principles of human-computer interaction.

The user can either use a "mouse" to make the selections or use the "tab" key in combination with the "enter" key on the keyboard. On each module, help is provided to the user on the terminology used in the questions asked by ERNAP. Clicking the mouse on the hot words brings up more information about that section of the audit. The user can also get general help from the "Help" section of the "pull down menu". This provides information about ERNAP, its developers, and other relevant information. Furthermore, help on the menu item selected is shown in a status box towards the bottom of ERNAP main screen. The user can also directly go to the required audit by selecting the audit module from the "pull down menu". The index tabs help the user move to different sections within each module. The user can exit from ERNAP by selecting the "exit ERNAP" option in the pull down menu. After the user completes all the audits that were selected earlier, the expert system CLIPS, analyzes this information and compares it with the standards database. Based on its analysis, it provides the user with suggestions. The analysis is based on existing models developed by researchers, the National Institute of Occupational Safety Hazards and the Occupational Safety and Health Administration. This information about its findings and its suggestions is presented to the user, as shown in ([Figure 8-5, appendix](#)).

The Expert System module helps update the database, based on new research. Specific information is provided to the user about the operations that were under audit. ERNAP shows the results of the audit to the user when requested. ERNAP also saves this information in a file. This information from the file can also be printed by selecting "print audit" from the pull down menu.

## INSTALLATION AND SYSTEM REQUIREMENTS

ERNAP requires a IBM-PC compatible - 486 with SVGA monitor running MS Windows 3.1 and having at least 4MB RAM. However, it is recommended to have 8MB RAM. It has been designed to run in the 640 x 480 resolution, but can adapt to the 1024 x 780 resolution. ERNAP can be installed from the CD-ROM by either double clicking the "setup.exe" under the ERNAP directory, or by running "setup.exe" directly from the File manager (or Program Manager) from within the windows

environment.

## DISTRIBUTION

ERNAP shall be available with the CD-ROM for E-Guide, the *Human Factors Guide for Aviation Maintenance*.

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## APPENDIX



**Figure 8-1:** Begin a "New" or "Open" an Existing Document



**Figure 8-2:** Main ERNAP Screen



**Figure 8-3:** Sample Module of Ergonomic Evaluation



**Figure 8-4:** Example Questions



**Figure 8-5:** ERNAP Analysis

**Table 8-1:** Classification of Modules in ERNAP

Human Factors Grouping	Pre-Maintenance Phase	Maintenance Phase	Post-Maintenance Phase
Information Requirements	1. Documentation	6. Documentation	23. Buy-back
Environment	2. Communication	7. Communication	
	3. Visual Characteristics	8. Task Lighting	
	9. Thermal Characteristics		
	10. Thermal Perception		
	11. Auditory Characteristics		
Equipment/Job Aids	4. Equipment Design	12. Equipment Availability	
	5. Access Equipment	13. Access Availability	
Physical Activity/Workspace	14. Hand Tools		
	15. Force Exertion		
	16. Manual Materials Handling		
	17. Vibration		
	18. Repetitive Motion		
	19. Physical Access		
	20. Posture		
	21. Safety		
	22. Hazardous Materials		

# Use of the Maintenance Error Decision Aid (MEDA) to Enhance Safety and Reliability and Reduce Costs in the Commercial Aviation Industry

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## INTRODUCTION

Cost competition in the commercial aviation industry has increased greatly in the past few years putting the squeeze on air carrier profitability. In order to reduce costs, Engineering and Maintenance organizations are being challenged to improve maintenance efficiency to reduce costs while maintaining or increasing safety and reliability standards. One method for helping achieve these goals is a structured maintenance error investigation process to reduce human errors that have costly outcomes, e.g., air turnbacks, gate returns, and flight cancellations ([Allen and Rankin](#), 1995a).

Major interest in the scientific study of human error began following the Three Mile Island (TMI) nuclear power plant accident in the USA in the spring of 1979. According to [Woods et al.](#) (1995), the cross-disciplinary national and international scrutiny of human error began with the "clambake" conference on human error in Columbia Falls, Maine, in 1980 and with the publications on slips and lapses by [Norman](#) (1981) and [Reason and Mycielska](#) (1982). In addition, work in the area of human reliability, for example, by [Swain and Guttman](#) (1983) and [Swain](#) (1987), began in the late 1970s and accelerated following TMI (see [Gertman and Blackman](#), 1994).

More recently, there has been an interest in studying human error in airline maintenance. For example, the United Kingdom Civil Aviation Authority ([UK CAA](#), 1992) released a study on the top eight maintenance problems affecting aircraft over 5,700 kg. in weight. More recently, the relationship of pilot crew error and maintenance crew error to commercial aircraft accidents has been evaluated (see [Boeing](#), 1993; 1995). For purposes of studying maintenance human error, maintenance error is defined as the action or inaction of an aircraft maintenance technician that leads to an unexpected aircraft discrepancy (physical degradation or failure) ([Graeber and Marx](#), 1993).

The [UK CAA](#) (1992) study found the major types of maintenance error included:

1. Incorrect installation of components
2. The fitting of wrong parts
3. Electrical wiring discrepancies
4. Loose objects (tools, etc.) left in the aircraft
5. Inadequate lubrication
6. Cowlings, access panels, and fairings not secured
7. Fuel/oil caps and refuel panels not secured
8. Landing gear ground lock pins not removed before departure

A more recent [Boeing](#) study (1995) found that 15% (39 of 264) of commercial aviation accidents

from 1982 through 1991 had maintenance as a contributing factor. More specifically, 23% of the 39 accidents had removal/installation as a contributing factor, 28% had the manufacturer or vendor maintenance or inspection program as a contributing factor, 49% had the airline maintenance or inspection program policy as a contributing factor, and 49% had design as a contributing factor. Other important contributing factors included: manufacturer/vendor service bulletins and in-service communication (21%), airline service bulletin incorporation (21%), and missed discrepancy (15%).

Even if everyone agrees that intentional malevolent behavior should not be included in the study of human error, the phrase "human error" still carries negative connotations - connotations that can hinder the in-depth study of the causes of error and error management (e.g., [Woods et al.](#), 1995; [Reason](#), 1990; [Lorenzo](#), 1990). This is because most people attribute the causes of human error to the person rather than to the environment. [Reason](#) (1990) discusses this phenomenon as the "blame cycle." He believes that we attribute blame to people and not situations because of the Western culture's illusion of free will and the ability to determine one's own destiny. We can break out of the blame cycle only if we:

- | Recognize that human performance is shaped by the situation or environment
- | Recognize that errors have multiple contributing factors
- | Recognize that situations are often more easy to change than people.

[Woods et al.](#) (1995) are also concerned about the prejudicial effect that comes from labeling a cause of an accident as human error. One reason is that saying that an accident was due to human error is often seen as the causal explanation for the accident. It can restrict the true investigation that should occur, which is to determine what the interaction was between the person, the equipment, and other situational variables that lead to the error.

These situational variables that contribute to the error have also received much investigation, especially by those working in the Human Reliability Assessment (HRA) and Probabilistic Risk Assessment (PRA) field. [Swain and Guttman](#) (1983) have an in-depth list of these variables, which they call performance shaping factors (PSFs). They distinguish among these types of PSFs. External PSFs include situational characteristics (e.g., heat, lighting, supervision, and shift rotation), job and task instructions (e.g., procedures and shop practices), and task and equipment characteristics (e.g., task complexity and human machine interface issues). Examples of internal PSFs include previous training/experience, intelligence, and motivation. Stressor PSFs include psychological stressors (e.g., task speed, monotony, and distraction) and physiological stressors (e.g., fatigue, pain, and disruption of circadian rhythm).

The important thing about PSFs within the HRA/PRA framework is that they are seen as contributing to the cause of the human error. Thus, the concept of PSFs can be used to help break the blame cycle. An obvious second important aspect of PSFs is that they help indicate where changes are needed to reduce human error. Swain has estimated (see [Lorenzo](#), 1990) that only 15-20% of workplace errors are caused by internal PSFs, while the remaining 80-85% are primarily caused by external PSFs and stressor PSFs, many of which are directly under management control.

Thus, it is not surprising that the concept of PSFs or contributing factors is used as a basis for error reduction programs. For instance, [Lorenzo](#) (1990) lists the [Swain and Guttman](#) (1983) PSFs, and then discusses many of them point-by-point as to how to enhance a PSF in order to minimize human error in the chemical industry. As another example, [McDonald and White](#) ([McDonald](#), 1995; [White](#), 1995a; [White](#), 1995b) looked at the PSFs that lead to airport ramp accidents/incidents and developed a ramp safety program based on changes to these PSFs.

As noted earlier, the study of human error in aircraft maintenance is still in its infancy. Data now exists ([Figure 9-1](#) and [9-2](#), appendix) to show that maintenance error is a contributing factor in aircraft accidents/incidents. There are also some data to indicate what types of errors are occurring. However, what is now needed with regard to maintenance human error is to collect empirical data on the types of errors that are occurring, their consequences, the PSFs that contribute to that error, and intervention strategies for preventing future errors attributable to the same PSFs. That is the purpose

of the Maintenance Error Decision Aid (MEDA).

## THE MAINTENANCE ERROR DECISION AID TOOL

MEDA was developed over a two-year period by a team of airline representatives, regulators, and Boeing maintenance human factors personnel. The objectives of MEDA are to:

- | Provide a better understanding of how performance shaping factors contribute to maintenance error
- | Provide maintenance organizations with a standardized methodology for analyzing maintenance error, its causes, and intervention strategies
- | Provide a means of error trend analysis for the commercial airline maintenance organizations.

The MEDA tool consists of the Results Form (a paper tool used in the error investigation), a User's Guide to facilitate the investigation process, and Supplemental Assessment Information to facilitate the use of the Results Form. The Results Form consists of five major sections:

1. General
2. [Events](#)
3. [Maintenance Error](#)
4. [Contributing Factors](#)
5. Corrective Actions

The General section asks for information about the aircraft, the airline, the analyst, and where and when the incident occurred. The Event section asks for the type of *event* that triggered the MEDA investigations. Events include flight delay, flight cancellation, gate return, in-flight shut down, air-turn-back, aircraft damage, injury, diversion, and rework. The Maintenance Error sections asks the investigator to check the one type of maintenance error that caused the incident. The major categories of error include improper installation, improper servicing, improper/incomplete repair, improper fault isolation/inspection/testing, foreign object damage, surrounding equipment damage, and personal injury.

The Contributing Factors section is used to help guide the analyst in thinking about what performance shaping factors affected technician performance resulting in a maintenance error. There are ten major categories of contributing factors, and each category has several examples in checklist format. The major categories include: information, equipment/tools/parts, airplane design/configuration, job/task, technical knowledge/skills, factors affecting individual performance, environment/facilities, organizational environment issues, leadership/supervision, and communication issues.

The Corrective Actions section includes three sub-sections. The first sub-section asks whether existing maintenance procedures, inspection or functional checks, maintenance documentation, supporting documentation, or company maintenance policies were intended to prevent the error but didn't, and how this could be resolved. The second and third sub-sections ask, respectively, for local corrective actions and other corrective actions that can be taken.

## FIELD TEST EVALUATION

In order to evaluate the MEDA tool and process before beginning implementation at customer airlines, eight domestic and international air carriers and one repair station agreed to participate in a Field Test ([Figure 9-3, appendix](#)). The Field Test training and evaluation were carried out under

FAA contract over a period of eight months from November, 1994, to July, 1995 (see [Allen and Rankin](#), 1995b). Employees from these organizations were trained to use the MEDA process in a 3 to 8 hour training session, which included a case study exercise.

Three methods were used to collect Field Test evaluation data. First, five questionnaires were filled out by participating personnel regarding work environment, causes of maintenance error, and perception of error investigations. Second, the nine participating organizations used the MEDA Results Forms to investigate maintenance error event occurrences. Seventy-four completed Results Forms were sent to Boeing for analysis during the data collection period. In addition to quantitative analysis, data from completed Results Forms were analyzed to determine whether the forms were being filled out logically and consistently. Third, meetings were held mid-point through the Field Test and approximately six weeks after the end of the Field Test to get feedback from representatives of the participating organizations.

The Field Test found a wide variation in the manner in which MEDA was implemented in the participating organizations. Two of the organizations never fully implemented MEDA. The others implemented MEDA in various ways regarding which maintenance organization carried out the investigations, what types of events triggered an error investigation, and how corrective actions were implemented.

The evaluation surveys found that respondents generally agreed that the MEDA Results Form helped them with their error investigation and that it was easy to use. A large majority of the respondents believed that MEDA will have a positive impact on their maintenance organization, although they are much less certain that MEDA will reduce punishment for making errors or that MEDA will cause new corrective actions to be taken. The experience of the erring technician in the error investigation was positive. They did not feel intimidated during the investigation, they felt that the purpose and philosophy of the process was made clear to them, and they believed that MEDA would improve their work environment. However, they were not certain whether corrective actions would be taken. Managers agreed fully with the MEDA philosophy, understood how MEDA was being implemented at their airline, felt that there was strong acceptance of MEDA by airline management and technicians alike, strongly supported MEDA themselves, and felt that it was important for other airlines to adopt MEDA and to share MEDA data.

Seventy-four completed Results Forms were sent to the Boeing team members for analysis.

([Figure 9-4, appendix](#)) graphs the operational events that triggered the MEDA investigations. Flight delays (22), aircraft damage (17), and air turn backs (11) were the major triggering events. The 11 "other" events included workshop errors, vendor problems, and a few events that probably could have been described by the existing event types in the Results Form but were coded "other" by the investigators.

([Figure 9-5, appendix](#)) graphs the types of maintenance errors that caused the event. Improper installation (26 errors) was, by far, the major error type, which was followed distantly by improper fault isolation/inspection/testing (11 errors), and improper servicing (9 errors). Of the 17 "other" maintenance errors, eight were related to errors that caused ground damage.

([Figure 9-6, appendix](#)) graphs the factors that contributed to the errors. There was an average of 3.2 major categories of contributing factors selected per Results Form. Information was a contributing factor in 50% of the investigations, followed closely by communications (43%), job/task (42%), environment/facilities (38%), factors affecting individual performance (35%), qualification/skills (31%), airplane design/configuration (30%), equipment/tools/parts (27%), organizational environment (26%), and supervision (16%). It is interesting to compare these empirical data with the survey opinions of the managers and investigators concerning which of these factors was most likely to contribute to error. The managers and investigators correctly believed that information and communication were high in importance. However, they greatly overestimated the importance of supervision and qualification/skills, and they underestimated the importance of environment/facilities and factors affecting individual performance.

Two meetings were held during and immediately after the Field Test to get suggestions for improvement from the participating organizations. A major recommendation, regarding the presentations/training needed for implementation at other airlines, was that three separate presentation/training packages be developed: a senior management presentation, and investigator training package, and a maintenance team briefing.

## CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the Field Test evaluation determined that the MEDA objectives were met. The MEDA tool and investigation process did provide an easy-to-use standardized investigation methodology to airline maintenance organizations. However, it took the participating airlines longer to implement MEDA than first anticipated. Determining the events that will trigger a MEDA investigation, assigning MEDA administrative responsibility to an organization, selecting and training MEDA investigators, and (especially) setting up a corrective action process and feedback mechanism were time consuming and were impacted by the organizational climate.

The MEDA tool also helped uncover maintenance system deficiencies. All of the participating airlines had successfully solved maintenance error problems using MEDA.

Finally, the educational process that was used for implementation did provide maintenance personnel with a better understanding of how human performance is influenced by local and organizational factors. Trend analyses were begun by the participating airlines, although additional data are needed for these analyses to be more useful.

Several recommendations resulted from the Field Test. Air carriers should continue to promote the use of event-driven analysis tools to foster error management within their organizations. MEDA Field Test participants should continue to use the MEDA tool in its present or customized form. Industry should also continue to develop modular human factors-based training programs (modeling successful CRM concepts) to complement the use of technology-enhanced, event-driven analysis tools and to promote organizational recognition of error producing factors and the importance of team work in error management.

Issues that inhibit maintenance error reporting and analysis within individual organizations and industry-wide must be addressed by the individual organizations, where applicable, and within industry by its governing bodies. These issues include, but are not limited to:

- | A uniformly accepted limited immunity policy governing technician participation in these event reporting programs, consistent with the standard established for similar flight operations programs

- | Definition of an acceptable standard of organizational disciplinary action to complement a limited immunity policy and the use of event-driven analysis tools.

Also, Boeing should develop three presentation/training packages for future MEDA implementation: the first to present the concept to senior management to gain their support and to lay out the organizational model required to implement MEDA successfully; the second to train the selected MEDA investigators; and the third to present the MEDA process to the maintenance technicians and their management to allay fears regarding punitive actions, to inform them about how the investigation process is carried out, and to discuss the benefits of MEDA.

Boeing is now making the MEDA tool available to customer airlines to help them improve their maintenance operations and as a means to more efficiently communicate with Boeing about events that have design or manufacturing as a contributing factor. The Boeing Maintenance and Ground Operations Systems (MGOS) group within Customer Services Division will assist customer airlines with training and implementation of the MEDA process. Air carriers interested in MEDA may contact MGOS through their Boeing Field Service Representative.

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## APPENDIX



**Figure 9-1:** Airlines with 500,000 - 1 Million Engine Hours



**Figure 9-2:** Airlines with over 1 Million Engine Hours



**Figure 9-3:** Field Test Participants



**Figure 9-4:** Operational Events



**Figure 9-5:** Maintenance Error Types



**Figure 9-6:** Contributing Factors

# Maintenance Resource Management Update at Continental

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## INTRODUCTION

One of the things that is apparent to me is that as you start to implement maintenance resource management within the organization, you've got to be very perceptive about where you look for the benefits of the program. Sometimes, the benefits don't always show up in operational measures and other statistics on which we all like to focus. A good example of this is that for years I am sure most major carriers have had what we commonly refer to as "our morning delay meeting," where everybody in maintenance gets together, hashes through the yesterday's operation and begins to focus on what we are going to do today to fix what happened yesterday.

I've sat through our delay meetings for years and, as is probably the case in many carriers, if you really sat through and looked at the delay meetings, they are not really conducted the way a meeting should be to get things fixed. They are usually pretty negative, focusing in on what happened yesterday, who was to blame, who was at fault, why do we have this delay, these delays weren't our's they were somebody else's. It's really a lot of haggling back and forth and usually not very positive. But look at the meetings from another perspective; go back and really focus on delay meetings held about a year ago. You'll see that it's kind of like watching a clock. If you sit there and watch it for long enough you really can't tell that it is changing, but if you step away for a while and then you come back you realize the amazing amount of difference. The delay meetings that we have today are radically different from the past from the standpoint of the change in focus. Although we still talk about what happened yesterday, the primary focus is corrective action for today and tomorrow.

A good case in point happened just last week to George Mason, our VP in maintenance. We had a really bad delay out of LA, an international flight, which required an engine change. This was a six-hour delay, and we all know the importance of international flights. George asked a very simple question: "What happened?" In the past that type of question from the VP of maintenance would have caused all kinds of wailing and gnashing of teeth, cover up and excuses, but in this instance that didn't happen. The supervisor happened to be on the call; he specifically said what had happened. The inspection revealed that an engine change needed to happen and the supervisor admitted on the call in front of tons of people that they just screwed up; they didn't have an engine ready. Rather than castigating the supervisor publicly, the general response was: "O.K. what do we need to do to fix it, so that it doesn't happen again? What do we need to do in terms of focusing our operation to make sure that we have got an engine prepared, standing by ready, or whatever we need to do in terms of contingency plans to make sure that it won't happen again."

George Mason didn't shy away from the fact that he really needed to know what happened, because someone above him was going to be calling about the delay on an international flight, but it was a completely different tone, a completely different way of focusing on exactly the same problems in terms of being more proactive. Everyone who was involved in that delay really felt much more comfortable. The consensus of opinion was that here is an organization that supports me and we are really focusing on what we can do to fix it so that it doesn't happen again, as opposed to focusing on the negative side of the situation. This was a totally different tone, different way of problem-solving.

I really want to focus on three things today. I want to give all of you a program update on what's happened from 1991 through 1996 to maintenance resource management at Continental Airlines. I am going to speak briefly on some operational performance indicators -- what we have done and

how we have seen our operational performance have been impacted by this program. Then I want to spend a couple of minutes on lessons we learned. I am a firm believer in being able to share with you information we have learned from our program. There are some things that I have learned over the years, instances where we could have done a little bit better, and if we could have done a little bit better, I want to be able to share that with you. I heard yesterday that many of you are beginning to embark upon similar programs. Frankly, if there are some things that you can take out of this that will help you avoid the mistakes we made earlier in our program, I want to share those with you. These are the topics we are going to go over -- Program Updates, Operational Performance and Lessons Learned.

## PROGRAM UPDATES

First -- Program updates. We changed the name of our program from CCC to MRM -- Maintenance Resource Management -- kind of an update to freshen it a little bit. It's from past proceedings. It's a two-day program focused primarily on awareness and built around case studies. We use, for example, as our intro the famous incident in Portland. We study as examples of maintenance mishaps the Eastern Airlines 855 and a couple of rather significant ground mishaps that happened within Continental Airlines. Both of them happened in Guam. One was two DC 10s that decided to try to get too close to one another. The wing tip of one sheared off literally everything from the nose up to the forward pressure bulk head of the other DC 10. Another incident was a towing mishap we had where we put a DC 10 on top of a house, in navy housing, which was a rather significant event to say the least. Phase 2 of MRM is a one-day program. We focus on conflict resolutions and the case study we use is the Continental Express Eagle Lake accident which, if any of you have read the NTSB report, is chock full of good information on how maintenance operates within the environment

Some background on the program. In June 1991 we implemented the program. We focused primarily on management supervisors within the line operation. You will hear me speak more about that in terms of our lessons learned. We started some operational attitude performance measurement. That really started in May 1991; just prior to that was a base line survey that Bill alluded to earlier. Actually Jim Taylor and Michelle Robertson assisted with that -- doing a base line survey, and actually tracking operational performance measures. We looked at 14 to 15 different operational performance measures on a monthly basis at the station or departmental level. Now we have five to six years worth of data for all those and correlated back to attitudes.

Back to the point I made about management; in 1991 when we started, the sponsor of the program said we had to include everybody. That meant VPs on down; no one was excluded. It's 100% participation -- everyone's got to go. In those programs we had everyone from the Vice President Maintenance through the VP engineering, all actually sitting through the program. This was a tremendous benefit and really sent a strong managed message to the other members of the work force that management was committed to this program. If management can take two days out of their busy schedules to attend, it sends a very strong message. I would highly encourage this kind of participation if you plan to implement a similar program.

In 1992 and in 1993 we expanded the population to include lead technicians and inspectors. It was our intent from the inception of the program to ultimately include everyone within the maintenance workforce and any one who was peripheral to that work force as well -- people in materials and purchasing, financial people. Basically, anyone who had a connection to the maintenance operation should participate in this training. However, we kind of triaged it and moved downward from management to leads and supervisors, and later on we got to the technicians.

One of the things we found when we got to this is that you get some very interesting case studies that come right out of the workshop. These become excellent food for thought in terms of providing additional information. For example, I was facilitating one workshop and a lead says that his work group got into the discussion of norms. In these discussions you always ask "Has anything ever

happened; have you been subjected to this and had something bad happened?" We finally had one lead raise his hand. This is the power of this type of training -- when people within the group volunteer information and relate their own war stories, it has a tremendous impact on the entire group. As I said, one lead technician raised his hand and said that several years ago it was a norm within their operation on DC 10s rather than changing a slide to just change the bottle on the slide while it was aboard the aircraft. He says there were three of them on a DC 10 about to leave on an international flight and they were supposed to change the slide. They didn't have to change the slide so they figured how to get the case open and just change the bottle. They got the old bottle off; they got the new bottle on. They did something wrong. They still don't know what they did wrong, but guess what happened -- pop the slide, slide began to inflate in the cabin of the forward galley of the DC 10 15 minutes prior to departure. So there are three technicians pulling out their pocket knives trying to stab at the slide while first class passengers are boarding the aircraft. One of them is pinned up against the other bulk head saying: "Get me out of here." These type of stories are tremendous in terms of the effect that they can have on a class and then are shared elsewhere within the organization. You will hear some really humorous things as you move along this path.

In 1994, we opened the course up and included all of our technicians. We also made the course available to our compatriots at Continental Express. We began an MRM for management, the one-day course I spoke of earlier. Prior to July of 1994 here at Continental Airlines we were really focusing on re-engineering -- what we can do to improve the operation, improve our cost structure. Actually in July 1994 we began to implement many of the decisions that we had been researching for the six to eight months prior to that. Let me touch on that briefly in a moment because I think it has a significant impact on how we proceeded.

## OPERATIONAL PERFORMANCE

In 1995 many of the major things we did in re-engineering were completed. We implemented the MEDA process that you heard about yesterday from Jerry Allen. In fact, all ground mishaps attributed to maintenance were investigated during 1995 using the MEDA process. In July of 1995, we suspended our workshops on MRM 1 & 2 primarily because of the turmoil resulting from the re-engineering effort. I'll also touch on that in a moment. We also began a research project with Drs. Endsley and Robertson, who you will hear from shortly, on researching team situation awareness and how that's going to merge with our existing awareness programs. Let me talk about the impact on operational performance for a moment. I am actually going to cover these in reverse order. I am going to cover re-engineering first, and then maintenance mishaps.

If you can imagine for a moment, think of your own operation, think of how you do business today, and focus on your operation. Try to put yourself in this frame of mind. Imagine within your own airline today, or within your own operation, that within a span of a year, while operating under bankruptcy, you are going to cut your hourly work force by 50%. You are going to cut your management work force by 50%. You are going to rewrite your entire maintenance program on all your fleets. You are going to outsource 90% of all your heavy maintenance. You are going to outsource some of your line maintenance, but not too much, about 10%. You are going to outsource your component maintenance. You are going to shut down obviously two or your three major maintenance bases. You are going to move all those people and centralize them in one spot. That, by the way, will cut off 50% all at the same time and do that within a six-month window.

What do you think is going to happen to the operational performance of your airline? To dispatch reliability? To on-time performance? In reality that didn't happen. I personally think that one of the reasons that didn't happen was because of the maintenance resource management program that we had implemented early in 1991. We prepared the workforce and had created a sense of awareness within the workforce regarding communication, decision making, assertiveness. When these rather dramatic changes occurred within the workforce, we had people within the workforce who said, at the appropriate time wait, stop, this is unsafe we need to do this, or we need to do this differently. It really created an environment that, I think, allowed us to get through the rather radical changes that

we went through in 1994 and 1995.

This is what we did. We outsourced practically everything. In June/July 1994, we shut down our Denver maintenance space -- seven heavy check lines. We didn't take a long time to do it. It happened in 30 days -- here today, gone tomorrow. On November 6, 1994 we did the same thing in LA, and then had to try to regroup and get everything taken care of. We consolidated all of our support departments out of LA and Denver into Houston. We rewrote our entire maintenance program just prior the consolidation. ([Figure 10-1, appendix](#)) shows what happened on maintenance mishaps during that same period. The blue represent the number of mishaps that we had. These are ground mishaps related directly to maintenance by year. The yellow line is the trend. For example, in 1995 we had 27 ground mishaps. We keep track of everything. A ground mishap is anything from a technician running a ladder into an airplane to anything else that may happen. Obviously we had a spike in 1994. For 1991, 1992, 1993, we were on a good downward trend. We had a spike in 1994 primarily attributed to a lot of internal turmoil. But in 1995 we recovered and we were right back where we were supposed to be.

Dollar figure wise, if you take out the Guam incidents, which were rather spectacular, and throw out the high ones, we were averaging over this five-year period about a million dollars in damage to our aircraft from ground mishaps, damage attributed directly to maintenance. The 1995 number is actually four hundred and sixteen thousand dollars; we are about a half a million dollars below our five-year average, a rather significant improvement. To date in the last two months of 1995, we have had only two mishaps. We had one on November 1st; we didn't have another one until December 8th. Of course, I have been here for the last 24 hours, but as of now we haven't had one since December 8th. We are rapidly approaching the point where we are going to be able to say that we can go a month or two without having a mishap. This is really significant because, as many of you know, the two most expensive ways to have a mishap are to have a pilot in the cockpit or a mechanic in the cockpit. Usually they are involved in moving an aircraft and when they are involved in moving an aircraft you can do some rather dramatic things to all that metal out there -- these are the two guys who can damage an aircraft rather tremendously.

[Figure 2](#) shows our MELs from 1992 through very recently and into 1996. I would like to point out that, although it tracks fairly well, this peak in 1995 was the result of the LA base shut down, the Denver base shut down a few months prior to that. Obviously, when you shut down a major facility in the middle of a holiday period and try to outsource all these components and the work, you are going to have a spike. But as you can see, we dramatically recovered in February/March and April. We had another spike in the June/July time frame primarily due to some discussions management was having with the pilots relating to their contract. Those discussions were resolved. And, as you can see, now we are down consistently below a 100 on a fleet of 320 airplanes. Our goal in 1996 is to maintain that at 90 or below on a consistent basis.

Given all the dramatic changes that we have had within the organization, it's amazing to me that our MEL count had as much stability as it did. We did not see it spike up to 200 to 300 to 400 and then take a number of months or a year to come back down.

## LESSONS LEARNED

If you implement an MRM program, you are going to have some effects on your culture. It's really going to change the climate within your organization. You are going to have some cases, such as those Comdr. Smith talked about yesterday, where there's even a greater effect on a military environment. We need to remember that a lot of our technicians came out of the military environment or come out of the "Old School". In that regard, when you start talking about giving the technicians the right to speak up and become assertive there are going to be some leads and some supervisors who are going to resist. It's going to really take a strong emphasis by your management team to reinforce what you need to have in place in order for assertive communication to happen. But you really can affect climate; you really can affect culture. It takes a long time to do, but it can

have a dramatic effect. You can have an impact on both safety and efficiency.

Most importantly -- Don't underestimate the power of awareness. Most programs are going to start off with an awareness building workshop similar to what we did in some respects. We underestimated the power of simply providing information to employees and then letting them do with it what they saw best in the workplace. However, we saw from a lot of our studies that this trickle down created a sense of awareness. It had a delayed effect according to the surveys we got back. After three to six months, that information kind of percolated through them and through their organization. Employees became much more pro-active and we started to see the emergence of a new attitude -- "Not only do I focus on what and what's happening, on how we do shift briefings, but I am taking a more active role. I am speaking up when there is something wrong." Employees begin to take a more active role after a certain period of time. Allow that to happen and don't underestimate the power of awareness.

Let me go back to something I touched on earlier. I would strongly recommend that as you embark upon a program you integrate your work groups. By that I mean from the top of the organization down -- from Vice Presidents all the way to technicians. Don't stratify the program. Attempt to construct a class or a workshop where ideally you have someone from every level from within the organization right there in the work shop. The other thing that I would recommend -- don't break the program up by departments. Don't do it just for line maintenance, then just for heavy maintenance, then just for support organizations. Mix them all up together -- have a homogeneous group that has Vice Presidents, directors, technicians, supervisors, maintenance controller, engineers, planners, throw in a couple of clerks as well. It's amazing the amount of synergy that you will get out of that group. You'll hear things like "I didn't know you were the SOB I talked to all the time in maintenance control." You will find that after two days they are best friends and, in addition, they now have a contact down in maintenance control, or maintenance control now understands more of what is happening out on the line and vice versa. This homogeny has a tremendous effect; don't underestimate that. I would encourage even those of you who have some constraints relating to unionized environments. If these constraints cause you any restrictions, I would encourage you to do whatever you can to break down those barriers and mix those groups together. It will have a tremendous effect and you will be extremely pleased.

My third point is -- measure what you do, even if it is nothing more than keeping track of who went through the program. Then, when you look at operational performance measures at that station or whatever you normally track today, watch as people go through the program. If operational performance improves, or as in the case of Northwest talking about their 747 lines, if you get a benchmark prior to starting the training and you put everybody through the training, watch what happens afterwards. This tracking is going to be extremely valuable to you in being able to keep the program going, to sell it to upper management. As we all know, there is always change in upper management and they are always looking for the value of programs. Additionally, tracking gives you an opportunity to tweak the program as well as to tailor it more specifically to your needs. It always feels good to be able to look back on a program and say we implemented this. This entire work group went through it. We can discount all the other factors; we can attribute increased performance to a number of things from structural changes within the organization to improve automation. But there is always going to be that piece of increased performance directly tied to maintenance resource management. Justify that piece and you keep the program going.

## APPENDIX



**Figure 10-1: Maintenance Mishaps**



**Figure 10-2:** Maintenance Mishaps

# Team Situation Awareness in Aviation Maintenance

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**T**o assess team situation awareness in an aviation maintenance setting, a methodology was developed for examining situation awareness requirements that incorporates both individual and team situation awareness perspectives. In the present study, inquires were conducted in the field maintenance setting at a major airline. Contextual inquires were combined with a goal directed task analysis to specify the situation awareness requirements involved in each of the interactions (between and within teams) required to perform maintenance tasks. Situation awareness requirements in a team context are discussed along with recommendations for training programs directed at improving situation awareness with and between teams.

## INTRODUCTION

Insufficient attention has been paid to problems involved in aircraft maintenance. While the number of incidents due to mechanical failures that can be traced to maintenance problems are relatively few when compared to other causal factors (e.g., in-flight human error), they do exist and can be systematically addressed. [Marx and Graeber](#) (1994), for instance, report that 12% of accidents are due to maintenance and inspection faults, and around one-third of all malfunctions can be attributed to maintenance deficiencies. In addition to its impact on safety of flight, the efficiency of maintenance activities can also be linked to flight delays, ground damage and other factors that directly impact airline costs and business viability.

In examining problems that occur within the maintenance arena, several types of difficulties can be identified:

- 1) The first involves shortcomings in the detection of critical cues regarding the state of the aircraft or sub-system. Several accidents have been traced to metal fatigue or loose and missing bolts that should have been visible to maintenance crews. There have been incidents where aircraft were returned to service with missing parts or incomplete repairs. Frequent errors include loose objects left in aircraft, fuel and oil caps missing or loose, panels and other parts not secured and pins not removed ([Marx & Graeber](#), 1994). While several factors may contribute to this type of error, in each of these cases the state of the system was not detected prior to returning the aircraft to service.
- 2) Even when important information is perceived, there often may be difficulties in properly interpreting the meaning or significance of that information. For instance, [Ruffner](#) (1990) found that in more than 60% of cases, the incorrect avionics system is replaced in an aircraft. While the symptoms may be observed correctly, a significant task remains to properly diagnose the true cause of the failure. While not much data exists regarding the impact of misdiagnoses of this type, there is a significant increase in the probability of an incident occurring when the aircraft undertakes the next flight with the faulty system still aboard.
- 3) These problems are compounded by the fact that many different individuals may be involved in working on the same aircraft. In this situation, it is very easy for information and tasks to fall through

the cracks. The presence of multiple individuals heightens the need for a clear understanding of responsibilities and communications between individuals to support the requirements of individuals in performing those tasks. In addition to the need for intra-team coordination, a significant task for maintenance crews is the coordination of tasks and information across teams to those on different shifts or in different geographical locations. The Eastern Airlines incident at Miami Airport ([National Transportation Safety Board](#), 1984) has been directly linked to a problem with coordination of information across shifts (along with other contributing factors). In addition, considerable energy is often directed at coordination across sites to accommodate not only maintenance tasks within the flight schedule but also parts availability constraints. These factors add a level of complexity to the problem and increases the probability of tasks not being completed or completed properly, important information not being communicated and problems going undetected as responsibility for tasks becomes diluted.

## Situation Awareness

All of these difficulties point to a problem of situation awareness. That is, maintenance crews need additional support/training in ascertaining the current state of the aircraft system (supplementing current technical training programs). Situation awareness has been found to be important in a wide variety of systems operations, including piloting, air traffic control and maintenance operations. Formally defined, "*situation awareness is the detection of the elements in the environment within a volume of space and time, the comprehension of their meaning, and the projection of their status in the near future*" ([Endsley](#), 1988). In the context of aircraft maintenance, this means being aware of the state of the aircraft system (and the sub-system one is working on). Termed Level 1 SA, this would include perception of the state of the factors listed in item number one above. Level 2 SA would involve the technicians' understanding or comprehension of the significance of observed system states. Specifically this would include their diagnosis of the causal factors associated with observed symptoms.

While SA has generally been discussed in terms of the operation of a dynamic system, such as an aircraft, the concept is also applicable to the maintenance domain. The complexity of aircraft systems and the distributed nature of equipment and system components poses a significant challenge to the technicians' ability to determine the state of the system (Level 1 SA) during diagnosis and repair activities. Putting together observed cues to form a proper understanding of the underlying nature of malfunctions (Level 2 SA) is a significant problem in diagnostic activities. Level 3 SA, the ability to project the state of the system in the near future, is considered the highest level of SA in dynamic systems. In the maintenance domain, technicians may need to be able to project what will happen to an aircraft's performance with (or without) certain actions being taken or with given equipment modifications/repairs/adjustments occurring. This task may be even more difficult for maintenance technicians, as they often receive little or no feedback on the effects of their actions, and thus may have difficulty developing an adequate mental model for making accurate predictions. The ability to project system status forward (to determine possible future occurrences) also may have a significant relation to the ability to project system status backward, to determine what events may have led to an observed system state. This ability is particularly critical to effective diagnostic behavior.

## Team SA

In aircraft maintenance, as in many other domains, the requirement for situation awareness becomes compounded by the presence of multiple team members, and multiple teams. Individuals need not only to understand the status of the system they are working on, but also what other individuals or teams are (and are not) doing as well. Both factors contribute to their ultimate decision making processes and performances. Team situation awareness can be defined as "*the degree to which every team member possesses the situation awareness required for his or her responsibilities*" ([Endsley](#), 1989). In this context, the weak link in the chain occurs when the person who needs a given piece of information (per his or her job requirements) does not have it. The level of SA across the team,

therefore, becomes an issue of some concern. The objective of the current study was to identify situation awareness requirements for aircraft maintenance teams, analyze how SA needs are currently being met in a typical maintenance environment and establish concepts and requirements for training Team SA in this domain.

## METHODOLOGY

A Team SA Context Analysis methodology was developed for this project. This method consists of two parts: An SA Requirements Analysis and an SA Resource Analysis, as shown in ([Figure 11-1, appendix](#)).

### SA Requirements Analysis

The first step in addressing situation awareness was to determine the specific situation awareness requirements of individuals in the aircraft maintenance arena. This was addressed through a goal-directed task analysis which assessed: 1) the goals and sub-goals associated with maintenance crews, 2) the decision requirements associated with these goals, and 3) the situation awareness requirements necessary for addressing the decisions at all three SA levels - detection, comprehension, and projection. This type of analysis has been successfully conducted for several classes of aircraft ([Endsley, 1989](#); [Endsley, 1993](#)), air traffic control ([Endsley & Rodgers, 1994](#)) and airway facilities maintenance ([Endsley, 1994](#)).

Analyses were conducted through expert elicitation with experienced maintenance personnel, observation of aircraft maintenance activities, and review of all available maintenance documentation. The analysis concentrated on the B-Check maintenance activities conducted by a major airline company at a major airport. To date, interviews have been conducted with three maintenance supervisors, four lead technicians and four A&P technicians at the site.

### SA Resource Analysis

The second part of the Team SA Context Analysis concentrated on identifying the SA Resources used in the current environment to achieve the SA Requirements. Two major categories of resources were considered:

- | Other technical operations personnel as a source of information and
- | The technologies used as sources of information.

To provide an assessment of the personnel SA resources in the aviation maintenance setting, an analysis of communications between organizations and individuals was conducted using a contextual inquiry approach. The contextual inquiry approach ([Robertson & O'Neill, 1994](#); [Endsley, in press](#)) focused on understanding and describing the communication patterns within and between teams as related to their performance goals. The contextual inquiries were conducted simultaneously with the interviews for determining the SA requirements. The contextual inquiries involved semi-structured interviews in which each individual was asked to describe his/her major job functions and goals and the organizations, departments or individuals that served as resources in meeting those goals. A context mapping was then determined showing the communication patterns among and between team members. Each individual was asked to make an estimate of the overall frequency of communication with each identified unit or department and the importance of the communication for achieving his/her goals. Finally each person was asked to identify system, technology or personnel barriers to effective communication and performance in the work setting.

In addition to identifying the SA requirements of teams working on each maintenance task, the technologies for obtaining each requirement within the current system are documented. Based on this analysis, an assessment can be made of the degree to which the current system supports Team SA

and the skills and abilities that are required for achieving good SA within this environment.

## RESULTS

Examples of the results of the application of the Team SA Context Analysis methodology in the maintenance domain are presented here. Job goals in the aircraft maintenance domain appear to be oriented toward the dual goals of ensuring aircraft safety and delivering aircraft for service on time. A breakout of A&P technician goals is shown in ([Figure 11-2, appendix](#)). The major decisions that need to be made for achieving each goal were determined during the analysis and the associated SA requirements were delineated. An example of the output of the SA requirements analysis for one sub-goal is shown in ([Figure 11-3, appendix](#)).

The contextual inquiry depicts the personnel SA resources, in terms of the individuals or units within the maintenance technical operations, that are needed to meet the maintenance team's SA requirements. ([Figure 11-4, appendix](#)) shows the units and individuals that the A&P technician interfaces with. Lines show communication patterns among and between units. In addition the importance and frequency of each interaction is depicted in ([Figure 11-5, appendix](#)).

Problems and barriers for situation awareness at the team level were also identified in the analysis. These include: parts availability and status information; tooling and out-sourcing; tracking of parts and getting parts to the aircraft; instability of the organization; personality conflicts; lack of teamwork and information sharing; shiftwork and fatigue; organizational downsizing; computer system used for tracking parts and materials; workcards and changing procedures; poor housekeeping and maintenance of tools.

## DISCUSSION

Overall, the applicability of the concept and importance of situation awareness in maintenance teams has been supported by the preliminary data. Teams of technicians are supported by many other personnel and organizational units to achieve their goals, each of which has a major impact on the attainment of maintenance goals. In the maintenance environment it is necessary to examine how information flows between and among team members in order to identify system and personnel factors that will impact on the degree to which team members are able to develop and maintain an accurate picture of an aircraft's status. This knowledge appears to be crucial to the technicians' ability to perform tasks (as each task is interdependent on other tasks being performed by other team members), their ability to make correct assessments (e.g. whether a detected problem should be fixed now or deferred to later (placarded)), and their ability to correctly project into the future to make good decisions (e.g. time required to perform task, availability of parts, etc.). Five specific recommendations have been identified for training concepts to improve situation awareness. These include:

- | Shared mental models
- | Verbalization of decisions
- | Better shift meetings and teamwork
- | Feedback
- | Individual SA training.

Each of these concepts will be discussed along with ongoing implementation and evaluation efforts.

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## APPENDIX



**Figure 11-1:** Team SA Context Analysis Methodology



**Figure 11-2:** A&P Technician Goals



**Figure 11-3: SA Requirements - example**

### 1.1.1 Make repairs

#### Part availability

- | correct part supplied?
  - | manufacturer's part number
  - | aircraft type, model, tail number
  - | maintenance and equipment list (M&E) number
  - | effectivity number
- | how long to get part here?
  - | in-stock status
    - | manufacturer's part number
    - | aircraft type, model, tail number
    - | maintenance and equipment list (M&E) number
    - | effectivity number
  - | part & tooling availability
    - | where
    - | when it will be here
    - | delivered or pick-up
    - | arrival flight number
    - | arrival gate number

#### Placard problem

- | can problem be placarded?
  - | type of problem
  - | Minimum Equipment List (MEL) status
    - | Deferred information placard (DIP)
    - | Open item list (OIL)
  - | redundant systems available
  - | control number
  - | log page number
  - | flight number
  - | employee number



**Figure 11-4:** SA Resources - A&P Technicians Communication Patterns



**Figure 11-5:** SA Resources - Importance and Frequency

## Panel Presentation: Perspectives on TRM Training for Maintenance - Komarniski

**Richard Komarniski**

*President, Grey Owl Aviation Consultants*

### INTRODUCTION

When we look at and hear about aviation incidents the focus is usually on the cockpit. I guess this is why they have had CRM training for the last 20 years. It only has been the last couple of years since we have even heard the words "Human Factors Training" mentioned in the maintenance department. Most companies provide their maintenance personnel with excellent technical training, and yet very few companies provide any form of Human Factors (or Human Element) training for the very thing that causes about 80% of their maintenance errors. The more progressive companies have implemented programs in their organizations during the last 5 years, others are still reading about the concept. In Canada it has taken 10-15 years just to get used to the idea of technical initial and recurrent training, never mind Human Factors.

But I guess, in this group today we have the converted, so we all realize the importance of having an effective *Human Factors Awareness* program available to us.

As John Stelly indicated yesterday Continental Airlines has seen a great benefit in their organization from Human Factor training and are moving forward with a Phase II. John and his group at Continental Airlines were a great influence with the development of our program.

John Goglia indicated that US Air has seen great paybacks from a Human Factor Awareness Program.

In Canada, the tragedy of an F28 crash at Dryden, Ontario on March 10, 1989, due to snow and ice on the wings resulted in the largest investigation and inquiry to an aviation incident in Canada to date. The inquiry recommended that Human Factors training be extended beyond the cockpit to include among others, maintenance personnel. Thus funding became available to create the HPIM (Human Performance in Maintenance) program.

### HUMAN FACTORS WORKSHOP

We have made available to the aviation community in Canada and just recently in the United States our Human Factors Workshop for Aircraft Maintenance Technicians.

The objective of the two-day workshop is: "To examine the chain of events that cause an aviation occurrence and develop ways to prevent the occurrence." The workshop gives an insight on the human factors that affect aircraft technicians' good judgement and how to create safety nets to prevent us from being a contributing link to an aviation incident.

As we mentioned, this is a new concept in aviation so we start off slowly. We give them a two day general overview of the major Human Factors, about 12 total - discuss each human factor - the safety nets that could be created to prevent a factor affecting our judgement. We also look at about 6 documented case studies from the industry ([Figure 12-1, appendix](#)) that these human factors had a direct bearing on.

In this same workshop we talk briefly on our emotional and rational ego states and how they effect our judgement at critical moments throughout the day. We start right back at the basics with an event

to which there is a reaction. But before the reaction can take place the mind has to give the event both thought and meaning. A simplified version of the Transactional Analysis model helps us understand the thought process. The brain is divided into two parts, the conscious and sub-conscious or the rational and the emotional or the adult and the child ([Figure 12-2, appendix](#)). When we are born only the child (emotional) mind exists and as we grow, the adult (rational) mind begins to develop and the child becomes lost in the subconscious (habits). The workshop gives examples of the adult/child interaction and how it can effect a person's judgment while at work.

To date between Gordon Dupont and myself this workshop has been presented to about 1,000 of the 10,000 AME's in Canada. All of the critiques indicate that human factor awareness training for the AMT is long overdue.

We have developed a follow-up session (Phase II) to deal with specific human factors: Fatigue; Complacency; Communication; and Awareness along with relevant case studies. We hope to have a Phase III Workshop developed by mid spring on attitude/ego states related to aircraft maintenance.

We will not facilitate to a total maintenance organization unless the top managers have committed to the workshop themselves. Otherwise it is very frustrating for the employees after the workshop to communicate to the supervisors their thoughts and concerns (the effectiveness). We focus on what the employees can do for themselves and the company vs what the Company can do for them (most people want responsibility - it gets them motivated).

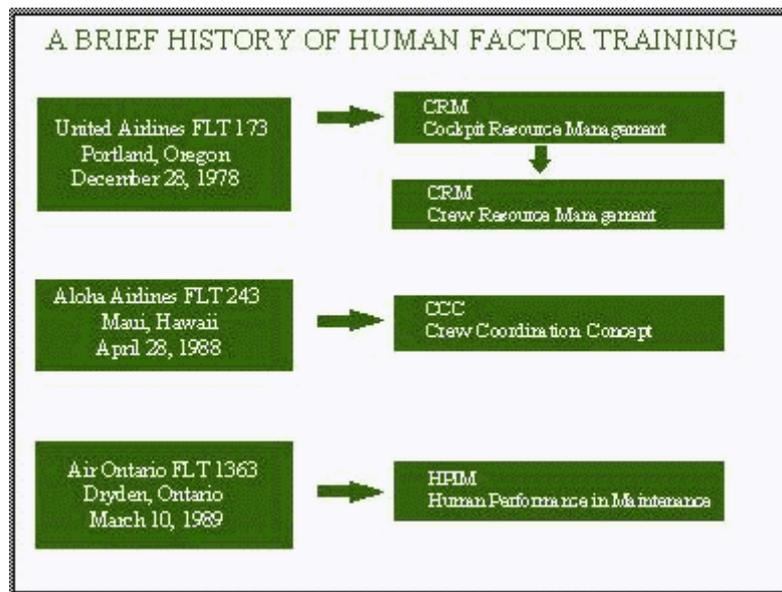
There are several levels of foundation that have to be poured before this program is effective in an organization:

1. Driven top down
2. Managers attend workshops, Director of Maintenance / Director of Q.A.
3. All employees attend
4. Attendees - participate in a behavioural analysis

## CONCLUSION

We believe that this is the first time a Human Factors workshop has been put together by maintenance personnel for maintenance personnel. The pilot community has had a 20 year head start on applying the principles of "cockpit resource management" - so lets not forget that AMTs are human too and we are all responsible for the safety of the aircraft.

## APPENDIX



**Figure 12-1:** Brief History of Human Factor Training



**Figure 12-2:** Ego State

*Panel Presentation:*  
**Perspectives on TRM Training  
for Maintenance - Russell**

**Bob Russell**

*Flight Safety International*

## INTRODUCTION

I couldn't help thinking -- sitting there listening just now and, of course, all day yesterday -- it would have been nice to have all this information 25 or 30 years ago.

The first thing I have to do is clear up some confusion. I discovered yesterday in talking to some of you that there is confusion about the name "Flight Safety". When you say "Flight Safety", some people think of the Flight Safety Foundation, and some think of Flight Safety International. For those of you who don't know the difference, the Flight Safety Foundation promotes safety interest of the aviation industry. Flight Safety International is what I am discussing. We are a training company. I just want to make that distinction today so we don't have any confusion. Let me give you a little background on Flight Safety International.

We are, as I said, a training company. We started back in the '50s when our founder Mr. Al Ueltschi began teaching Pan Am Crew members some instrument training on a sort of part-time, ad hoc basis. By the early '60s, he had the training program up and running. Since then we have been moving onward and upward. This year 45,000 to 50,000 people will receive some form of Flight Safety training. The vast majority of those, of course, are flight crews. That's what Flight Safety is really known for -- training flight crews. However, we have over 200 active maintenance courses right now. We have been involved in the human factors training for about two decades, perhaps a little longer than that. In the field of human factors training we are best known for CRM -- Cockpit Resources Management. Literally thousands of air crew members have been trained in CRM by Flight Safety.

We are also active in the petroleum industry. We teach human factors to refinery folks. Like flying, that's an industry that has a very great need for human factors training. Our third major involvement in human factors training is the maritime industry. We have a course that we call Bridge CRM for ship captains. We have been doing that for a number of years. It seems ironic to me that in spite of this background here at Flight Safety International, specifically in human factors, it was only last year that we brought human factors training to the maintenance environment. We are guilty, like a lot of folks in the industry, of not recognizing the need or being able to convince folks that the need is there, and convincing them well enough so they are willing to pay for the training. My purpose here is to discuss our concept of human factors training for the maintenance environment. What we try to accomplish with this training, the content of this course, benefits to the recipients, and the problems that we have to overcome to present this training effectively.

## GOALS

Our concept is to focus on the basic human factors issues. Human factors in maintenance are not that much different from some of the other areas of industry in which I've been involved. Our goal is to take basic human factors and bring them to the maintenance industry. We are using non-technical human factors training to influence technical outcomes in the maintenance environment. That's really what it boils down to; that is what nearly everybody in this business is doing.

We do this through a two-day interactive workshop -- 16 hours. It's aimed primarily at technicians and lead technicians, supervisors, although it's applicable to everybody. I like the ideas, the discussions, we have heard here about diversity. Diversity in the classroom really does help. We try to keep the class not less than six to eight. We really don't like to have less than eight people or more than 12 to 15. One of the things about the class is that we have people from different companies; that adds a little more diversity, and seems to help, too. Basically, what we are trying to do with this training is to enhance performance through awareness of basic human factors concepts. Safety obviously, is a priority, but you also look to enhance efficiency and productivity.

## COURSE CONTENT

As for course content, these are the six broad issues, concepts, we explore in our two-day workshop.

1. Situational Awareness, of course, you heard the importance of that. We try to define it, to teach how it reduces risk, how you achieve it, how to know you have it, how to know you have lost it -- if you loose it. We think situation awareness is very, very important and I, personally, really enjoyed hearing all the discussions we have had about it.
2. We also spent some time on Error Chain. We think there are 12 factors or links that make up the error chain. We use many examples of real accidents, most of those you have already discussed here. To us right now, a series of seemingly unrelated events link up to cause accidents, incidents, problems.
3. Communication Skills. We have already touched on the basics. What we are trying to do is expose people to many of the qualities of effective communication -- what are the processes, what is the basic process. We give them some techniques to improve the process. We talk about some barriers to effective communications and try to give them some specific skills to overcome these barriers.
4. Synergy, and Team Work. We are just reintroducing the dynamics of what is synergy, what is team work. Are they related, if so how.? We introduce and explore types and quality of effective leadership, leadership styles, characteristics of team support, suggestions for building effective teams and conflict resolution.
5. Decision Making. We talk a little bit about the process and use some of the models for decision making. Of course, some of the folks, actually a lot of them, have never had any exposure to this. We try to keep this fairly basic. We don't want to have an information overload on this, and you can. We talk about the decision process, accelerated response process, techniques to improve decision making. What we are trying to do is to give people some tools to make better decisions in an environment that sometimes requires quick decisions. The tools to make decisions when you don't have all the information that you would like to have.
6. Lastly, Stress. We try to identify what it is, give people an awareness of what it is, how it effects them, that it doesn't effect everybody the same way, what are some of the signs, how do you observe it in others, how do you know when it is affecting the performance of others, and how do you cope with it, or how do you manage it.

## HOW THE CUSTOMER BENEFITS

We believe the benefit to the customer is safety, safety, safety. As you see here, that's the thing that all of us have to keep in focus in this industry. It is paramount. This industry should be like the delivery room in a hospital. Theoretically, there are no dropped babies in hospitals, and we should have the same standards. Quality, efficiency, productivity -- those are all important, and they all should be affected, if the training is effective. As for quality of life, we believe that there is

enhancement of the quality of life in the maintenance environment for folks who are exposed to this kind of training. It improves their confidence because they know more than they did before. I also believe there is another benefit. I think it enhances professionalism. People who take this course have exposure to concepts that are unfamiliar to many of them.

These are what we think are the benefits to the user.

## OVERCOMING HURDLES

Some of our hurdles as a producer of training are internal; some are external. Externally, we, like most of you, know that the need for training is out there. The need is out there, but not, perhaps, the demand. The difference between need and demand is perception. The demand is just not as great as the need. A lot of folks view training as an added cost program. It's just something that is another cost, and they have a hard time seeing the benefit of it. This is not necessarily the view of the maintenance folks, but the folks who approve the dollars to get the training.

Internally, one of the problems is a limit on time. Some of you folks know this better than us. You can only have access to these people for a limited amount of time -- two days seems to be about it. You can't get them away from their jobs for longer than that for this kind of training. The task then becomes how do you build real substance into two days. You can spend two days on any one of these six major areas. We see that as a challenge -- exposing these folks to some real substance, yet confining it to two days. Of course, like every other business, we have the problem of producing this training and being able to make money doing it. We have to be cost-effective.

## WHAT'S NEXT

In summary, the need is out there. Our initial efforts has been very well received. We are scheduled through June/July right now. We do take this program around the country. The seven or eight sessions that we have scheduled now are in different cities. We will bring it wherever we need to take it for a group of at least six, seven, or eight -- something like that. The rest of the year is still out there. We see ourselves overcoming the perception that training is an added cost program, that it doesn't contribute anything as a marketing problem.

What we got to do is go out there and convince folks of the benefit of this training. Typically, we are dealing with the chief of maintenance, or somebody who feels like he wants it. He or she needs it; he knows he needs it; he knows his people need it, and his people are all for it. But the folks who approve the money -- that's where the stumbling block comes in. If we are going to stay in this business, we've got to overcome this stumbling block one way or another. Perhaps that is a marketing challenge. We are probably going to devote more resources to it. There is such a need out there for training.

This has been a real quick summary of how we go about trying to train maintenance technicians and maintenance resources management.

*Panel Presentation:*  
**Perspectives on TRM Training  
for Maintenance - Johnson**

**William B. Johnson, Ph.D.**  
*Galaxy Scientific Corporation  
Atlanta, GA*

*HUMAN FACTORS IN MAINTENANCE COURSE\**

A human factors in maintenance course must have the goal of lowering costs by reducing error and increasing maintenance efficiency. Such a course ensures continuing maintenance quality with resultant customer comfort, satisfaction and safety. A human factors course promotes improved communication and maintenance teamwork. The course also creates an awareness toward workplace safety with resultant reduction in a variety of measures like equipment ground damage and job-related injury.

Maintenance personnel learn best when the information has high face validity -- that is, it must be obviously applicable to maintenance tasks. A course must apply basic scientific principles to real-world problems. The course must not only offer guidance and "how to" information, it must also provide a basis upon which students can locate additional information and guidelines. Human Factors knowledge, procedures and tools must remain at the airline when instructors leave.

Our course provides a blending of scientific principles with real-world maintenance challenges. The learner becomes aware of human capabilities and limitations in regard to physical, sensory, cognitive and environmental factors. The result is that the trained technician, upon completion of the course, is able to recognize human-centered ways to minimize error and enhance human performance in maintenance.

We created the FAA *Human Factors Guide for Aviation Maintenance*. Therefore, the *Guide* is an important part of our course. We also developed the Ergonomic Audit Software provided by FAA. The combination of the *Guide* and the audit software provides our course graduates with the knowledge and tools to integrate human factors with airline maintenance. The course instructors each have over 25 years of experience working with a variety of applied aspects associated with human factors in maintenance.

The accompanying presentation slides preview our approach to the Human Factors Course and provide an outline for the class which can range in length from two hours to three days. Our course covers all the topics proposed by [JAR 65](#), and has evolved from numerous interactions throughout the international aviation maintenance community.

# Team Training for the Aircraft Maintenance Technician: The Aircraft Maintenance Team Training (AMTT) Software

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## ABSTRACT

Previous research on civil aircraft inspection and maintenance has shown the important role teamwork plays in completing aircraft inspection/maintenance tasks. Hence, it is necessary to develop team training tools for aircraft maintenance technicians (AMT) to enhance team skills and team performance within the aircraft inspection/maintenance environment. In response to this need, this paper describes the development of a computer-based multimedia team training tool, the Aircraft Maintenance Team Training (AMTT) software.

## BACKGROUND

Recent FAA reports on human factors in aviation maintenance ([Shepherd](#), 1991, [FAA](#), 1993) have recognized the importance of training. Training for aircraft maintenance and inspection systems has essentially aimed to improve individual skills. This training has ranged from improving diagnostic skills for aircraft maintenance training ([Johnson](#), 1990) to acquiring and enhancing visual inspection skills to improve airframe structural inspection ([Latorella et al.](#), 1992; [Gramopadhye et al.](#), 1993). A large effort in the past has concentrated on developing individual skills of AMTs; however, very little effort has been placed on developing team skills.

The task analysis of aircraft inspection and maintenance activities ([Shepherd](#), 1991) has revealed the aircraft inspection/maintenance system to be complex, requiring above average coordination, communication and cooperation between inspectors, maintenance personnel, supervisors and various other sub systems (planning, stores, and shops) to be effective and efficient. A large number of activities of a maintenance technician or an inspector necessitates teamwork and can be performed more effectively and efficiently in a team. Though the advantages of teamwork are widely recognized ([Hackman](#), 1990) in the airline industry the work culture assigns responsibility for faulty work on individual AMTs rather than on the teams in which they work. The reasons for this could be the individual licensing process and personal liability, both of which often result in AMTs and their supervisors being less willing to share their knowledge and work across shifts with less experienced or less skilled colleagues. The problem is further compounded since the more experienced inspectors and mechanics are retiring and being replaced by a much younger and less experienced workforce. Not only do the new AMTs lack knowledge or skills of the far more experienced AMTs they are replacing, but they are also not trained to work as a team member.

The earlier problem of the development of individual AMT skills has been continually addressed by FAA. For example, the newly established FAR Part 66 (new AMTs certification requirements) specifically addresses the significant technological advancements that have taken place in the aviation industry and the advancements in training and instructional methods that have arisen in the past decade. The FAA, through the Office of Aviation Medicine, has also funded efforts for the

development of advanced training tools to train the AMTs of the future. These advanced tools include intelligent tutoring systems, embedded training, etc. which will be available to A & P training schools. It is anticipated that the application of these new training technologies will help reduce the gap between current AMT skills and those needed for the maintenance of advanced systems.

## NEED FOR TEAM TRAINING

A large portion of inspector and maintenance technician work is accomplished through teamwork. The challenge is to work autonomously but still be a part of the team. In a typical maintenance environment, first, the inspector looks for defects and reports them. The maintenance personnel then repair the reported defects and work with the original inspector or the buy-back inspector to ensure that the job meets predefined standards. During the entire process, the inspectors and maintenance technicians work with their colleagues from the same shift and the next shift as well as personnel from planning, stores, etc. as part of a larger team to ensure that the task gets completed ([FAA, 1993](#)). Thus, in a typical maintenance environment, the technician has to learn to be a team member, communicating, and coordinating the activities with other technicians, and inspectors. However, the AMTs joining today's workforce are lacking in team skills. The current A & P school curriculum often encourages students to compete against one another, and often AMTs are not fully prepared for co-operative work in the future. To prepare student AMTs for the workplace, new ways have to be found to build students technological, interpersonal and socio-technical competence by incorporating team training and communication skills into their curriculum. Additionally, the importance of teams has been emphasized in the National Plan for Aviation in Human Factors ([FAA, 1993](#)), where both the industry and government groups agreed that additional research needs to be conducted to evaluate teamwork in the aircraft inspection/maintenance environment. As part of an effort focused on teams in the aircraft maintenance environment, the current study achieved the following: - developed a framework to understand the role of teamwork and team training in the aircraft maintenance environment, - conducted a controlled study to evaluate the effectiveness of team training with AMTs from an A & P school, and - developed a computer based team training software entitled "Aircraft Maintenance Team Training" (AMTT).

## FRAMEWORK AND CONTROLLED STUDY OF TEAM TRAINING IN THE AIRCRAFT MAINTENANCE ENVIRONMENT

Drawing from the task analysis of aircraft inspection and maintenance operations ([Drury, 1990](#); [Shepherd, 1991](#)), site visits to the repair facilities, observations with training personnel and A & P school instructors, and a detailed review of the various team models, a framework for team training was developed. This framework, serving as the first step in understanding teamwork in aircraft inspection and maintenance operations, illustrates the interaction between internal factors, external factors, the team process, training strategies and outcome measures. The framework assisted in the development of a team training program ([Gramopadhye et al., 1995](#)). Then, the effectiveness of this program in enhancing team skills was tested in a controlled study conducted with student AMTs from an A & P school. The framework and the results of the study have been reported extensively in [Ivaturi et al. \(1995\)](#), [Gramopadhye, et al. \(1995\)](#). The results of this study were encouraging as to the potential of team training in improving team performance and overall task performance. The results showed that AMT teams which underwent team training exhibited a larger percentage of team behaviors related to successful team performance as compared to teams with no training. Having developed a framework and demonstrated the effectiveness of team training, it is clear that student AMTs need to be provided with training and tools which they can use to enhance team skills and prepare them for cooperative environment in the future. Since advanced technology may have a role to play in developing team training tools, specifically computer-based team training tools, evaluation is needed.

## ADVANCED TECHNOLOGY APPLIED TO TEAM TRAINING -- THE AIRCRAFT MAINTENANCE TEAM TRAINING (AMTT) SOFTWARE

With computer based technology becoming cheaper, the future will bring an increased application of advanced technology to training. Over the past decade, instructional technologists have provided numerous technology-based training devices with the promise of improved efficiency and effectiveness. Examples of such technology include computer simulation, interactive video discs and other derivatives of computer based applications ([Johnson](#), 1990), several of which have been employed in maintenance training ([Johnson](#), 1990, [Johnson et al.](#), 1992; [Shepherd](#), 1992). Furthermore, multimedia has assisted in teaching difficult and complex skills ([Gordon](#), 1994). [Andrews et al.](#) (1992) also describe various multimedia technologies that have been effective in simulating combat situations for team training in the military. Because of the advantages offered, computer-based training may have a role to play in team training in the aircraft maintenance environment. As part of the effort which examines the application of advanced technology to team training, a computer based team training software--Aircraft Maintenance Team Training Software (AMTT) was developed.

Specifically designed for training aircraft maintenance technicians in basic team skills, AMTT uses a multimedia presentational approach with interaction opportunities between the user and the computer. The multimedia presentation includes: full motion videos which provide real life examples of proper and improper team behavior, photographs and animations that illustrate difficult concepts, and voice recordings coupled with visual presentations of the main contextual material. Since the software was developed as a training and research tool, a database program was developed to collect demographic information as well as pre and post performance data.

### SPECIFICATIONS

AMTT was programmed in Microsoft Visual Basic and runs in the Microsoft Windows environment. AMTT uses the 486 DX2 66 MHz platform, with a 15 inch SVGA monitor, 16 MB RAM, 2 MB video RAM, MCI compatible sound card, and a multispeed CD.

### DEVELOPMENT

To ensure that the software addressed the needs of the aviation community, the designers worked in close cooperation with a major aircraft maintenance repair/overhauling facility (Lockheed Martin Aeromod Centers, Inc.) and an A & P school (Greenville Technology--Aircraft Maintenance Technology Program). The requirements of the aircraft maintenance environment guided the development of the software program, which was centered on human (AMT) requirements and evolved through appropriate stages of specification, story-boarding, prototyping, development and testing.

### STRUCTURE OF THE AMTT SOFTWARE

AMTT is divided into three major programs: Team Skills Instructional program, Instructor's Program and Printing Program.

#### **Team Skills Instructional Program.**

The team skills instructional program consists of the following modules: introduction, team skills, team skills overview, task simulation and the critical path method (supplemental) module.

*Introduction module:* The objective of the introduction module is fourfold. First, it provides the user with definitions of terms and concepts found throughout the software. Team and teamwork are both defined and described, and the types of teams normally found in the aircraft maintenance environment are illustrated. Second, the importance of teamwork and the resulting effects on performance are detailed for the user. Third, the user is introduced to the organization and layout of the tutorial. Finally, the introduction acquires demographic information about the user.

*Team skills module:* Team skills factors or skills dimensions have been identified and defined by a number of authors ([Cannon-Bowers, et al.](#) 1993, [Glickman, et al.](#), 1987; [Nieva, et al.](#), 1978). [Gramopadhye, et al.](#) (1995) and [Kraus et al.](#) (1996) describe the six team skills factors that are relevant specifically to the aircraft maintenance environment. Training material relevant to the above skills was developed and the different skill dimensions were combined to form four separate sub-modules--Communication sub-module, Decision making sub-module, Interpersonal Relationships sub-module and Leadership sub-module. ([Figure 13-1](#)) shows a prototypical layout of the team skills module. The right side of the screen is dedicated to key points being discussed in the voice-over, while the left side of the screen provides supporting material. This supporting material comes in a variety of formats which include, but are not limited to, animations, videos, photographs, diagrams and flow charts. Buttons on the command line at the bottom of the screen can be clicked on to exit, advance, back-up, stop and replay audio, replay of video and access the navigational map. On-line help is also available and is structured similar to Microsoft Help. A window is also provided which provides the user information on whichever object the mouse is residing. Each of the team skills sub-modules has a similar structure. The sub-modules start with a questionnaire wherein users rank ten subject related questions on a seven point Likert scale. The objective of this questionnaire is to collect user's perception on specific team skills prior to training. The questionnaire is followed by a short test that is intended to measure the user's current knowledge on the subject matter. On completion of the test, the user is presented with the instructional material. The tutorial material is broken down by major topics. After each topic, a test is presented to the user before proceeding to the next topic. These embedded tests serve two purposes: first, it serves as a check to verify that the user has understood the material just presented, and second, it serves to reinforce what the user has just learned. The same questionnaire and test question asked at the beginning of the module are posed to the user at the end. This was done to measure the effect, if any, the subject material had on the users' understanding of the material and changes in user's perception related to the specific team skill.

**Figure 13-1: Team Skills Module**



*Team skills overview module:* In a short 10-15 minute slide show presentation, the team skills overview module was designed to encapsulate all the general information provided in the four sub-modules of the team skills instructional module.

*Task simulation module:* The task simulation module was designed to allow the users to apply the skills learned in the team skills instructional module in an aircraft maintenance situation. To accomplish this, a virtual aircraft maintenance environment was created with a virtual team of seven technicians (one crew lead and six crew members). The virtual team had three consecutive tasks which required a team effort. These tasks were: testing the extension and retraction of the landing gears, jacking down the plane, and finally, towing the aircraft to another location. A narrative was provided about the crew and their efforts to complete these teamwork tasks. Problems which involved team skills arose in the normal course of work, and the user, acting as a consultant, was queried as to the correct course of action. To simulate real life, wrong answers were carried forward to a potentially disastrous end. False problems or situations were introduced to determine if the user recognized when situations were progressing within bounds. ([Figure 13-2](#)) shows a prototypical

screen of the task simulation module. To assist the user in understanding the story line, photographs of the team members working together were presented on the left side of the screen. Data concerning the number of correct and incorrect decisions made by the user was stored in the database for analysis.

**Figure 13-2: Task Simulation Module**



*Critical Path Method (supplemental) module:* Teamwork often leads to making decisions concerning how to perform or improve future work. Decision making, however, does not end with achieving agreement with all the team members. Decisions must be converted into an action plan. The Critical Path Method (CPM) Supplemental Module was developed to teach the user the most common method of scheduling and analyzing a team process ([Paulson, 1995](#)). After the user is introduced to the background and capabilities of CPM, the module proceeds to instruct the user on how to construct CPM diagrams using the activity-on-node approach. Users are tasked with calculating the critical path of several networks to enhance the learning experience. CPM networks answer "what if" type of questions to help determine the impact of a decision before implementation. The impact of changes are taught with a series of "what if" exercises to help clarify the process, to practice calculating critical paths, and to demonstrate how the critical path may become altered due to minor changes in resources. The supplemental module concludes with a practical exercise in which the user observes an aircraft towing task.

### **Instructor's Program**

The instructor's program facilitates the collection and analysis of data on each user. It consists of two main modules: the report generation module and the field study module. The report generation module allows the instructor to retrieve, analyze and print performance data for all users as they complete the various sub-modules within the team skills instructional program. The field study module was designed to enable the instructor to print the questionnaires and use them to collect field data. Data obtained can be entered and further analyzed using this module.

### **Printing Program**

In a situation wherein computer support is lacking, it may become necessary to present the information in an alternate format. The printing program was designed specifically to provide the instructor with the resources and structure necessary to print the different screens in the team skills instructional modules and sub-modules.

## **FUTURE PLANS**

The next phase of this project will involve testing and evaluation. The software will be tested for robustness. Recommendations forthcoming from this testing will be incorporated to enhance the software. The evaluation phase will analyze the utility of computer-based team training in the aircraft maintenance environment. A detailed experimental protocol will be developed and the evaluation will be based on an experimental design using an experimental treatment group and a control group. The above phases will be conducted in cooperation with an A & P certified school, aircraft maintenance facility and a partner airline.

## **CONCLUSIONS**

The paper has described ongoing research and development related to the application of team training in the aircraft maintenance environment. The research demonstrates the current application of advanced multimedia technology in developing a team training software for training aviation maintenance technicians in team based skills. Subsequent phases of this research will evaluate the utility of AMTT in an operational setting. Training team skills of AMTs is critical to ensure successful team performance in the aircraft inspection/maintenance environment. In the future, as the composition of the AMT workforce changes, team training will become more critical. In such an environment, computer-based team training coupled with technical instructors will provide an effective training solution.

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# Automation Lessons Learned

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## ADVENTURES IN AUTOMATION

Having an interest in both aviation and computing, its rare to find a story that can cross both paths. I would like to share a brief story that fits the bill:

There was a pilot flying a small single engine charter plane, with a couple of very important executives on board. He was coming into Seattle airport through thick fog with less than 10m visibility when his instruments went out. So he began circling around looking for landmark. After an hour or so, he starts running pretty low on fuel and the passengers are getting very nervous.

Finally, a small opening in the fog appears and he sees a tall building with one guy working alone on the fifth floor. The pilot banks the plane around, rolls down the window and shouts to the guy "Hey, where am I?" To this, the solitary office worker replies "You're in a plane." The pilot rolls up the window, executes a 275 degree turn and proceeds to execute a perfect blind landing on the runway of the airport 5 miles away. Just as the plane stops, so does the engine as the fuel has run out. The passengers are amazed and one asks how he did it.

"Simple" replies the pilot, "I asked the guy in that building a simple question. The answer he gave me was 100 percent correct but absolutely useless, therefore that must be Microsoft's support office and from there the airport is just a few miles away."

Today, I would like to share with you a little bit about Maintenance Automation and the human factors associated with the development, design and implementation of Client-Server PC-based applications at American Airlines.

I would like to start out telling you a little bit about me, and how I became involved with Americans Automation Program. As Supervisor of the Production Control Organization in Chicago, my challenge was clear. I had to find a way to administratively deal with a planned doubling of head count and workload in Chicago. I had to accomplish that goal with a minimum increase in administrative head count. I consider my introduction into Automation, more an act of survival, than anything else! We were however, blessed with a Local Management organization that was very pro-automation. This as I later found out, was our biggest asset.

Many of our organizations have spent enormous amounts of money and other resources for what amounts to .....Not much. We spent these resources, with carefully justified ROI, using the latest, carefully selected equipment in the hope of reducing the cost of doing business, improving efficiency and other corporate goals. The economics of industry dictate ever increasing spans of control and the need for real-time communication. The people being automated, however, take a different view of your efforts. One of the issues all organizations struggle with is honestly facing this issue with our employees. We ask them to assist in the design and development of what they see as a way to eliminate there jobs. We feel the best approach, and the direction we have chosen to go is to describe the automation in terms of giving management "options." The "options" we now have that we didn't previously include:

1. The ability to grow an operation without a proportionate increase in head count.
2. The ability not to replace an individual in a given position following his transfer or retirement

This is the way we have looked at it. The big reason we automate is to save money. That is the bottom line. We need to be more accountable for the money we spend in maintenance. Maintenance is a cost of doing business.

When making the determination to automate, three issues come to mind:

1. *What processes require repetitive entry of the same data?* I am talking at the user level -- the person who does the entries.
2. *Who else in my organization has a similar need for that information?* Nothing bothers me more than to see a guy sit at a terminal, pull information up, write it down, turn around and enter it into another computer. What we are trying to do is get away from that as much as we possibly can.
3. *Who is the customer?* In many cases, the sponsoring organization may not be the ultimate user of the end product developed. Failure to include the final user leads to failed automation, as explained below.

I do not intend to give you an in-depth look at each of the five applications we have developed at American, nor do I have working models or demos of them. I do plan to identify how each of the applications impacted our thought processes about automation and what we learned from each application as we went along. What I hope to provide you is one individual view of the human impact of introducing PC-based applications to a non-automated environment.

## **APPLICATION 1: CD-ROM Based Maintenance and Parts Manuals**

Engineering thought they were the customer. American Airlines at one point contracted with Maxwell Data, now Jouve Data Management to convert all of our maintenance manuals into a digital format, by converting all the aircraft manufacturer's maintenance data. One of the first things we ran into was that the data we were getting from Aircraft Manufacturers was inconsistent. What we found was that if the manual says "Boeing 767-200", the "0" which is the number "0" may be the character "O". To the casual reader, this difference is invisible. If one is trying to convert this data to digital information however, one has a problem.

The end user application created by Maxwell is a Microsoft Windows-based product. We made the assumption that the end-user, the Technician, had the skills to use it. Being a Windows-based product; we assume the technician knew what a mouse is, and knows not to step on it. We are assuming he/she knows how to type. People resist change. Technicians quickly became very possessive of their microfiche. We started to talk about words like AMTOSS...what is it? The original "Pinpoint" interface was not intuitive. It represented the thought processes of an Engineer, not a Line Technician. The lessons we learned about our CD-ROM maintenance manuals were:

1. Involve the user group in the design of the interface.
2. Find user advocates.

Go into a facility and sit down with a group of technicians. Out of a group of twenty technicians, I would probably get two or three that really were "turned on" by the computer application. They really liked it; and recognized its potential. They became my advocates. They were the on-site peer-level guys other technicians could go to and ask questions. These individuals are the salespersons who are going to sell your automation for you. These individuals should receive special training, and attention! This will assure they can answer their peers' questions.

3. Do not get in their way. The end-users will find ways to use the applications you never dreamed.
4. The last lesson we learned about CD-ROMs was:

*"Automation developed and not used is an absolute waste of time and money."*

## APPLICATION 2: Entering PIREPs into a Computer Tracking System

All air carriers are required to have logbooks in their aircraft. Most have some sort of large mainframe-computer based system to record and track Pilot and Maintenance write-ups. We find in most cases the data structure needed to enter these items are cryptic, involving difficult codes and sequences. Most entries also require multiple transactions to obtain any useable data. You end up with some very interesting write-ups too. I have a few examples here to share with you. The name of the airline will not be mentioned, to protect the guilty:

*The first discrepancy:*

PIREP: Test flight after maintenance OK, auto land very rough.  
SIGNOFF: Auto land not installed on this aircraft.

*Another example:*

PIREP: The auto pilot does not..... (*Apparently, the pilot was distracted and failed to finish his entry.*)  
SIGNOFF: It does now.

*Yet another:*

PIREP: Number two propeller seeping fluid.  
SIGN-OFF: Propeller seepage within normal limits, aircraft OK to go  
NEXT PIREP: Propellers one, three, and four lack normal seepage.

*This one had to be military, as this never happens in the airlines:*

PIREP: The pilot crew bunk mattress is lumpy and not comfortable enough for sleeping  
SIGN-OFF: Mattress ground checked OK by night shift

The resolution to this cryptic data entry problem was the creation of little application that we call PCFMR. We have recently converted this application to a Microsoft Window's<sup>(r)</sup> platform and call it WINFMR. "FMR" is the acronym for "Field Maintenance Reliability" program for American Airlines. We found as we went into a large station with users experienced on the old system that they looked at our new platform and said, "This is slow." I was crushed. We spent all this time and money developing this neat thing and they did not like it. We later found that as we deployed it to the smaller down line stations where no clerk existed to input the PIREPS, where we had the crew chief or line technician doing the cryptic entry, the acceptance level went way up. Life was good again.

Training is another issue one really needs to consider. We found ourselves using the user-advocate concept developed with the CD-ROM maintenance manuals for all our automation. Another issue is -- this is really common issue, as I discovered from talking with my counterparts in various airlines - - Can the MIS group support your new applications? Development groups are often separated from the local field-level MIS group. We found that as we migrated from a host-based "dumb-terminal" system, to a client-server, PC-based system, we changed the field support guy's job and never told him. To our group's credit, they have really come around, but it has not been without pain. On the plus side, it forced us to come up with a standard interface to ease the support issues. Our standard interface now for our client-server-based applications is Windows 3.1 and the WINFMR product.

### Application 3: WORKLOAD PLANNER

Over night workload planning at a line station is common throughout the industry. Most cities end up with anywhere from 15 to 50 airplanes nightly (depending on the station) for hubs in the common hub-and-spoke system. A common scenario is that planning has identified 30 airplanes for overnight maintenance by noon. Then by four o'clock in the afternoon, 20 of those are gone and you have got 30 different aircraft. Now you are up to 40 planes. It is very hard to do overnight-line planning that truly keeps up with the real world. It takes a lot of people. There is a lot of information coming from different places. In our case, we get our information coming from Dallas systems operational control group. (SOC) We get maintenance bill-of-work information from our maintenance control group in Tulsa. (MOC) Everyone has the information on the computer, but it's not really in a user friendly format. There are lots of ways to get bit. If an airplane comes in at night and the Planning group does not have the parts or people to work on it, the airplane does not go out in the morning. Nobody wants to hear about it. That was the problem with work load planning at American Airlines. Our solution was an application called "Workload Planner." This is one of the lessons we learned. We actually sat the developer down and taught him manually to plan a night workload. We had his undivided attention for about three days. He was very happy to go back to his office after that three-day period, but at the end of it he knew exactly what he had to do. The application developed accurately reflects the job tasks and processes. Initial Application Development should be limited to a single site to maximize speed. However, input should always be requested from all different end-user groups to assure universal buy-in. Chicago has served as the beta test site for all the automation for aircraft maintenance for American Airlines.

After we developed this application, and while still in Beta form, we deployed Workload Planner to Dallas-Fort Worth (DFW). Dallas is a little bigger than Chicago, and a little busier. We loaded the application on the server. The station planner asked, "How does it work?" I asked him to begin planning their over night workload the old way and I would start the new way. Three minutes later, I handed him his completed workload, printed. He had not yet completed pulling the reports required to be able to begin planning manually. I sat down with him for ten minutes, to show him how the application worked. As it was a user-designed the interface, he immediately saw the benefit. He said, "Get out of here -- I know what to do." I had a convert.

### Application 4: M and E Administrator

We know the problems with employees -- they must have a work schedule; they must have vacation time; they must be paid correctly. You do not ever want to mess with the technicians' pay. It is just wrong. Operations Management people have their own needs. Their big concerns are:

- | How many guys will be in tonight to work?
- | I need eight technicians for four hours of overtime from midnight to four in the morning. How do I get them?
- | Who is on vacation?
- | Who is their vacation relief?

We need to be able to answer all those questions. We found that of all the applications that we did, this was the most money saving application we developed. The whole concept behind the administration program is to empower the employee. If the employee's address changes or phone number changes, the employee enters the changes into the computer. Once this entry is made, all information related to the phone number receives an update. He is now accountable for that information. In this system, the employee also wins.

Let's look at technicians' shift changes. If two technicians want to swap shifts, if it is a man-for-man swap, with no loss of time, most Supervisors would approve it without question. Why do I care who

it is? If the technician can input the change into the computer automatically and if it is within certain station guidelines, such as entering it more than 24 hours in advance, the computer simply just accepts it. The beauty of this procedure is that only the guy working the change-shift (CS) has to sign up. For the employee asking to be off his shift, the working technician puts whom he is relieving into the system. Crew lists and overtime information are automatically updated to reflect this change. From a management perspective, this is what happens: the technician who has agreed to work the shift change shows up to work. The worst thing that can happen is that the supervisor notes that two employees show up for one slot. The employee who signed up for the change and is working and the guy who wanted to be off that day, but may have forgotten, or never asked for or approved the change. So what do we do? We send the CS work guy home. The employee normally scheduled to work stays. What is the problem? Miscommunication occurred at the employee level, not the management level. Management got the coverage needed. The problem is between the two guys who agreed to the shift change. Management stays out of the discussion of who screwed up, saving lots of hassle.

### **Application 5: Work card Management System (WCMS)**

We all have manuals and they are a pain to work with or modify. Changes are difficult to track and distribute reliably. The current revision process may not lend itself to automation. Most maintenance organizations have work or task cards. American is in the process of going from a document printing organization to a document publishing environment. Here is the difference. Let's start with is a ten-page work or task card, which is not uncommon in most environments. Each page of the card is stamped with the last revised date for that page. It is easier to copy and replace a single page of a multiple page card that reproduce the card in its entirety. The engineer wants to make a change to page 6 of ten. In most processes, he pulls page 6, makes his change, inserts a newly dated page 6, and slides it back in the stack. At this point, I have nine pages of my ten-page card with one date and one page (page 6) with another date. It's not hard to imagine all ten pages with different dates. Now lets go into a publishing environment. In a publishing environment, we track a document by a version number into a "library." Let's take the same ten-page document, and check it into the library. As in the previous example, lets say then that I check it out of the library to make a revision to page 6. What am I changing? Am I changing the version of the document? Am I changing version of page 6 of the document? In the old system, each page of the work card became a discrete document with a version date. In a publishing environment, the dates of each of the ten pages of the revised card are updated to reflect the date of the latest change, regardless of the page revised. This change was a major effort for our engineering group to comprehend. It is OK to change the date on every page of the document, even though no information on that specific page changed. After grappling with the concept for a while, and realizing that safety and accuracy would not in any way be compromised, we were able to make the change.

Once again, the question was "who is to customer?" Engineering thought they were the customers for the work cards. They write them, approve them, and store and track them. The real customer is the technician on the floor. The technician is the one working with the card, is the one who really needs to use the data in the maintenance of the aircraft. Due to financial constraints, we were asked to limit some of the functionality of the application as designed. The functions were:

- | The technician can download a card into a local workstation, make changes to the text of the card, and submit the changes directly to engineering for update, right on line. The revision is tracked from point of origin and the status of the suggested change can be checked at any time.

- | The system must provide data relating to work hours needed and parts required for each card associated with a maintenance check. This function provides a major return on investment related to inventory control and personnel tracking.

- | The work card revision part stayed. The return-on-investment part was placed on a back burner.

Again, who is the customer? The technician on floor needs the ability to communicate easily with engineering on card changes. This is a significant Human Factors issue.

## LESSONS LEARNED: A Summary

### **Big Ship. Little Rudder.**

Organizations resist change. Just like a big boat, when the rudder turns, nothing happens for awhile. Accept the fact that it is going to take time to turn that big boat around. Things that are obvious to you may take time to be embraced by others.

### **Re-engineering**

Re-engineering is actually questioning how you are doing business and what value you create for the customers. The question remains -- who is the customer? That is the important thing. Re-engineering often calls for drastic changes.

### **Return on the investment may not be the priority.**

This is a tough one. We need to educate people on this. Return may be difficult to quantify at the beginning. Your business and operations instincts tell you that the automation makes sense, but it's not easily quantifiable. The most dramatic returns-on-investment of automation projects are invisible to those not involved directly, but make the financial go-no go decisions.

### **Baby Steps**

Do not make big changes fast, as we are talking safety aircraft here. We are not going to do anything stupid while we re-engineer or invent a process. Most organizations have realized their success on doing some things the same way for 50 years or more. Most aviation professionals are the same, and live by the creed "If it ain't broke don't fix it." What we are really telling them is that it's not broken but there is a better way to do it.

### **Know when to say when**

Senior management in most organizations is very skeptical of development groups. The people who sign the checks want to know that the development process is going to end at some point, and want to be able to quantify and realize their return on their investment in your programs. Programmers are paid and live to do one thing: develop. Know when to stop. Develop an application, get as much input as you can lock it down, roll it out and STOP. Large organizations spread across the country will have large variations in their ability to absorb automation. Don't be afraid to reap benefits of the automation you have developed. If you do not take time to reap the benefits, you are going to lose the support of senior management.

### **Automation not used is a waste of time and money.**

Involve the development group in your business. Involve the users in your design. Give the users free access to the development group, and make the developers accountable to them. Do not try to change too fast. Remember the big ship with the little rudder. Give products time to deploy and mature and give the end user community time to get used to the changes. Use your development group to support and maintain their applications during this deployment time. You have invested a significant amount of money and time in exposing them to the intricacies of your business, and you don't want to lose them or have to train new programmers. As users fully gain confidence in and embrace your technology, they will detail changes to your application that increase its effectiveness

beyond your imagination! Just one more short story before I close:

The British Airways 747 was executing an ILS into London Heathrow. All the way down, he was out to the left of the localizer, but landed safely. The tower controller cleared him off the active runway, and then said: "...and for your information, you were slightly to the left of the centerline on that approach." The Captain came straight back: "That's correct and my First Officer was slightly to the right".

May you share the same level of confidence in your efforts.

# Field Evaluation of Simplified English for Aircraft Workcards

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## ABSTRACT

The restricted technical language Simplified English ([AECMA](#), 1995) was evaluated using aircraft maintenance workcards. One hundred seventy-five practicing Aircraft Maintenance Technicians (AMTs) were given a comprehension test of four different workcards, each produced in Simplified English (SE) and Non-Simplified English (Non-SE) versions, and with two different layouts. Simplified English versions gave improved performance as measured by comprehension error rate which was reduced from 18% to 14% with SE. Most of the improvement was obtained where conditions were most challenging: for more difficult workcards and with non-native English speakers. No effects of workcard layout on performance were observed.

## INTRODUCTION

The importance of good document design practices to the writing of aircraft work control cards (workcards) has already been documented ([Bohr](#), 1978; [Patel, Drury and Lofgren](#), 1994). Patel, et al (1994) showed several deficiencies in structuring, wording, layout and typography, and related these to potential errors by Aircraft Maintenance Technicians (AMTs) in performing their tasks. An improved design was developed and evaluated to demonstrate its superiority. This design was based on the application of the principles of document typography and layout from the human factors literature. Documents produced in the [Patel, et al](#) (1994) study had a better choice of case and font, a more consistent paragraph structure and better integration of text with graphics. There are, however, issues in document design which go beyond layout and typography.

Most major transport aircraft manufacturers now use Simplified English (SE) in their documentation. However, the impact of this restricted language on AMTs has not been directly measured. The current study provides such an evaluation to determine whether SE enhances (or degrades) comprehension of workcards by AMTs.

## Simplified English

Since Latin faded as the common scientific language, there have been various attempts to produce artificial languages to allow people of different countries to intercommunicate. For general use, the early twentieth century saw Esperanto and later Basic English ([Ogden](#), 1934). More recently,

restricted technical languages have appeared, such as Caterpillar Fundamental English (CFE) for the documentation of agricultural vehicles, and Simplified English (SE) for the documentation of procedures on commercial aircraft. More information on the development and details of these restricted languages can be found in [Shubert, Spyridakis, Holmback and Coney](#) (in press).

## Issues in Evaluation

While restricted languages such as SE make logical sense, there is still a need to evaluate their effectiveness. Despite potentially reduced ambiguity, there are still feelings among some technical writers that SE prevents them from expressing instructions in the most obvious manner. *Restricted* languages can appear *restrictive* to some. Since the documentation is designed for the user, the effect of SE on the AMT is the ultimate criterion. Hence direct evaluation of SE using actual workcards and practicing AMTs is an obvious step.

Evaluation by users has a long history in document design. For example, [McLaughlin](#) (1966) compared the readability of two versions of a government pamphlet using a comprehension test. He found the version which had been revised for readability gave improved comprehension. The relationship between readability and comprehension has been further documented in a number of studies reviewed by [Klare](#) (1978). A more recent compilation of studies of warnings ([Edworthy, Hellier and Stanton](#), 1995), showed speed of use, accuracy and rating scales as frequently-used measures of the performance of different aspects of warning design.

A major evaluation study of SE, by [Shubert, et al](#) (in press) followed a methodology similar to that of [McLaughlin](#) (1966) using a comprehension test. SE and Non-SE versions of two maintenance manual procedures were tested on 127 engineering students. While having comparable overall lengths, the two procedures differed in a number of measures of writing complexity, one being more complex than the other. A between-subjects experimental design was used, where each subject was tested on only one of the four documents. The comprehension test was timed and performance on the test was measured both by whether each question had the correct answer and whether the information used for the answer could be located correctly within the maintenance manual procedure.

Analyses were performed separately for native English speakers and non-native English speakers and for the two maintenance manual procedures which differed in complexity. Measures of both the comprehension and the content location showed a significant effect of Simplified English and a significant Simplified English  $\times$  Procedure interaction. The native English speakers scored higher than their non-native English speaking counterparts. Simplified English gave higher comprehension and location scores than non-Simplified English for the more complex procedure only. Performance time was not a significant factor, except that non-native English speakers were slower overall.

From these studies it was concluded that to evaluate a restricted language we must control both the users' native language and the document complexity. In addition, the evaluation should focus on the accuracy of comprehension using a comprehension test based upon the documents themselves. "Accuracy of comprehension" should measure the correctness of both comprehension questions and location questions.

## METHODOLOGY

The basis of our methodology was to extend the comprehension test technique to the use of workcards by practicing AMTs. Differences from the [Shubert, et al.](#) (in press) study were the choice of subjects (AMTs *versus* students), levels of document complexity (four workcards *versus* two procedures) and the addition of two levels of workcard layout to provide a test performance of the [Patel, et al.](#) (1994) results.

## Choice of Workcards

Following discussions with computational linguists at Boeing Inc. and with Aerospace Industries Association of America (AIAA) Simplified English Committee members, it was decided to use actual examples of existing workcards in the evaluation. For two aircraft types, Boeing had produced workcards in pre-SE maintenance manual language and had later modified these to Simplified English standards. Thus the workcards were realistic AMTs and represented actual writing practice by those who write maintenance manual procedures. In this way, difficulties of translating Simplified English workcards back into artificial non-Simplified English versions were avoided. The one drawback of this decision was that the SE interpretation was not always "perfect", *i.e.*, AIAA committee members could still identify a few possible changes needed to ensure full compliance with the latest release of SE. The standard of SE in these workcards was high, and represented real-world "good practice." The benefits of using "real" workcards were considered to far outweigh the few possible non-SE interpretations introduced by real technical writers in their normal writing practice.

Seventeen potential workcards were analyzed for possible inclusion in the study. The Boeing computational linguists and University of Washington technical communications researchers analyzed the non-SE versions of each in terms of total words, mean words per sentence, percentage passive voice, and Flesch-Kincaid reading score. A task difficulty rating of each workcard by an experienced engineer was also used for guidance. Each of these variables was split at the median to be able to match workcards at the high or low level of each variable. From this analysis, four workcards were chosen: two "easy" on all the measures and two "difficult." Within each pair the document lengths were different, which would presumably mainly affect performance times, although document length could also affect comprehension through additional cognitive load. ([Table 15-1, appendix](#)) shows the four workcards chosen.

Each of these four workcards were then prepared in four versions:

1. Simplified English, original layout
2. Simplified English, [Patel, et al.](#) (1994) layout
3. Non-Simplified English, original layout
4. Non-Simplified English, [Patel, et al.](#) (1994) layout

The four versions were critiqued by our Boeing, University of Washington colleagues and the AIAA Simplified English Committee members. Based on their feedback, minor corrections were made to ensure consistency between versions.

## Choice of AMTs

Following pre-tests in a Greater Buffalo International Airport facility to determine the adequacy of the methodology, contacts with airline partners allowed testing to take place at eight facilities of major air carriers. These carriers were chosen to represent the USA from east coast to west coast, from northern to southern states, including the midwestern region. All the AMTs who participated in the study were volunteers, and were assured of anonymity.

One hundred seventy-five licensed AMTs, all with Airframe and Power Plant licenses, from eight major air carrier maintenance sites were tested. The age distribution of this sample shown in ([Figure 15-1, appendix](#)) and the AMT experience distribution is shown in ([Figure 15-2, appendix](#)). Mean age was 37.7 years, and mean experience 13.2 years. The data from our sample can be compared with demographic data on aircraft mechanics (in all branches of aviation) compiled for 1988 by the Bureau of Labor Statistics (BLS) ([Wash, 1991](#)). ([Table 15-2, appendix](#)) shows this data comparison. ([Table 15-3, appendix](#)) summarizes other characteristics of the AMT sample used in our study.

Wilcoxon tests of the median age in our sample shows that it was not significantly different from the BLS data ( $t = 7879$ ,  $p > 0.50$ ). For the experience distribution, the sample median was significantly

greater than the BLS data ( $t = 10,142$ ,  $p < 0.001$ ), showing that the AMTs in our study were more experienced than the AMTs of the earlier data. In particular, there were far fewer AMTs with three years or less experience, a finding probably representing reduced hiring patterns in major airlines during the 1990s.

([Figure 15-3, appendix](#)) shows the distribution of scores on a reading ability test -- the Accuracy Level Test. Scores are equivalent to reading grade levels. [Carver](#) (1987) provides data for this test for two appropriate comparison groups: freshmen undergraduate and beginning graduate students. The mean score of our sample (13.35) was significantly higher than for college freshmen (12.5) with  $t(174) = 6.95$ ,  $p < 0.001$ . However, it was significantly lower than for graduate students (14.3) with  $t(174) = -7.85$ ,  $p < 0.001$ . Thus the reading level of our AMT sample was typical of an educated adult group, i.e., above college freshmen but below graduate students. The mean was less than one grade level different from either group, showing that while the differences may be significant, they are not large in absolute terms.

## Evaluation Procedure

All the testing took place at airline maintenance facilities, in whatever room was made available. AMTs were tested individually or in groups depending upon their arrival times. Each AMT was given written instructions for completing a demographic questionnaire, a reading comprehension test, the actual workcard comprehension task and a set of workcard rating scales.

Each AMT was given one of the 16 possible workcards, i.e., four complexity levels each in four versions. Workcards were distributed in order, with a different starting point at each carrier. For the comprehension test, each AMT was given the workcard and a set of questions (20 each for three workcards, 19 for the other). Generally, a question concerning specific technical information was followed by a question asking where this information was located in the workcard. The questions demanded either a short answer, a "fill in the blank," or a multiple choice. Because the four workcards represented different procedures, there was no way to match the individual questions across workcards, i.e., ensure that the same questions were asked across all workcards.

Although there were four different versions of each workcard, there was only one version of the comprehension test to eliminate any bias in constructing or wording this test. Also, in some cases, different words were used in Simplified English and Non-Simplified English workcards to refer to the same object. In this case a neutral word with similar meaning was chosen in order to prevent bias. For example, in Simplified English, the term "Do-Not-Operate tag" was used to indicate a card that was placed on an inoperative control lever, whereas in the Non-Simplified English workcard the term "Do-Not-Operate identifier" was used. In this particular case, questions regarding these cards used the term "Do-Not-Operate marker".

The dependent variables measured were defined as follows:

1. *Demographic Variables*: Age, experience as AMT, experience with different aircraft types, native language.
2. *Reading Comprehension*: The Accuracy Level Test ([Carver](#), 1987). This was a ten-minute timed vocabulary test which measured the reading level of the AMTs as an equivalent grade level. This test has high reliability (0.91) measured on college students (Carver, 1987) and has a high validity (0.77 to 0.84) when compared to a longer standard reading test (the Nelson-Denny Reading Test).
3. *Workcard Comprehension*: Accuracy score on comprehension test, called "Test Completion Accuracy" and given as the percentage of correct answers combining accuracy of answers and accuracy of locating the answer in the workcard. Time taken to complete the reading of the workcard and the comprehension test, called "Test Completion Time" and measured with a stopwatch.

4. *Rating Scales*: Rating scale responses were based upon the evaluation scales used by [Patel, et al \(1994\)](#). They covered ease of use of the workcard and its graphics attachments, the simplicity of the English used and, finally, an overall rating of workcard usability. All were nine-point scales (0 to 8) anchored at each end with an appropriate adjective, and with their midpoints located at a scale value of 4.5.

## Experimental Design

This was a three-factor factorial experimental design with AMTs nested under all three factors. The factors were:

- | Language at two levels:
  - | Simplified English
  - | Non-Simplified English
  
- | Layout at two levels:
  - | Original layout
  - | [Patel, et al. \(1994\)](#) layout
  
- | Workcard complexity at four levels:
  - | Easy 1
  - | Easy 2
  - | Difficult 1
  - | Difficult 2

## RESULTS

All of the data from each subject were coded using the ACCESS<sup>(tm)</sup> program, and brought into MINITAB<sup>(tm)</sup> for statistical analysis. There were three main groups of variables:

### 1. Independent Variables.

- Language
- Layout
- Workcard complexity

### 2. Dependent Variables.

- | *Performance Measures on comprehension test:*
  - Test completion time
  - Test completion accuracy
  
- | *Ratings of workcard:*
  - 15 rating scale results

### 3. Possible performance predictors or co-variates.

- Age
- Experience as mechanics
- Experience with different aircraft
- Native language
- Reading comprehension score

In this report, no distinction was made between scores on correctness of answers and correctness of location. Only a single score was derived, called test completion accuracy (or just "accuracy"). The first analyses presented here assess statistically the effects of the three independent variables on the two performance measures, using selected performance predictors as co-variates. Subsidiary analyses explore the role of some of the co-variates further, e.g., native language and experience with different aircraft. These analyses are followed by those of the effects of the independent variables on rating scale scores. All analyses used analysis of variance or covariance procedures, specifically the General Linear Models technique which allows for unequal sample sizes between conditions. Statistical significance is defined here as odds of greater than 1 in 20 against an effect having arisen by chance ( $p < 0.05$ ).

## Performance Effects

For the analysis of the three major factors, a co-variate was used to reduce the expected variability between individual AMTs. The four possible individual variables which may affect performance, and therefore could be useful co-variates, were: AMT experience, inspection experience, age and reading ability score. An intercorrelation matrix of these and the two performance variables (time, accuracy) showed that inspection experience was uncorrelated with other variables and that AMT experience was highly correlated with age. The other two variables, age and reading ability were moderately correlated with time and accuracy. Correlation coefficients were calculated as 0.217 between age and task completion time and -0.158 between age and task completion accuracy. Age and reading ability were tested, singly and together, as co-variates, and gave almost identical results. Only the analyses using age as a covariate are presented here for simplicity.

([Table 15-4, appendix](#)) shows a summary of the significant effects for task completion time and task completion accuracy. The covariate (age) was significant in each case showing that times increased and accuracy decreased with increasing age. Both performance measures (time and accuracy) showed a significant workcard effect and a significant interaction between Simplified English/non-Simplified English and workcard, as shown in ([Figure 15-4, appendix](#)) and ([Figure 15-5, appendix](#)). For times, [Figure 15-4](#) shows that each workcard had a somewhat different effect of Simplified English. Workcards Easy 1 and Difficult 2 gave slower performance times, and the others faster performance times. However, for accuracy ([Figure 15-5, appendix](#)) the effects were much clearer. For the two Easy workcards, there was no significant change in accuracy between Simplified English and non-Simplified English versions, but for the two Difficult workcards, Simplified English gave clearly superior accuracy.

To determine whether the AMTs' experience on Boeing aircraft had an effect on their performance on the comprehension test, a factor of whether or not each AMT had worked on Boeing aircraft in the past two years was added to the ANCOVAs of time and accuracy. No main effect or interaction with Boeing experience was found to be significant.

In the [Shubert, et al.](#) (in press) study it had been found that SE was of greatest benefit to non-English speakers, so that a similar test was appropriate in our study. Of the 175 AMTs tested, 157 were

native English speakers and only 18 non-native English speakers. Because there was an even distribution of the 16 workcards to AMTs, nine non-native English speaking AMTs were given SE workcards and nine non-SE workcards. The number of non-native English speakers was too small for this characteristic to be used within the main ANCOVA, either as a co-variate (Boeing experience), or as a fourth factor. Hence, a separate ANOVA was performed with only two variables, each at two levels:

Language of workcard: SE or non-SE  
Native language: English or non-English

([Table 15-5, appendix](#)) shows the significance of the main effects and their interaction for task completion time and task completion accuracy. Only the AMT's native language affected task completion time significantly. Native English speakers took an average of 20.5 min. while non-native English speakers took longer, an average of 24.7 min. to complete the comprehension test. Accuracy was different between the two types of English, between native and non-native English speakers, and for the interaction of these two factors. ([Figure 15-6, appendix](#)) shows all of these effects. There was a clear superiority for Simplified English, with accuracy increasing from 76% to 86% overall. Equally important is the finding that the effect was most marked for non-native English speakers, where the improvement in accuracy was from 69% to 87%. Indeed, Simplified English allowed non-native English speakers to achieve about the same level of performance as native English speakers. Performing multiple comparisons among the four means in ([Figure 15-6, appendix](#)) shows that only the differences between the lowest mean (non-SE/non-native English speakers) and the other three were significant at  $p = 0.05$ . Thus, the scores for both groups of native English speakers and the SE non-native English speakers were essentially the same, *i.e.*, use of SE brought the non-native English speakers up to the same accuracy as native English speakers.

## Rating Scale Analyses

In the [Patel, et al](#) (1994) study, the rating scales were used to compare new and old workcard layouts. For such a simple comparison, a non-parametric statistical test could be used. However, the current study had a more complex multi-factor experimental design so that analyses of variance or covariance were the only feasible statistical analyses. This meant that the rating scales had to be assumed to produce normally-distributed responses. Histograms of the responses to each scale were plotted and no marked departures from normality noted.

In the rating scale data there were few significant effects noted in the ANCOVAs. ([Table 15-6, appendix](#)) shows the significance levels for the main effects; only a single interaction was significant. There were significant layout differences for six of the fifteen rating scales, all in favor of the original rather than the [Patel, et al](#) (1994) layout. ([Table 15-7, appendix](#)) shows the mean ratings for these significant measures. Of the four ratings which gave significant workcard effects, ([Table 15-8, appendix](#)) shows that AMTs gave low ratings to the Difficult 2 workcard on the measures listed in the table. Amount of graphics information and simplicity of English used were both rated close to the center of the scale for all workcards. The single significant interaction was workcard  $\times$  SE/non-SE for the overall rating ( $p = 0.027$ ). Of the two Easy workcards, one had SE rated better than non-SE while the other was reversed. For the Difficult workcards, both had the SE version rated better overall. No clear pattern emerges from this significant interaction.

## DISCUSSION

This large and realistic study measured the effects of SE across a range of AMT backgrounds, types of workcard and workcard layouts. The aim was to determine whether SE helps (or hinders) comprehension of workcard information, and whether it does so uniformly or mainly in particular circumstances. In doing so, it was intended to confirm and extend existing comprehension studies, and to make sound recommendations on the use of SE by the aviation maintenance community.

The major result was that SE was indeed useful, having a positive effect on comprehension accuracy without any consistent negative effect on the speed of performance. On a representative sample of 175 practicing AMTs from sites across the USA, it was accuracy which was impacted by SE, showing that performance changes with SE would be in the direction of error reduction. In this aspect, the current work mirrors that of [Shubert, et al](#) (in press), where comprehension, correctness and content location (accuracy measures) were also the affected outcome measures.

In terms of which factors interacted with the SE factor, again previous research was confirmed and extended. Both the native language of the AMT and the complexity of the workcard interacted with the SE/Non-SE factor. As ([Figure 15-6, appendix](#)) showed, the effect of SE was to improve the accuracy by about 2% for native English speakers, but by about 18% for non-native English speakers. If we consider error rates, the inverse of accuracy rates, the results look even more dramatic, as shown in ([Table 15-9, appendix](#)).

The conclusion is simple and direct: Simplified English workcards allowed non-native English speakers to achieve the same level of performance as native speakers; the non-Simplified English versions of the workcards did not.

An analogous effect was seen for the interaction between workcard complexity and Simplified English ([Figure 15-3, appendix](#)). The two Difficult workcards were the only ones where Simplified English made a significant difference. Again, in terms of error rates, we have the data in ([Table 15-10, appendix](#)).

Here, for the Easy workcards there was no difference between Simplified English and non-Simplified English, but for the Difficult workcard the errors were reduced by a third, for all users (native and non-native English speakers).

Overall, Simplified English proved to have the most effect where the most effect was needed, i.e. for those whose native language was not English and where the material was more difficult.

Because of our large and varied sample, this result is generalizable across a range of age and experience levels, and appears independent of the particular make of aircraft with which the AMT is familiar.

There were no effects of layout on performance. From the rating scale data, AMTs preferred the original workcard layout to one incorporating the [Patel, et al.](#) (1994) guidelines. This is contrary to the previous finding, but in fairness it should be pointed out that the original workcards in this study were much closer to meeting human factors guidelines than the originals in the [Patel, et al.](#) (1994) study. Here, all workcards used an easily readable typeface, laser printer output, high contrast and good paper stock. Given these improvements, AMTs may have preferred to see workcards with a more familiar layout. Also, in the [Patel, et al.](#) (1994) study, the inspectors used both types of workcards to perform an actual task on the aircraft. Perhaps rating of layout after a short comprehension test cannot be expected to give the same results as rating after use on an aircraft.

## CONCLUSIONS

1. Aircraft manufacturers and technical operations departments in airlines can use SE for workcards and be confident that it will improve comprehension accuracy.
2. The effectiveness of SE is greatest where it is most needed: for non-native English speakers and for difficult workcards. Under more favorable conditions, i.e. with native English speakers and easier workcards, SE will not adversely affect performance.
3. Workcard layout differences had no effect on comprehension.

## ACKNOWLEDGMENTS

The authors would like to acknowledge the active cooperation of many individuals and groups in this project. Special mention is made of *Boeing* (Heather Holmback, Rick Wojcik, Paul Montague), to the *University of Washington* (Jan Spyridakis, Serena Shubert) and the *AECMA Committee* (Kathleen Barthe).

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## APPENDIX

**Table 15-1:** Characteristics of the four workcards used

Workcard	Word Count	Words per Sentence	Percentage Passive	Flesch-Kinkaid
Easy 1	472	13 (lo)	13 (lo)	9.3 (lo)
Easy 2	254	8 (lo)	3 (lo)	8.6 (lo)
Difficult 1	554	19 (hi)	31 (hi)	10.8 (hi)
Difficult 2	491	17 (hi)	25 (hi)	10.4 (hi)

**Table 15-2:** Comparison of sample age and experience to 1988 Bureau of Labor Statistics data.

Measure	Range, years	Percent All Av. Mtc	Percent Current
AMT Sample			
Age	29	31.3	21.8
	30-49	50.7	63.8

	75	18.0	14.3
Experience	<3	22.9	4.6
	4-9	28.5	42.9
	10-19	16.2	32.6
	>20	32.5	20.0
	<b>All Av. Mtc Median</b>	<b>Current AMT</b>	<b>Sample Median</b>
Age	36.2	35.0	
Experience	9.4	10.0	

**Table 15-3:** Characteristics of AMT sample used in our study.

Question	Answer	Percentage
Type of Maintenance:	Line	12%
	Hangar	73%
	Shop	14%
	Other	2%
Native Language	English	90%
	Other	10%
Worked in past two years on:	Boeing	87%
	McDonald-Douglas	76%
	Airbus	22%
	Other	14%

**Table 15-4:** Significance levels for all factors and interactions in GLM ANOVA with age as a covariate.

Performance Measure		
Factor	Task Completion Time	Task Completion Accuracy
Age (covariate)	p = .001	p = 0.006
Workcard (W)	p = .001	p = 0.004
SE/Non-SE (S)	not significant	not significant (p = 0.073)
Layout (L)	not significant	not significant
W x S	p = .001	p = 0.024
W x L	not significant	not significant
S x L	not significant	not significant
W x S x L	not significant	not significant

**Table 15-5:** Significance levels for SE/Non-SE and native/non-native language effects.

Performance Measure		
Factor	Task Completion Time	Task Completion Accuracy
Language of workcard	not significant	p < 0.001
Native language	p = .010	p = 0.043
Interaction	not significant	p = 0.011

**Table 15-6:** Significance levels of main factors for rating scale data.

Measure	Workcard	SE/Non-SE	Layout
1. Readability of text	not significant	not significant	not significant
2. Continuity of information flow	not significant	not significant	not significant
3. Ease of information location	not significant	not significant	p = 0.046

- 4. Chance of missing information not significant not significant not significant
- 5. Ease of understanding p = 0.002 not significant not significant
- 6. Ease of location on aircraft not significant not significant p = 0.024
- 7. Ease of relating figure numbers not significant not significant p = 0.01
- 8. Amount of information provided not significant not significant not significant
- 9. Ease of readability of attachments p = 0.038 not significant not significant
- 10. Relating graphics to aircraft not significant not significant p = 0.016
- 11. Consistency of presentation not significant not significant p = 0.012
- 12. Compatibility with attachments not significant not significant p = 0.001
- 13. Amount of graphics provided p = 0.001 not significant not significant
- 14. Simplicity of English used not significant not significant not significant
- 15. Overall ease of usability of w/c not significant not significant not significant

**Table 15-7:** Mean ratings of both layouts for significant measures.

Measure	Original Layout	Patel, et al (1994) Layout
3. Ease of information location	5.5	5.0
6. Ease of location on aircraft	6.1	5.6
7. Ease of relating figure numbers	5.9	5.3
8. Amount of information provided	5.9	4.7
10. Relating graphics to aircraft	5.7	5.2
11. Consistency of presentation	5.8	5.3
12. Compatibility with attachments	5.9	5.1

**Table 15-8:** Mean ratings of workcards for significant measures.

Measure	Easy 1	Easy 2	Difficult 1	Difficult 2
5. Ease of understanding	5.8	5.6	5.8	4.7
9. Ease of readability of attachments	5.7	5.5	5.7	4.9
12. Compatibility with attachments	5.5	5.7	5.7	5.0
13. Amount of graphics provided	4.5	5.4	4.2	4.8
14. Simplicity of English used	5.1	5.3	4.8	4.8

**Table 15-9:** Error rates across native language for Simplified English and Non-Simplified English.

Error Rates			
Speaker Type	Non-Simplified English		Simplified English
Native English Speakers (157)	17%	15%	
Non-Native English Speakers (18)	31%	13%	
Whole Sample (175)	18%	14%	

**Table 15-10:** Error rates for easy and difficult workcards for Simplified English and Non-Simplified English conditions.

Error Rates			
Workcard Complexity	Non-Simplified English		Simplified English
Easy Workcards	17%	19%	
Difficult Workcards	18%	11%	



**Figure 15-1:** Age Distribution of AMTs in Sample



**Figure 15-2:** AMT Experience Distribution



**Figure 15-3:** Distribution of Reading Ability Test Scores



**Figure 15-4:** TIME - Simplified English vs. non-Simplified English



**Figure 15-5:** ACCURACY - Simplified English vs. non-Simplified English



**Figure 15-6:** Simplified vs. non-Simplified English for native English speakers and non-Native English speakers

## CLOSING REMARKS

*Bill Shepherd, Ph.D.*  
*Federal Aviation Administration*  
*Office of Aviation Medicine*

I have just a couple of closing comments. We are going to continue, as I said yesterday, to have these meetings on an annual basis. I always look forward to them because I have never left one of them without feeling that I have learned at least something, and often times a lot. I hope you feel the same way. I hope everyone of you has gotten at least one thing out of these meetings that will be an improvement or change for the better-- something that you are doing in your offices, work sites, etc.

Again, I want to solicit any input that you have on the kinds of things we ought to be doing in these meetings. We want to focus these meetings as much as possible-- make them as useful as possible. There is no point in having these meetings if we are talking about a lot of things that are of no interest to folks who are primarily in the airline maintenance business. So stay in touch with us and we'll stay in touch with you. You are all on our mailing list. Everybody, I think, has a copy of the [attendee list](#) and we'll continue to send things out as they materialize.

Use our Guide. I hope that is something you have incorporated into your business, in one form or another. We are going to continue to update the Guide on a regular basis, too. We will be sending you new CD-ROMs as those things are developed.

Network with each other. I think that's something that is useful. Talk to each other. You've got the attendee list, make sure that you talk to people who have said some things here that you think are useful, things that you might learn from. I think that is what makes these meetings worthwhile.

## SPEAKERS' BIOGRAPHIES

Listed Alphabetically

Alexandria, Virginia  
January 17 - 18, 1996



### JERRY P. ALLEN, JR.

*Consultant · Maintenance Human Factors · Boeing Commercial Airplane Group*

Jerry has been a Consultant on Maintenance Human Factors for the last two years at Boeing Commercial Airplane Group - Customer Services Division. He has a Master's of Science in Aviation Safety and a Bachelor's of Science in Aviation Science. Jerry was with Continental Airlines for eight years as the MX of Operations, reliability quality assurance, and safety, CRM for MX Facilitator. He was also with TWA for one year as the Flight Safety Training Instructor, trained accident investigator.

### STEVE CHERVAK

*Masters Student · Department of Industrial Engineering · SUNY-Buffalo*

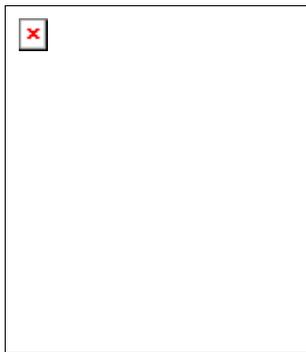
Steve has his Bachelor's of Science in Interdisciplinary Engineering and Management from Clarkston University and is currently completing his Master's of Science in Industrial Engineering with a concentration in Human Factors at the University of Buffalo. He has worked for both DuPont and McGuard Industries implementing ergonomic improvements, and is currently working under the guidance of Dr. Colin Drury on the FAA Office of Aviation Medicine's Aging Aircraft Program. Steve is also the vice-president of the Student Human Factors and Ergonomics Society.

### BILLY G. CUNNINGHAM

*Director · Technical Operations Training · Northwest Airlines*

Billy is presently Acting Director, Quality Assurance for Northwest Airlines, Technical Operations. In his position, he is responsible for Technical Training, Audit and Surveillance, Reliability Control and Maintenance Programs. He has held several management positions in both Flight and Technical Operations since joining Northwest Airlines in 1988. From 1958 to 1988 he was on active duty with

the U.S. Coast Guard, and retired with the rank of Captain. He has a Bachelor of Liberal Studies Degree from the University of Oklahoma and is also a graduate of the National War College.



### COLIN G. DRURY

*Professor · Department of Industrial Engineering · State University of New York at Buffalo*

Colin is Professor of Industrial Engineering at the University at Buffalo, where his work is concentrated on the application of ergonomics techniques to manufacturing and maintenance processes. Formerly Manager of Ergonomics at Pilkington Glass, he has over 200 publications on topics industrial process control, quality control, aviation maintenance and safety. He was the founding Executive Director of The Center for Industrial Effectiveness, which works with regional industries to improve competitiveness and has been credited with creating and saving thousands of jobs in the region. He is a Fellow of the Institute of Industrial Engineers, the Ergonomics Society and the Human Factors Ergonomics Society and the Fitts Award of the Human Factors Ergonomics Society. He has a private pilot's license.



### DR. MICA ENDSLEY

*Associate Professor · Department of Industrial Engineering · Texas Tech University*

Mica R. Endsley is an Associate Professor of Industrial Engineering at Texas Tech University. Dr. Endsley has been working on issues related to situation awareness in high performance aircraft for the past ten years, most recently expanding this research to air traffic control and maintenance for the Federal Aviation Administration. She received a Ph.D. in Industrial and Systems Engineering from the University of Southern California, with a specialization in Human Factors. She is a registered Professional Engineer and a Certified Professional Ergonomist.

## The Honorable JOHN GOGLIA

*Member · National Transportation Safety Board*

John Goglia is a member of the National Transportation Safety Board.

## DR. ANAND GRAMOPADHYE

*Professor · Department of Industrial Engineering · Clemson University*

Anand is an assistant professor of Industrial Engineering at Clemson University. His research interests are concentrated in the area of modeling humans in process and quality systems, aviation human factors, training and inspection. He is a member of the Human Factors and Ergonomics Society, Institute of Industrial Engineers and American Society for Quality Control.



## DONNACHA HURLEY

*Chief Executive · Team Aer Lingus*

Mr. Hurley took up his appointment as Chief Executive of TEAM Aer Lingus in June 1994. Since then he has been leading the drive in implementing the changes required to ensure survival and restore TEAM to profitability.

Mr. Hurley joined Sterling Drug (Ireland) in 1986 as Project/Engineering Manager where he had responsibility for the building of the manufacturing facility in Dungarvan, County Waterford.

He was appointed General Manager of the Irish operation in 1988. In 1990 Mr. Hurley was appointed Director of Manufacturing Operations, Europe/Meeasc for Sterling International where he had responsibility for manufacturing in Europe and the Middle East and Africa. In February 1991, Mr. Hurley was appointed Vice President for Manufacturing and Logistics and then Vice President Operations in March 1993 for Sterling Health Europe.

Between 1974 and 1986, Mr. Hurley held a number of senior positions with M.F. Kent - the Irish based Electrical Engineers and Contractors. He worked on a number of projects in Ireland including Project Director on the Aughinish Alumina Plant in Limerick and overseas projects in Libya, Iraq and Holland.

Mr. Hurley graduated with a first class honours degree in electrical engineering from University College Cork.



## DR. WILLIAM B. JOHNSON

*Galaxy Scientific Corporation*

Bill has a unique combination of qualifications. He is an Aviation Maintenance Technician, a pilot for 30 years, and a Ph.D. He has also served as a Designated Mechanic Examiner for the FAA. He is the Vice President of the Information Division for Galaxy Scientific Corporation in Atlanta. His Division specializes in human factors, technical information and digital documentation systems, mobile computing, and computer-based job-aiding and training systems. He is the Galaxy Program Manager for the Human Factors in Aviation Maintenance research program sponsored by the FAA Office of Aviation Medicine. Dr. Johnson, working with Professor Colin Drury, and Dr. Michael Maddox, offers custom airline human factors courses ranging from 1 to 3 days.

## JOSEPH R. KANIA

*Senior Director of Quality and Safety · USAir*

Joe was appointed Senior Director of Quality and Safety for USAir in June 1994. He has over 40 years of aircraft experience, and 33 years with USAir. He has held leadership positions in Line Maintenance, Powerplant Maintenance, Ground Equipment, and Maintenance Control. He is currently responsible for Human Factors, Safety, Quality Assurance, Inspection and Technical Records.

Joe is a member of the American Society for Quality Control, Chairman of ATA Quality Assurance Committee, Former Vice Chairman of [C.A.S.E.](#), and is involved in several ARAC Working Groups. Joe was recently honored by the Air Transport Association with the "Nuts and Bolts Award".

Joe is a graduate of the Pittsburgh Institute of Aeronautics. He holds an A&P Mechanic's License.



## *RICHARD KOMARNISKI*

*Grey Owl Aviation Consultants*

Richard is President of Grey Owl Aviation Consultants, Onanole, MB. He has worked as an aircraft maintenance technician for the last 20 years holding AME and A&P ratings. His maintenance experience has been with Regional Airlines in central Canada and Transport Canada Airworthiness Department in Central Region for five years.

His diversified career in aviation led him to the opportunity of investigating human factors and how they affect the aircraft maintenance technicians' judgment.

Richard has been providing human factors training to various aviation maintenance departments over the past two years in Canada and the U.S. He is excited about the future and the positive response that is received from the participants.



## *FRED LEONELLI*

*Manager · Aircraft Maintenance Division · FAA Flight Standards Service*

Fred is Manager of the Aircraft Maintenance Division at the FAA Flight Standards Service in Washington, D.C.



## *GOPINATH MEGHASHYAM*

*Senior Engineer · Galaxy Scientific Corporation*

Megh is currently Staff Analyst at Galaxy Scientific Corporation. He has a BS in Mech. MS

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His current projects include the Ergonomic Audit Program (ERNAP) for the FAA/AAM; the Aircraft Systems Alert Program ASAP, a Multimedia-based Aviation Fire Fighters Information Application; and the On-line Aviation Safety Inspector System (OASIS), the wireless communication application for aviation and maintenance inspectors being developed for the FAA. Among his past projects is the Advanced Technology Training System (ATS), a multimedia based tutoring application developed for EPRI and CRIEPI.

## *DAL MORTENSEN*

*Senior Staff Executive · Maintenance & Engineering-SFOEG · United Airlines*

Dal held the position of Director of Quality Assurance at United Airlines. He is currently the Senior Staff Executive of Maintenance and Engineering at United Airlines.

## *J.P. OUELLETTE*

*Program Leader · G.E. Aircraft Engines*

J.P. is the Program Leader of Maintenance Data Operation at G.E. Aircraft Engines.

He is a member of the AIA Simplified English Working Group, and is also a licensed airframe and powerplant mechanic.



## *DR. LAWRENCE J. RIFKIND*

*Associate Dean · College of Arts & Sciences · Georgia State University*

Dr. Rifkind received the Ph.D. degree in Speech Communication from Florida State University. He has been a member of the faculty at Georgia State University for 21 years. Dr. Rifkind is currently serving as an Associate Dean in the college of Arts and Sciences. His research and instructional areas include organizational communication, intercultural communication, gender and communication, sexual harassment, and nonverbal communication. He has written over 60 articles and papers. His most recent projects include the books, *Sexual Harassment in the Workplace: Women and Men in Labor* and *Cultural Collision: Quality Teamwork in the Diverse Workplace*.

## DR. MICHELLE M. ROBERTSON

*Assistant Professor · Institute of Safety and Systems Management · University of Southern California*

Michelle is an Assistant Professor at the Institute of Safety and Systems Management at the University of Southern California. Dr. Robertson has been investigating issues related to human factors and team training for the past ten years, recently focusing on the area of aviation maintenance and technical operations for the Federal Aviation Administration. She received a Ph.D. in Instructional Technology from the University of Southern California, with a specialization in Human Factors and Systems Management. Her undergraduate degree was in Human Factors from the University of California at Santa Barbara. She is a Certified Professional Ergonomist and also is a member of the executive council of the Human Factors and Ergonomics Society.



## BOB RUSSELL

*Flight Safety International*

Bob recently joined FlightSafety International as Project Manager for Maintenance Training Plans. His experience and training are in aviation maintenance management. He was Director of Aircraft Services at Duncan Aviation in Lincoln, Nebraska for seven years before joining FlightSafety. Prior to that, he was a career US Air Force officer with extensive aircraft maintenance and logistics management experience, including assignments in SR-71, U-2 and TR-1 Blackbird programs. He holds a Master of Science degree in Aviation Management from Embry-Riddle Aeronautical University.

## LCDR JOHN K. SCHMIDT MSC USN

*Human Factors Analyst · Naval Safety Center*

John is the staff Human Factors Analyst at the Naval Safety Center NAS Norfolk, VA. He has worked on military aviation human factors issues for over twelve years. His decorations include: the Meritorious Service, Navy and Army Commendation, and Navy and Army Achievement Medals. He holds a Doctorate in Psychology from the University of Houston, a License as a Psychologist in Pennsylvania, and a Certification from the Board of Professional Ergonomics. He is also a member of the American Psychological Association and the Human Factors and Ergonomics Society.

## DR. WILLIAM T. SHEPHERD

*Federal Aviation Administration · Office of Aviation Medicine*

Dr. Shepherd is the manager of the Biomedical and Behavioral Sciences Branch of the Federal Aviation Administration Office of Aviation Medicine.

WELCOME

CLOSING REMARKS

## JOHN STELLY

*Director · Systems and Training · Continental Airlines*

John was a graduate of Tulane University in 1977, after earning a BS Degree in Mathematics. He then was commissioned and officer in the U.S. Marine Corps. He served over five years on active duty in various assignments in Aviation Maintenance. After earning two personal awards for performance and innovation, he transferred to the Marine Corps Reserve where he still serves today having attained the rank of Lieutenant Colonel.

John joined Continental Airlines in 1985. His initial assignments were as Project Manager in the mergers of New York Air, People Express and Frontier Airlines with direct responsibility for Materials and Inventory Management.

The last five years, John's responsibilities shifted to maintenance as the Director of Training and Information Systems for Technical Operations. In this position he has been actively involved in diverse projects such as Technical Training Assessments, Work Card Automation, Inventory Management and Ground Damage Assessment. Additionally he has acted as Program Director for "Maintenance Resource Management" in Technical Operations since 1991.

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Diane is a Human Factors Engineer - Maintenance Human Factors Team, with Boeing Commercial Airplane Group. She has a B.S. in Metallurgical Engineering, University of Washington; M.A. in Psychology, Adler School of Professional Psychology - Chicago. Her experience includes: Materials Engineer at Puget Sound Naval Shipyard; Management Consultant to U.S. West; Human Factors Engineer at Boeing for over seven years. She created and developed the Task Analytic Training System and has been actively implementing it for the past six years.

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Terry is the Senior Systems Analyst for American Airlines in Chicago.

## Appendix A: Attendees List

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