GroundEffects

Reporting Aviation Maintenance and Groundcrew Error Reduction Efforts

January/February 1997

Volume 2

Issue 1

Visit our Web Site at:

www.groundeffects.org

Human Factors and Upper Management

by: Bonnie Hendrix

Two hours until takeoff and the engines still need to be run. There's only one person available to perform the necessary run checks. You realize you need more people to perform the task in order to maintain safety standards; however, there are no other warm bodies available to help. What do you do?

On the one hand, it is your responsibility for safety and upholding standards. On the other hand, it is your job to make sure the airplane departs on schedule. If the airplane is not ready, you've got to answer to upper management.

Today's aviation industry is built around schedules with set deadlines. In many organizations, if those deadlines are not met, management is put under a microscope. This results in pressure being put on technicians to do whatever it takes to get the job finished on time.

Compounding this pressure, today's cost saving environment has everyone trying to do more with less. Maintenance departments are trying to maintain rigid schedules with a shortage of either people, time, parts or tools. Combating these resource limitations would not pose such a dilemma if the clock wasn't so demanding; but because revenue is made by flying the airplane, the clock and schedules rule.

This critical issue of being schedule driven has two very negative effects on the industry. These effects are

(See Management page 2)

Conference 1997

Plans are well underway for the third conference to be held in Toronto, February 18 & 19.

Scheduled Speakers include:

- **John Goglia,** NTSB board member, Keynote Speaker
- **Mike Doiron,** Regional Director, System Safety, "Ground Damage Costs"
- **David Marx,** Aurora Safety and Information Systems Inc, "Discipline and Human Factors"
- **Alan Hobbs**, BASI, "Why Accidents Really Happen"
- **Ms. Lee Norvell**, FAA Aircraft Maintenance Division, "Discussing Available Safety Posters, Video Tapes, and Courses"
- **William Shepherd**, FAA and **William Johnson**, Galaxy Scientific Inc. "Human Factors Guide"

For information, contact Gordon Dupont at (604) 666-5876 or visit our web page at:

www.groundeffects.org

Visit Us On Line

Aviation Speedometers, Metrics on the Hangar Floor

by: C. Rayner Hutchinson III
CQA, DAR

During a routine audit of a large, fully rated, repair station, certificated by the Federal Aviation Administration (FAA) under Federal Aviation Regulation (FAR) Part 145, work document files were examined for compliance with the FAR requirements. An alarming rate of FAR §43.9 and §43.11 violations were discovered. This discovery triggered a detailed investigation of the facility focused on quantifying the extent of the problem. A detailed investigation of 200 randomly sampled work records, generated over the previous twelve months, revealed a violation rate of 40%. The typical entries contained abbreviations and phrases such as: R&R, Ck'd OK, Ops Ck'd Gd. or C/W. These do not meet the intent of the FAR because they are imprecise and leave much to the reader's imagination to determine what was done and what standard might have been met to allow an approval for

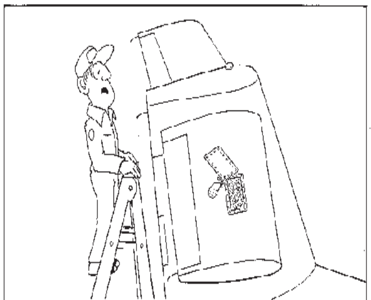
(See Speedometer pg. 4)

Inside This Edition

GroundEffects

"The Dirty Dozen"

1. Lack of Communication
2. Complacency
3. Lack of Knowledge
4. Distraction
5. Lack of Teamwork
6. Fatigue
7. Lack of Resources
8. Pressure
9. Lack of Assertiveness
10. Stress
11. Lack of Awareness
12. Norms



I guess day shift can finish screwing on the panel.

Safety Nets

- Use logbooks, worksheets etc. to communicate and remove doubt.
- Discuss work to be done or what has been completed.
- Never assume anything.

GroundEffects is published six times per year to discuss issues affecting maintenance safety and to promote the Maintenance/Groundcrew Error Conferences.

Newsletter Editor: Wayne Glover

(206) 869-5055

Graphical Layout: Rose Fechko

(206) 635-0521

Conference Director: Gordon Dupont

(604) 666-5876

Management (continued from pg. 1)

unsafe, inefficient and costly performance from technicians, and the inability of front line and middle management to create a safe and efficient work environment. These two issue are so closely related that it appears they have a cause and effect relationship. Does poor performance from the technician prevent the manager from creating a safe, efficient work environment, or does the manager's failure to create a safe, efficient work environment breed poor performance? If your perception is it could be either way depending upon the individuals, you might be correct. However, if we take the position that no technician or manger wants to be an unsafe or poor performer, then we must look elsewhere for the cause. We must acknowledge the push behind the behavior - time driven schedules. To examine the results of hard line scheduling, let's look into the negative effects it can have on the technician as well as line and middle management.

First, consider the maintenance technician who works in an environment based strictly on schedules. Too often these individuals of integrity are put in a position where they are expected to compromise their personal values, and an internal conflict builds. For example, if a technician is forced to deviate from standards, work in unsafe conditions, work to his/her physical limits, and in general try to rush quality in order to meet the schedule, the technician will suffer a loss of self esteem. Should this situation continue for an extended period of time, a survival instinct will take over and the technician will either adapt to their situation or try to change it. The more determined technicians will look for an employer they feel will allow them to use their skills in a professional manner. Some will stay and fight the battle for change. Others will adjust and become complacent and uncaring about what goes on around them. Take heed … *those that adjust may be an accident waiting to happen.*

Putting any employee in these conditions will (in the long run) cost the organization a lot more than it would if they allowed the technician the time and work environment to perform top-notch professional maintenance. Consider the cost of shotgun troubleshooting, damaged parts, hangar rash, rework, skipped items on an inspection and outright neglect of the airplane. Also consider the cost associated with morale or attitude problems: absenteeism, stress related illnesses, minor injuries, arguments, wasting time, labor disputes, high turnover and poor quality workmanship. According to the U.S. Department of Commerce 1993 Census, there were 1510 injuries with lost work days, and 280 fatalities in the aviation work place. Records indicate this cost the industry $59.9 billion in wages and lost productivity, $20.7 billion in medical fees, and $14.4 billion in administrative fees. Experience shows most accidents and injuries occur when the worker is in a hurry, under stress, and taking shortcuts to speed up a process.

Ideally, the work environment should allow a technician the time, tools and assistance to perform in a professional manner. The technician should be able to say, without fear of reprisal, "I think I need some help here," or "I'm really not up to par physically today, so double check me," or "That job really requires three people. I don't think it's safe doing it by myself." Unfortunately, the majority of organizations can't boast of having this ideal work environment. Usually the system is out of balance and standards get compromised. The average technician looks to his immediate supervisor to provide the balance, bringing us to the second negative impact of schedule demands - the inability of management to create a safe and efficient work environment.

Why doesn't the maintenance manager create a safe, effective and efficient work environment that promotes Quality, Safety and Customer Service? The most obvious reason is a rigid, demanding, do-or-die schedule. Managers appear to be placed in a position where their job and professional credibility are based on reduced operating cost and on-time departures. They feel pushed to cut corners wherever possible. They frequently spend most of their time trying to figure out how to make the schedule, rather than how to reduce risk and improve the work environment. Middle managers may be locked in the office with meetings, reports and explanations. Visits to the hangar may

Management (continued from page 2)

consist of a once or twice a week walk through on the way to a meeting. Submerged in the business end of aviation, their perception narrows. They forget the pressures in the hangar as well as the impact a technical mistake can have on the organization. Unfortunately, they fall into a job-saving survival mode.

Another reason the manager may not be able to improve the work environment is lack of training. The fact is that many times the technician that gets the front line or middle manager's position is just that, a technician. A technician who is intelligent, dependable, an excellent craftsman and usually well liked by their peers but someone who often has little understanding of Occupational Safety and Health Administration requirements, the Code of Federal Regulations, Federal Aviation Regulations, budgeting, establishing manpower requirements, justifying manpower and equipment needs, much less managing people. This individual is placed in an extremely stressful environment with a huge learning curve. This technician/manager is totally unprepared to balance the work environment.

It appears the industry has recognized the deficit in the technician's ability to deal with these out- of-balance situations and has given them much needed Human Factors training. Maintenance Resource Management training has been developed to heighten and improve the technician's ability to recognize risky situations and prevent accidents. In essence, we provide the tools for the technician to improve interpersonal skills, increase situational awareness, identify error chains, and enlighten them on how important their contributions are to the organization. But how effective is the training if management will not or cannot support and reinforce it by providing the proper work environment? It may be that management expects a short course in Human Factors to eliminate or ease what demanding schedules cause. The reality is, this will never happen.

Human Factors training will provide the technician the tools to increase productivity and safety; however, the repetition needed to perfect their use of these tools requires the support and in some cases, the demand of management. If revenue producing schedules take priority over the skill and judgment of a professional technician now, then providing Human Factors training will have only a marginal effect on the organization as a whole. You may see one or two technicians work for self improvement and become stronger contributors. However, to experience a drastic change and provide an improved work environment, first line and middle management must have the support of the schedule makers, those in upper management. The reality might be that upper management needs Human Factors training just as much, if not more than, the technicians.

Bonnie Hendrix is the manager of the Maintenance Resource Management program at Flight Safety International.

Why Would Anyone Want to Go to Toronto in February?

By Gordon Dupont

The third conference on Maintenance/Ground Crew Errors and Their Prevention will be held in Toronto, Canada on February 18 and 19, 1997. Now who would want to go to Toronto in February? You will if you have any interest in human factors training for maintenance people or groundcrews. This conference will assemble experts from various fields to discuss maintenance human factors and how you and your company can benefit from this training through improved safety and lowered costs.

Finally, the world is realizing that maintenance people and groundcrews are human and can benefit from human factors training that has long been offered to the pilots. It may have taken the famous Aloha "convertible" to focus our thinking on maintenance error or perhaps it was the gradual realization that "simple, stupid" groundcrew incidents reduce aviation safety and cost billions of dollars.

Since human factors training doesn't come with a double-your-money-back guarantee, there are many who doubt the cost effectiveness of this new maintenance human factors training. ***That is what this conference is all about***. We must develop techniques to show that the "maintenance error dragon" can be conquered. Unfortunately, even with the best of training, sometimes the maintenance error dragon wins.

This conference offers some well known aviation professionals to help us all learn some new information. The quest speakers include:

John Goglia, the keynote speaker, has looked the maintenance error dragon in the eye many times and as a board member of the NTSB is in a position to give us his view of what must be done to lessen its impact on aviation safety.

Mike Doiron will give us his view of the do-nothing cost of maintenance error. Some will suggest that these maintenance and groundcrew errors must be tolerated as part of the price of doing business. I believe that Mike, as a Regional Director of System Safety, will be able to convince you otherwise.

David Marx will provide us with a rare look at where discipline fits into all this human factors training. Dave will be asking every participant of this conference to complete a questionnaire on discipline prior to attending and the results may be released and debated at the conference during the panel discussion.

Alan Hobbs will speak on the results of an incident study he has carried out in Australia. A similar questionnaire has been distributed in Canada, and if the results are tabulated in time, they will be released at this conference.

Gisele Richardson, a long time advocate of human factors (See Toronto, page 4)

Toronto (continued from page 3)

training, will recap where we are and where we should be, as the luncheon speaker. If you can attend only one session then this is the one. For not only do you enjoy a good lunch, but you will hear her tell it like it is in her "velvet glove" style.

After lunch, **William Johnson** of Galaxy Scientific and **William Shepherd** of the FAA will take us through a Human Factors guide which has been produced to provide background information for anyone wanting to know more about the subject. This wealth of information is available on a CD ROM and will be demonstrated with an opportunity to try it yourself at the wine and cheese reception later that afternoon.

Lee Norvell of the FAA will give us an overview of what's available in maintenance human factors video's, posters, etc. Also, we will learn about exciting new maintenance human factors plans.

The day will finish off with **Jim Taylor** presenting a case study of some of the real costs behind a maintenance error – and it's not all dollar and cents.

The afternoon will conclude with a wine and cheese reception. This may be of the most valuable part of the conference as you will meet people and companies from around the world with the same interests as you in the new world of human factors training for maintenance and ground crew personnel. Toronto weather in February will certainly encourage all attendees to stay indoors and attend this four hour event.

The next day will have you deciding which of four workshops you wish to attend. One workshop is on the many human factors workshops now being offered by various companies. A second workshop discusses what's being done to lessen groundcrew errors. The third workshop focuses on what the military is doing to lessen their problems in this field. The final workshop takes a look at the Part 2 workshop to be offered as a follow on to Human Performance in Maintenance Part 1. Since you can't attend them all, you will have a difficult choice.

A preview of the "Dirty Dozen" posters for ground crew will be shown at this conference and it is hoped to have one of the 12 printed as a sample.

It will be an interesting time for all, so please plan to be there to help ensure it's success. The future of maintenance human factors in our industry depends on the interest we show now to solving this thing called "Human Error".

Note: This conference is sponsored to improve aviation safety. Any surplus funds from this conference are used to further Human Factors training for maintenance and groundcrew as determined by an aviation working committee.

Gordon Dupont is a Special Program Coordinator for Transport Canada. He developed the HPIM workshop in response to the F28 accident in Dryden, Ontario.

Speedometer (continued from pg 1)

return to service. Because of these non-compliances, any aircraft, aircraft engine, or component part approved for return to service based on the information in one of these documents could be considered unairworthy and the associated aircraft's airworthiness certificate could be rendered invalid.

Well established written procedures at the repair station and regulatory requirements, virtually unchanged for over 35 years, mandate that aviation work records contain at least:

- Description of the work performed, or reference to data acceptable to the Administrator
- Date of completion
- Name of the person performing the work
- Signature, certificate number, and kind of certificate of the person approving the work

During the post audit meeting, repair station management promised to issue a document to supervision requiring complete compliance with the repair station's procedures and the FAR along with a mandate for enforcement. Interviews with repair station employees indicated that repair station records have been a systemic problem for some time and supervisory enforcement of policies in general was very cyclical, very ineffective, and never lasting. During management crackdowns, the compliance rate would increase, only to return to previous levels when scrutiny was removed.

The audit team believed that a tried-and-true quality tool was in order. Something was needed to bridge the gap between management desires and work force implementation. Mechanics needed to fully understand the goal; equally important would be understanding their progress towards that goal. Some way to tell exactly how fast the organization was going (compliance rate) was what they needed. This repair station needed a speedometer.

The audit team recommended a simple metric at the floor level. The organization accepted the recommendations of the team and a customized measurement and feedback system (Maintenance Record Speedometer System) was implemented.

First, simple posters were created outlining the number of errors compared to the number of repair station records turned in to the records department (error rate). Each morning the collected data was added to a new chart and placed on the wall next to the FAR requirement posters.

This meant that those individuals creating the errant records could now see, within hours, the failure rate of their input. In addition, historical rate information remained on the graph so trend information was easily seen. The FAR documentation violation rate rose for the first flew weeks, likely due to increased scrutiny, but the competitive spirit of human nature quickly took over. Within six weeks the initial error rate was halved and within eight weeks it was at 0% and it DID NOT COME BACK! (See Speedometer, page 5)

Speedometer (continued from page 4)

Once the metrics approach began to rectify the records keeping discrepancies, it was also discovered that many technicians were performing work without using data acceptable to the Administrator, in violation of FAR §43.13(b). This violation had far worse implications than a records-keeping problem as using the incorrect data could lead to improper repairs. These incidences alos fell quickly when a similar tracking and feedback system was introduced. Again, visible and very quick feedback appeared to be the key to success. The transformation was incredible and the improvement seems to be very stable.

It seems that in any successful organized workgroup, the goal is to achieve a desired result through having the workforce exhibit a certain set of behaviors. What distinguishes exemplary management is their ability to achieve these desired behaviors effectively, repeatedly and efficiently. To this end, organizations that continuously measure their performance against their goals always seem to achieve their goals and usually much more. We found that driving the measurement/management concept down to the work level seemed to make FAR-compliant maintenance records happen with very little management involvement.

John Lingle, co-director of a survey on measurement-managed companies conducted by Wm. Schiemann & Associates, explained, "Much of the measurement-managed companies' success can be traced back to clarity of purpose and communication. When you begin to define things in measurable terms, they lose their fuzziness. You have a common language to discuss issues and assess progress."

I cannot possibly emphasize the overwhelming effectiveness we saw of communicating the goal, measuring the progress, and feeding back as quickly as possible to the workers. This is fairly simple when there is one task and a single work group. Add a whole manual of procedures and a number of different work groups with different functions and goals and you have very quickly a large number of potential progress measurement methods. If metrics help simple organizations, their benefit to complex, multi-layered organizations, albeit more challenging to implement, will be even more beneficial.

When I approach new consulting assignments I still ponder the lessons learned from this experience. My experience here suggests that simple management dictates will likely not fix the problem. Often information is lacking where it is needed most – with those performing the work. When the workers have the required information, it is amazing the improvements that can be achieved.

I promise you that some sort of metric mechanism shall be an integral part of my efforts for every future success I achieve.

Mr. Hutchinson lives in the Los Angeles area and is a licensed mechanic with inspection authorization authority, an engineering and maintenance process trainer, a certified quality auditor and teaches an IA course.

Human Factors in Maintenance: An Emerging Training Requirement

Part 2 of 2

William B. Johnson, Ph.D.
bjohnson@galaxyatl.com
Galaxy Scientific Corporation

Summary

Part one of this series described the growing demand and rationale for training related to human factors in maintenance. Part two describes the course offerings — content, instructor qualifications, course length — and experiences of the author as a provider of maintenance human factors training.

Human Factors in Maintenance: A Multifaceted Menu

Figure 1 shows the many disciplines of human factors ranging from cognitive science to organizational psychology. Because of the many disciplines, it is likely that the various maintenance human factors courses can have many approaches with a variety of instructional goals. Based on this author's review, there are significant differences, yet all of the courses available have value. The course selection must be based on the specific requirements and expectations of the student and the organization. Referring again to Figure 1, a course could be dedicated to only one of the disciplines, though from the standpoint of aviation maintenance personnel this is probably undesirable. For example, a human factors course that dwells only on human computer interface or only on principles of industrial design is not applicable to the daily job tasks of maintenance personnel. Similarly, a course that places too much emphasis on personality and human psychology also may miss the mark. A quality maintenance human factors course is likely to discuss applied principles of human-machine systems as well as appropriate applied psychology offering not only the rules of human behavior and performance, but also providing a scientific basis for the information. For example, most of the courses reviewed contain an element of "Workplace Communication." One course may offer the rule — "All supported by motherhood and apple pie. Instead, the scientific basis for the rule should be offered. A scientific basis for the above rule centers on the communication process, which includes transmitting, encoding, decoding, receiving, and providing feedback. Further, an ideal maintenance human factors course should provide numerous aviation maintenance examples to illustrate a rule or a principle. Practical examples also help to ensure user acceptance and reinforcement of the concept.

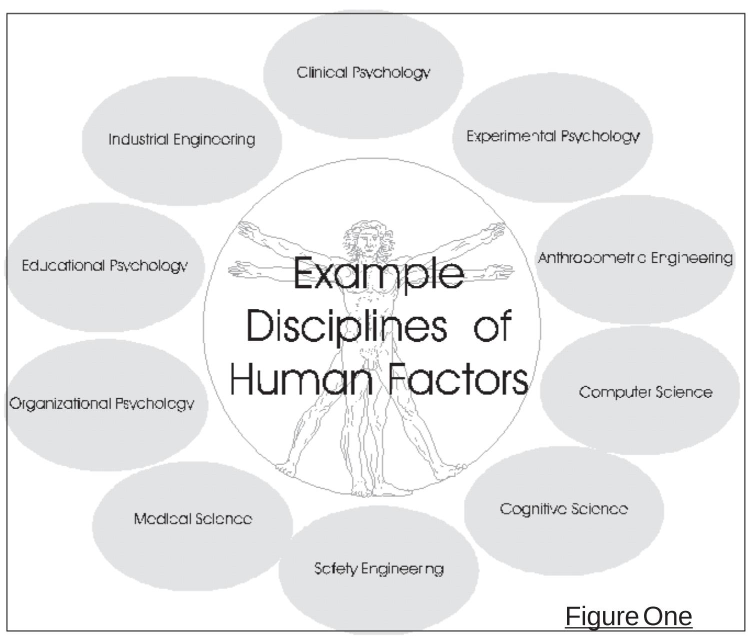


Figure One

Table 1 provides a list of topics that are candidates for a human factors course. The list is compiled of topics from many courses currently offered. The list is "Incomplete" as there are always additional topics of value. All of the topics listed in Table 1 are not likely to be covered in a single 2-3 day course. Furthermore, all of the topics may not be necessary to meet the instructional goals of all participants. A class that covers all the topics in Table 1 would require a minimum of five days.

Table 1: An Incomplete List of Human Factors Topics

- Communication in the workplace
  - Assertiveness
  - Conflict resolution
  - Decision making
  - Group dynamics/teamwork
  - Leadership
  - Planning meetings
- Economics of maint. human factors
- Error and error reporting
  - Corporate/regulatory discipline
- Human factors fundamentals
  - Analytic methods
  - Cognitive factors
  - Environmental factors
  - Human performance models
  - Physical factors
  - Medical factors and health
- Psychological Factors
  - Behavioral analysis
- Situation awareness
- Stress
- Workplace Safety

Staff Credentials

Before stating the staff credentials, first the title and number of the course staff should be discussed. The staff member(s) must be a combination of lecturer, instructor, discussion leader, group facilitator, and sometimes mediator. We shall use the term **"instructor"**. This author believes that best quality (although more expensive) is attained by having two instructors.

Who should teach/guide a human factors in maintenance course? Does the instructor need a Ph.D. degree, an A&P or pilot certificate, a human factors professional certificate? Must the instructor have airline or general aviation maintenance work experience? How many years of working/teaching experience constitute qualifications to teach/guide a course? What kind, if any, of a degree does a instructor need? Each of these questions is difficult to answer and there are varying opinions on the answer.

First and foremost the instructor must be able to define/understand the needs of the course participants. The instructor must be able to make adjustments to the planned course delivery based on the dynamic needs of the participants. To ensure such adaptability the instructor must be an excellent communicator. The instructor must have knowledge and experience beyond the lecture notes, which may have been prepared either by the instructor or by another party. Typically such capability comes from extensive experience, usually as a **teacher/instructor/public speaker**. The instructor must demonstrate an **obvious enthusiastic belief** in the value of the maintenance human factors topic.

The instructor must have knowledge and experience of human factors. This knowledge typically comes from **formal education** offered by academia and industry. Note that Flight Crew Resource Management started with extensive assistance from academic consultants. After enough flight crews were trained, the crew members became the facilitators and have done a very good job of integrating CRM into flight operations. The early academic CRM developers relied on the interactive relationship with flight crews to design appropriate CRM training. That same kind of relationship, transition of development and delivery to the maintenance personnel, is developing as the maintenance human factors courses evolve. Like CRM, maintenance human factors will have its early disappointments as well as successes.

Aviation **maintenance experience** is a very helpful, possibly even critical, attribute for a maintenance human factors instructor. Such experience is likely to ensure that the instructor understands the reality of the maintenance environment. Extensive maintenance experience means that the instructor can "talk the talk" of maintenance. Maintenance experience, in and of itself, does not qualify one as an instructor of maintenance human factors. Experience should be combined with academic and/or industrial training.

Credentials and diplomas are helpful. That includes certification as an Airframe and Powerplant Technician, Pilot certificate and ratings, and college degrees. If a person has spent 25 years becoming an expert in maintenance they probably have not had the time to become a human factors expert. Likewise, most long time human factors experts have not had the time to become maintenance experts.

The **best mix** is to combine the students, who usually have extensive maintenance experience, with trainers having reasonable human factors expertise. This combination ensures that all the topics are addressed and the maintenance personnel can help determine how the human factors principles can be applied.

The **airline specific training program**, then, is ideal because such a course will permit airline instructors to design and deliver a course catering to a company's needs. The airline instructors and developers can receive their training from academic and or special purpose courses. They can use this kind of information to design the airline specific training.

Lessons Learned

We have learned several lessons delivering human factors in maintenance courses. We have taught human factors to airlines, manufacturing engineers, nuclear utility maintenance workers, and a variety of industrial and military audiences. Without exception we have learned that **content specific examples** are the best instructional method. While examples from other industries may be helpful, aviation specific examples are absolutely necessary for aviation maintenance human factors training. Furthermore, examples must be tailored to groups comprised of maintenance training personnel, maintenance managers, or students from military, airline, or general aviation environments.

The **culture of the audience** drives the amount of classroom discussion and group activities. We have learned that the instructors must have a "bag of tricks" and must be prepared to do real-time course modification based on the class personality. Some cultures expect 2-3 days of lectures, while others will express dissatisfaction with such instructional methods. The instructor must learn as much as possible about the student expectations at the course outset. The "one size fits all" approach does not work for human factors in aviation maintenance training.

We have learned that discussions about **communication should start early** in the course. Such information reminds the student that communication is an active process and that being the student requires as much attention and work as being the instructor. A review of communication principles, at the start, also sensitizes all participants to work diligently to optimize communication throughout the course.

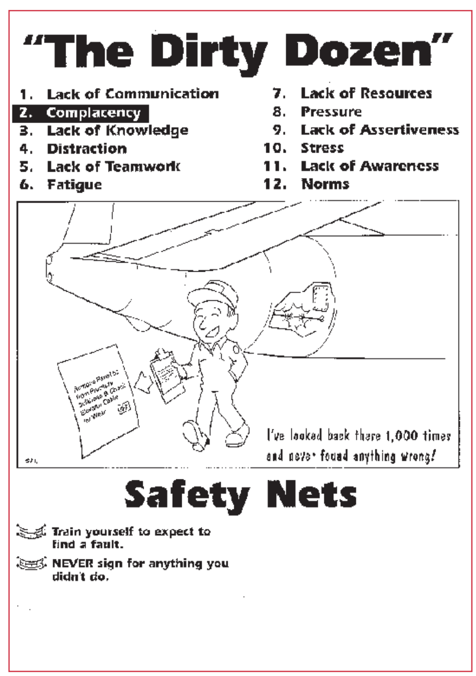
Course notes, handouts, books, and other multi-media materials should be provided to all students. We believe that the FAA *Human Factors Guide for Aviation Maintenance* is an important reference guide for a human factors course. The book was designed by a committee of airline maintenance personnel and written by human factors professionals. It is the only such source dedicated to airline maintenance and is filled with references to applicable human factors information sources. It is available from the US Government Printing Office (202-512-1800, US price is $43, International price is $53, Stock # 050-007-01098-2).

The Bottom Line

There is no question that industry interest in maintenance human factors is very high. Maintenance personnel and management recognize there is a large potential payoff in terms of continuing safety, worker satisfaction, and cost control. Maintenance human factors courses are available through a variety of consultants and professional organizations. In addition, airlines are developing and delivering their own courses to internal and well as external clients. The ball is rolling!

The next step is to share experiences throughout the industry, much as the flight CRM community has shared information. Another important step is quantify the performance change based on application of human factors principles to maintenance operations. We encourage the airline maintenance community to participate in such forums as the FAA Human Factors in Maintenance and Inspection Meetings, the Transport Canada Meetings on Maintenance Error, the variety of airline human factors seminars that are available, the FAA Maintenance Human Factors list server (hfami-l@galaxyatl.com) and website (www.hfskyway.com) , and the Ground Effects website (www.groundeffects.org). This newsletter is another excellent way to remain knowledgeable about trends and activities in airline maintenance human factors.

Dr. William B. Johnson is V.P. of the Information Division of Galaxy Scientific Corporation in Atlanta, Georgia. He is a licensed Aviation Maintenance Technician and a pilot. He has worked in Human Factors since 1976 beginning at the University of Illinois Aviation Research Laboratory.



Testing for Failure – not Success

by Wayne Glover

May 1995, an F-15 crashed on takeoff at Spangdahlem airbase in Germany killing the pilot instantly. The cause of the accident was cross-connected elevator control rods. Thus, the airplane was commanded nose down during takeoff, instead of nose-up the pilot anticipated when he pulled back on the stick.

The mechanic, Technical Sergeant Thomas Mueller, facing a court martial for his work on the accident airplane, committed suicide.

This same cross-connecting had occurred on at least two previous events, demonstrating that it was a foreseeable error and this tragedy could have been prevented. The first opportunity to prevent this tragedy was during the F-15 design and testing phase. It is here, if maintenance error is correctly integrated into the design analysis, that more of these potential maintenance errors could be detected and future accidents and economic losses could be reduced. What is needed is a better understanding of the importance of maintenance error and a systematic method to include potential errors in the design process. Understanding the likelihood and effect of these maintenance errors would allow the design or operating procedures to be modified to account for human foibles.

Lest anyone doubt it, data abounds showing maintenance error has a substantial impact on safe airplane operations. Review of industry data suggests that maintenance contributed to, but did not cause, many aviation accidents. Two studies, one of NTSB data and one by a recent industry team, assigned maintenance as a contributing factor in 14% and 15% (respectively) of all accidents; General Electric data shows 50% of all engine delays are maintenance related; and, approximately 20% of in-flight shutdown events involve maintenance. Reducing maintenance error will have a significant impact on aviation costs and safety.

Investigating a specific maintenance error, looking for contributing factors, often finds the subtle contribution of a less-than-adequate design. These contributions are seldom as conclusive or dramatic as the F-15 tragedy; however, the connection is there. For example, in the referenced industry study, design was sited as a contributor to maintenance events almost as often as mechanic actions (19 vs. 21). In fact, when all factors controlled by the manufacturers and vendors (design, manufacturing, airworthiness directive, service bulletins/in-service communications, and maintenance/inspection programs) were considered, the manufacturer/vendor were cited 47 times vs. 21 times for all factors controlled by the mechanic. This suggests factors outside the mechanic's control, but still critical to the operation, have a significant effect. The report takes pains to note they were not looking for cause, and these data should not be viewed as mechanic caused versus non-mechanic caused.

Design and testing of an airplane is a complex process. To include maintenance error in this process should not be seen as an attempt to "idiot-proof" the machine anymore than testing pilot reactions to new designs. However, the design process currently does not include human error, especially maintenance error, in a systematic method. Including human error in the design process will improve the design, and increase safety.

Understanding how design contributes to maintenance error, work must begin to improve designs by including human error in the design process of the airplane. One method would be to view the mechanic as simply another system within the airplane having it's own failure modes and analyzing their effects on the system. This type of analysis would meld well with an existing design process called Failure Modes and Effects Analysis (FMEA) and improve it.

When an airplane is designed, a failure analysis, often called a FMEA, is performed as part of the design. The intent of this FMEA is to perform a systematic analysis of each system to identify possible failure modes and ensure that the system has defenses against these failure modes. However, the current FMEA is weak in that it omits one significant source of failure – maintenance human error. Typically, the FMEA does not contain any human error in a systematic method and virtually never includes maintenance error in its analysis. However, maintenance human error is a significant source of system failure and human error data, when properly derived, can lend itself well to inclusion in the FMEA analysis and could improve the accuracy and usefulness of the FMEA.

Skepticism exists in the ability to include human error because of the virtually limitless ways people can make mistakes. Albeit true that there is a wide range of potential human errors, there are recurring threads of incorrect actions which could be accounted for in the FMEA. For example, review of incident data has shown there to be common maintenance mistakes such as: incorrect torquing and lockwiring, and missing fasteners, which are consistently mentioned. These data can supply guidance as to which maintenance errors should be included in the FMEA and which should be ignored as extremely improbable. This analytical approach to including human error should help convince skeptics that human error analysis can be logical and scientific and will not degenerate into a thousand "what ifs" of nonsensical maintenance actions.

Estimating human error has been done for several years in the nuclear powerplant designs. This work was pioneered by Dr. Alan Swain and is called human reliability analysis (HRA). This method does use a logical method and human error estimates

(Continued on page 10)

Testing (Continued from page 9)

to develop an estimate of human error potential. However, this work is nearly exclusively for control room operators and is not part of the FMEA process.

This process may not find as many new failure paths as may be anticipated because many of these maintenance-induced failure paths have already been included as equipment-induced. For example, incorrect installation of a pump would be included in the FMEA as a pump failure. Thus no additional design changes would be required based on that particular maintenance failure. However, cross connecting the inlet and outlet fluid lines, where the pump attempts to pump fluid in the wrong direction, would not likely be covered by an existing design failure mode. This failure mode, trying to pump fluid in the wrong direction, would be a new mechanic-induced failure mode requiring further review.

Another point in the design process which would benefit from including human error is the testing phase. During testing, components and systems are subjected to grueling tests looking for unanticipated failure paths. Components are subjected to conditions exceeding those expected in-service to cover unforeseen conditions. However, any maintenance procedure testing during this phase restricts mechanic actions to the correct actions. That is, the assumption is the mechanic will always have the correct tools, follow the procedure exactly, and perform the task correctly. In sort, maintenance testing (if any is performed) is a "test for success" process where design testing is "test for failure".

If the mechanic is viewed as one other component in the airplane, it stands to reason that the same level of testing should be applied to their actions as to testing components. We should actively look for maintenance errors during the testing phase by encouraging mechanics, in controlled scenarios, to deviate from procedures as they may in the real world, look for potential mistakes they may make, and, in short, look as closely for potential failures in the human component of the system as we do with any other component. At first these intentional error-promoting deviations may seem strange; however, isn't that analogous to what we do when we use design parameters for other components which exceed the expected in-service conditions ? Aggressively seeking human error may produce failure paths not anticipated by the designers, thus allowing the design to be improved.

Thus, including human error in the design and testing process, although challenging and requiring further study, can be accomplished using experiential maintenance data and the existing FMEA process. The results would be less error prone designs resulting in increased safety.

A process similar to this might have found the potential from cross connecting the cables, and an effective design change could have been developed to prevent this tragedy. It is too late for the two victims of this accident. But future accidents can be prevented.

Wayne Glover is the editor of GroundEffects and a former maintenance human factors engineer for Boeing currently working as a consultant in maintenance error management..

We Want To Hear From You

Name: Company:

Phone Number:

E-mail: Title:

Street Address:

City:

Country: Postal or ZIP code:

GroundEffects

GroundEffects
6317 157th Place NE
Suite 201
Redmond, WA 98052

Mailing
Address
Goes
Here