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I am submitting herewith a thesis written by Mark Thomas Blanks entitled "Feasibility of the Application of the Maintenance Error Decision Aid Process to General Aviation Maintenance." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

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(Original Signatures are on file with official student records.)

# FEASIBILITY OF THE APPLICATION OF THE MAINTENANCE ERROR DECISION AID PROCESS TO GENERAL AVIATION MAINTENANCE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee Space Institute, Tullahoma

Mark Thomas Blanks
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# ABSTRACT

The purpose of this study was to determine the feasibility of applying the Maintenance Error Decision Aid (MEDA) that was developed by Boeing to general aviation maintenance shops, either in its current form or with limited modification. The MEDA investigation process has been implemented successfully by several major airlines and it was assumed that general aviation could also benefit from this safety enhancing process. Because of the nature of the MEDA process, this paper only addresses the feasibility of applying the MEDA process to large shops. After consulting aviation professionals and performing extensive research, a questionnaire was created and sent to numerous general aviation (GA) maintenance managers to determine their opinion of the feasibility of the application of MEDA to GA. A total of 6 responses were received and analyzed, from which it was concluded that the MEDA system could enhance safety in general aviation with certain alterations to the system.

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# NOMENCLATURE

| Item | Description |
|---|---|
| AD | Airworthiness Directive |
| AMT | Aviation Maintenance Technician |
| ASAP | Aviation Safety Action Program |
| ASRS | Aviation Safety Reporting System |
| CAMI | Civil Aerospace Medical Institute |
| CFR | Code of Federal Regulations |
| DE | Decision Error |
| ERC | Error Review Committee |
| FAA | Federal Aviation Administration |
| FAR | Federal Aviation Regulation |
| GA | General Aviation |
| HFACS | Human Factors Analysis and Classification System |
| MEDA | Maintenance Error Decision Aid |
| NTSB | National Transportation Safety Board |
| SBE | Skill Based Error |
| US | United States |
| VMAINT | Violation by a Maintenance Technician |
| VOO | Violation by Owner/Operator |

# 1. INTRODUCTION

In a study conducted by the Civil Aerospace Medical Institute (CAMI), it was found that the accident rate for general aviation aircraft was twenty times greater than that of commercial aircraft. Also, maintenance-related errors were found to be associated with 15% of major aircraft accidents, second only to pilot error (Goldman, Fiedler, King 2002). These numbers take on more significance when the number of flight hours flown in general aviation operations is compared with those flown in scheduled air carrier operations. In 2001, there were 25,431,000 flight hours logged by general aviation operations (NTSB 2001) versus 17,157,858 hours flown by scheduled air carriers during that same year (NTSB 2005). These statistics show that general aviation flies 67% more flight hours than scheduled air carriers and also has an overall accident rate that is many times higher. One of the reasons for the disparity in these accident numbers may be that most scheduled air carrier maintenance shops have multiple measures that are used to prevent errors from going undetected. This is especially true at the large facilities that maintain the aircraft used by commercial airlines. In general aviation there are very few systems in place to eliminate errors. The purpose of this study was to determine the feasibility of applying a maintenance error investigation system to general aviation for the enhancement of safety. Specifically, the application to general aviation of the Maintenance Error Decision Aid (MEDA) system that was developed by Boeing to investigate errors and identify their contributing factors in order to reduce errors.

# 2. BACKGROUND

*2.1 – General Aviation Maintenance*

*2.1.1 – General Aviation versus Scheduled Air Carrier Operations*

Aviation is typically divided into three different segments: military operations, scheduled air carrier operations, and general aviation operations. The latter two are considered civil aviation. Of these, many people are surprised to learn that general aviation accounts for the majority of civil aviation operations. Roughly 59% of all civil operations flight hours are considered "general aviation" (NTSB 2001) and is defined as "any civil aircraft operation that is *not* covered under Federal Aviation Regulations (FARs) Parts 121, 129, and 135 commonly referred to as commercial air carrier operations" (NTSB 2001) Under this definition, general aviation encompasses a wide variety of operations and aircraft ranging from single-engine piston aircraft flown for personal use to large multi-engine turbine aircraft used for business flights. This could include everything from a Cessna 150 to a Boeing 737 Business Jet. In general aviation, the maintenance organizations vary from an aircraft mechanic/owner/operator maintaining their own airplane to large maintenance shops that employ hundreds of mechanics and avionics specialists.

Because of the wide variety of aircraft operated under the general aviation definition, the organizations that maintain these aircraft are also very diverse. Air Carrier maintenance is performed under FARs 121, 129, and 135 and has an extremely stringent set of maintenance requirements. However, general aviation is regulated by FAR 91 and maintenance requirements are not as strict. Most aircraft being operated in accordance with FAR 121 are maintained at a facility where there are numerous layers of quality

assurance and error prevention systems. In general aviation this is not normally the case. At many general aviation shops there are no systems in place to prevent or investigate errors.

*2.1.2 – General Aviation Maintenance Safety Record*

In many general aviation maintenance shops, mechanics succumb to pressure from customers to get aircraft back to flight status quickly and with minimal cost. It is not uncommon for a mechanic to allow a discrepancy to pass an inspection without correction if they do not judge it to be an immediate hazard to flight safety. This might even mean ignoring a mandatory Airworthiness Directive (AD) because of the time and cost required to perform the corrective action. This is evidenced by the statistic that 23.9% of maintenance related errors were associated with an Aircraft Maintenance Technician violation (Shappell and Wiegmann 2004). This type of error is considered an intentional violation by the FAA.

General aviation has a much higher accident rate in comparison to scheduled air carrier operations. Most of these accidents are caused by pilot errors, but there are also a substantial number of maintenance related accidents (Goldman, Fiedler, King 2002). Approximately 7.1% of all general aviation (GA) accidents that occurred between 1988 and 1997 had at least one maintenance related error as a primary cause or factor, amounting to 1,474 accidents during that ten year period (Goldman, Fiedler, King 2002). In Shappell and Wiegmann's study *General Aviation Maintenance Accidents: An Analysis Using HFACS and Focus Groups* maintenance errors were broken down into four categories: skill-based errors (SBEs), violations committed by Aviation Maintenance

Technicians (AMTs) (VMAINT), violations by owner/operators (VOO), and decision errors (DE). The percentage of which each of these categories were attributed to maintenance-related accidents is shown in Table 1 and a graphical representation is shown in Figure 1. It is noteworthy that of these errors the violations committed by owner/operators were by far the most likely to cause a fatal accident, in fact, "nearly 1/3 of the accidents attributed in part to a maintenance violation committed by an owner/operator were associated with fatalities" (Shappell and Wiegmann 2004).

*2.2 – Human Factors*

Wiener and Nagel's book, "Human Factors in Aviation", defines human factors (or ergonomics) as:

> ". . . the technology concerned to optimize the relationships between people and their activities by the systematic application of the human sciences, integrated within the framework of system engineering."

In simple terms, the field of human factors is the study of how humans interact with their environments. The goal of which is to create systems where the human element is integrated most efficiently and the system design considers human error, and attempts to minimize its occurrence. In the context of this thesis, human factors are considered with respect to the activities of the AMT in a general aviation environment. Whether dealing with confusing instruction manuals or inspecting aircraft under poor lighting conditions, human factors plays a role in every aspect of the aviation maintenance atmosphere. The following is a description of the tools that were used in the analysis of the data collected in this study.

Table 1: Maintenance-Related Accidents Causes

| Maintenance-Related Accidents Causes | | | |
|---|---|---|---|
| Skill-Based Errors (SBE) | Violations Committed by AMTs (VMAINT) | Violations by Owner/Operators (VOO) | Decision Errors (DE) |
| 50.0% | 23.9% | 12.1% | 8.2% |
| | | | |

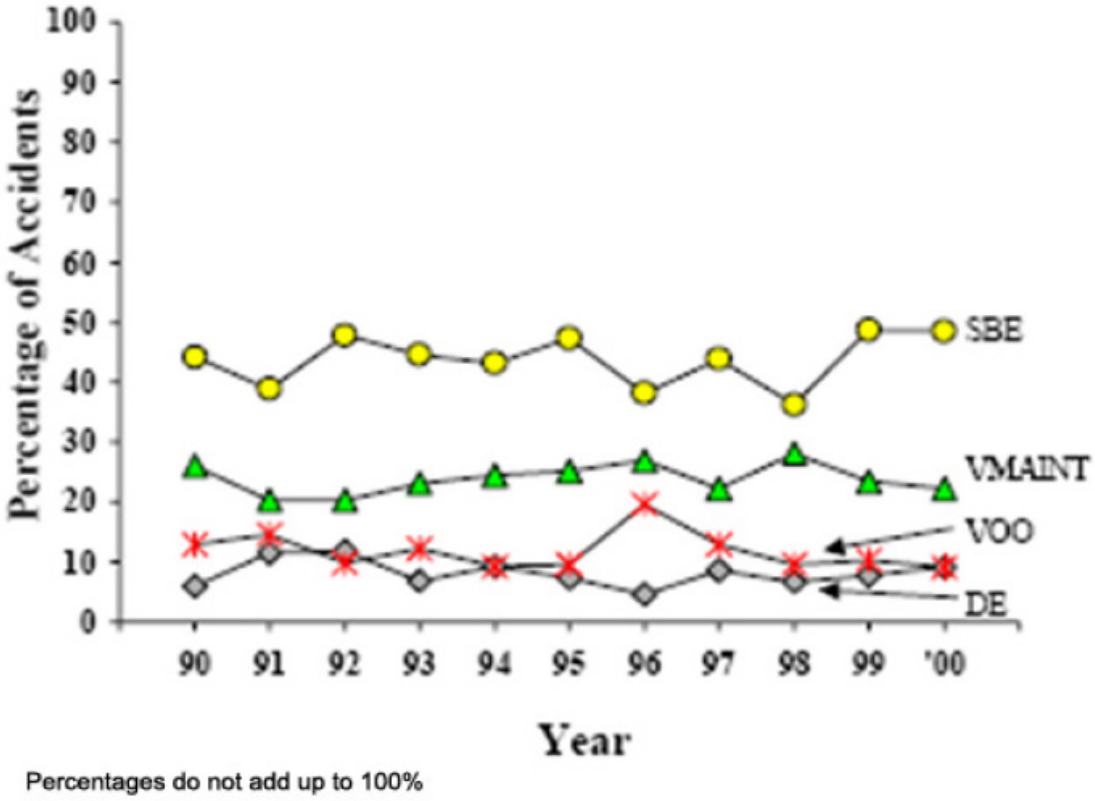



Figure 1. Maintenance-related accidents and their causes. Weigmann and Shappell 2004

*2.2.1 – The SHEL Model*

Developed by Elwyn Edwards, the SHEL model has been widely used to analyze the interactions between systems elements. For this study, problems were known to occur at the interfaces of system elements and this system provided a tool to study these occurrences. The four parts of the SHEL model are: Software, Hardware, Environment, and Liveware.

1. Software is the rules, procedures, and regulations that govern a particular activity, in this case GA maintenance.
2. Hardware is the physical property that is involved in this activity, such as the aircraft undergoing maintenance or the tools used to perform a task.
3. Environment is the setting under which all of these elements are brought together.
4. Liveware is the human factor that interacts with the other elements of the SHEL model.

Figure 2 shows a visual representation of the SHEL model and the way that the system elements interact. This shows that all of the elements are linked together and occur in the same environment.

*2.2.2 – Human Factors Analysis and Classification System (HFACS)*

Prior to the year 2000, there was no system in place to analyze aviation accidents from a human factors standpoint. Recognizing the need for such a system, Scott Shappell and Douglas Wiegmann from the FAA Civil Aeromedical Institute developed the Human Factors Analysis and Classification System (HFACS). This system is based on James

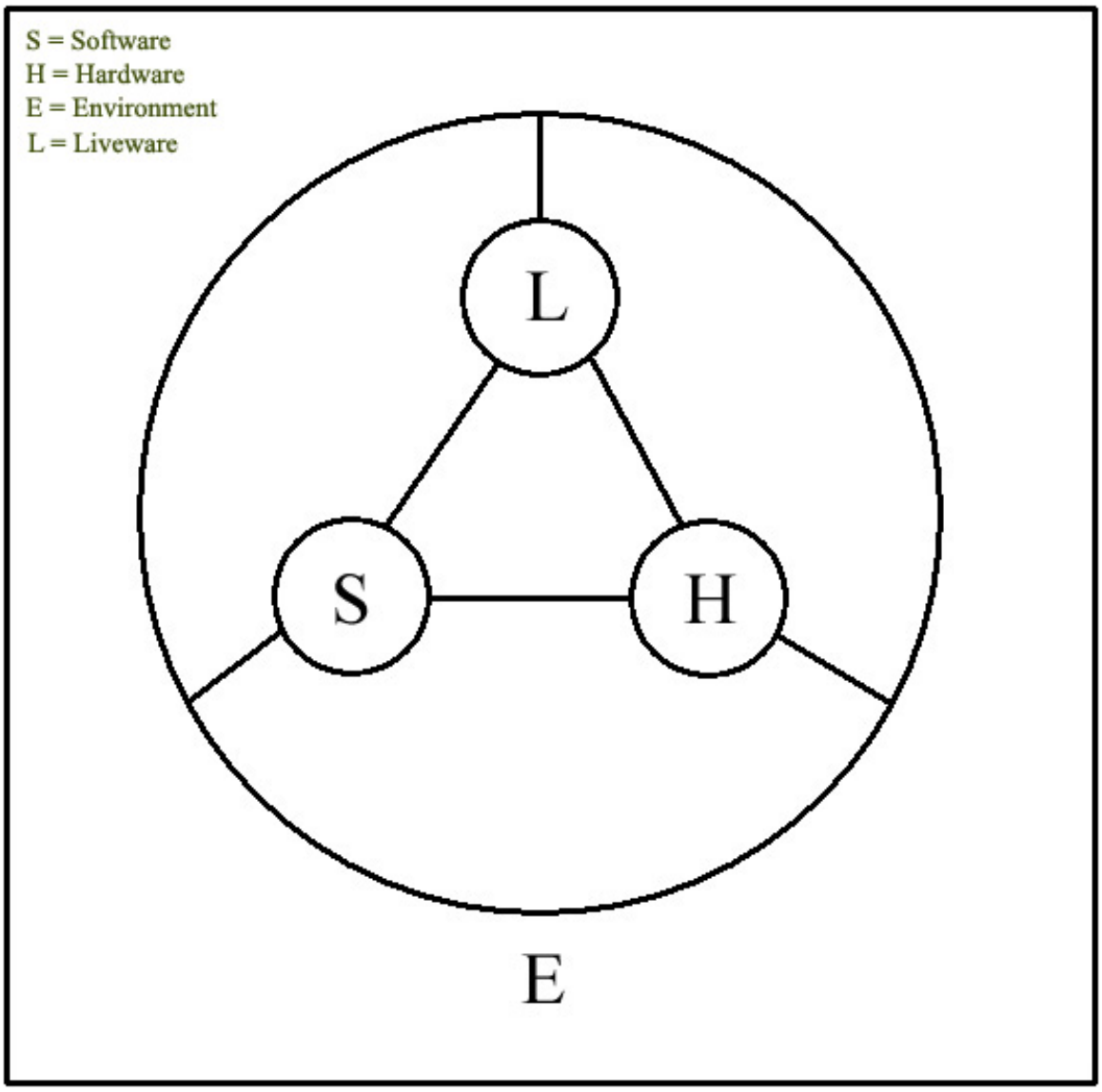



Figure 2. SHEL Model

Reason's "Swiss Cheese" model that describes the way that errors are not just a result of a single failure, but instead a series of latent failures that eventually allows an accident to occur (Reason 1990).The latent failures can be very difficult to identify, because they may have been present, yet undetected, for a long period of time before the accident occurs (Shappell and Wiegmann 2000). One of the main purposes of the MEDA system is to identify these latent failures. HFACS is a tool that can be used to analyze accidents to determine the cause of an error and are used later in this paper to look at some case studies that might be addressed by the implementation of the MEDA system.

*2.2.3 – Human Error*

In his book *Human Error,* James Reason states that the definition of human error is:

> "Error is intimately bound up with the notion of intention. The term 'error' can only be meaningfully applied to planned actions that fail to achieve their desired consequences without the intervention of some chance or unforeseeable agency. An error is NOT intentional. You make an error when: what you do differs from what you intended; or your plan was inappropriate." (Reason 1990)

It is important to notice the emphasis that errors are not intentional. Aircraft mechanics do not intend to commit an error, especially one that could lead to a tragic accident. This paper and the systems that it addresses are not intent on trying to place blame on a person for committing an error. Instead, the purpose of these systems is to identify the contributing factors that lead to errors and correct them to prevent future accidents.

The HFACS system identifies three types of errors: skill-based errors, decision errors, and perceptual errors (Shappell 2000).

1. Skill-based errors include errors due to attention failures, memory failures, and technique errors.
2. Decision errors are grouped into three areas: procedural errors, poor choices, and problem solving errors.
3. Perceptual errors occur when "one's perception of the world differs from reality." (Shappell 2000)

An in-depth description of these errors can be found in Shappell and Wiegmann's report titled *The Human Factors Analysis and Classification System – HFACS*. When used in this paper these terms for errors will refer to the HFACS definition presented in this report.

*2.2.4 – Contributing Factors*

Often called "performance shaping factors" in the human factors technical world, contributing factors are used to describe conditions that contribute to an error. The MEDA User's Guide defines "a contributing factor to an error is anything that negatively affects how a maintenance technician or inspector does his/her job." These contributing factors cover a very broad range. They can be as simple as having poor lighting during an inspection, or be as complicated as a decision that was made by upper management years before an incident that eventually led to an unsafe situation. The model shown in Figure 3 helps to clarify the concept of contributing factors.

A critical aspect of the idea of contributing factors is that errors are almost never

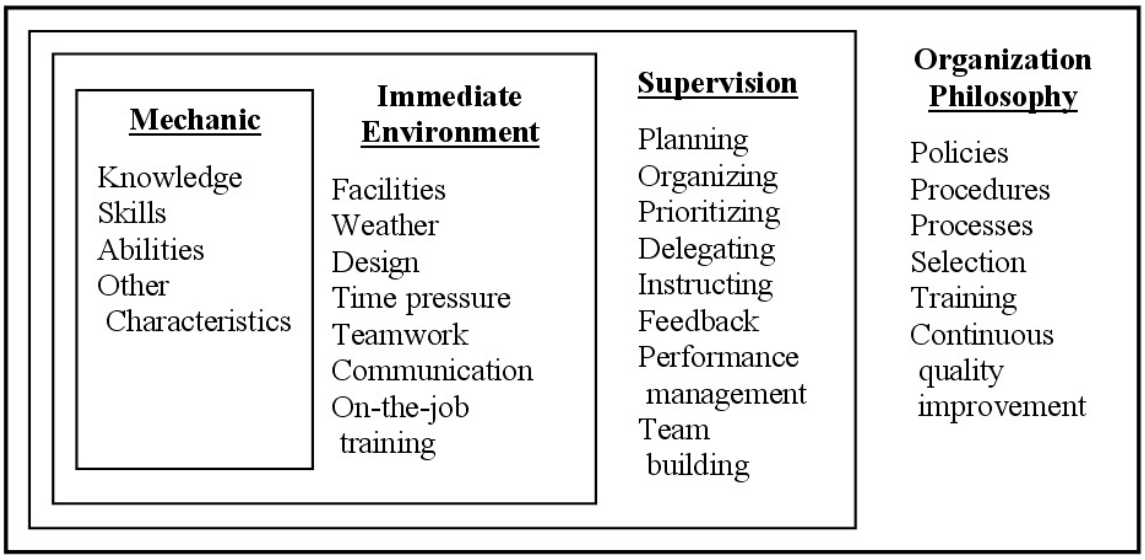



Figure 3. Contributing Factors to Maintenance Error. Source: MEDA User's Guide. 2003

caused by just a single contributing factor. Instead, it is a series of contributing factors that leads to the error. This once again refers to James Reason's "Swiss Cheese" model where "holes", which represent absent defenses against error, in multiple protection layers line up to allow a mishap to occur (Reason 1990). However, perhaps the most important thing to note is that "80%-90% of contributing factors to error are under management control, while the remaining 10%-20% are under the control of the maintenance technician or inspector" (MEDA User's Guide 2003). This concept forms the basis of how the MEDA system works and why it will or will not work in general aviation.

*2.2.5 – Human Factors in Aviation Maintenance*

There has been a large volume of research performed directly relating the application of human factors to aviation. The Federal Aviation Administration (FAA)

even has an entire division for human factors, along with a section for human factors in aviation maintenance. However, the large portion of human factors research in aviation maintenance that has been performed focuses on the scheduled air carrier maintenance setting. As discussed earlier, airline maintenance is very different than general aviation. Despite this, there have been a few significant works that directly address general aviation maintenance human factors. A paper written by the Civil Aerospace Medical Institute (CAMI), Drs. Shappell and Wiegmann, titled *General Aviation Maintenance Accidents: An Analysis Using HFACS and Focus Groups* noted that general aviation lagged behind commercial air carriers when it came to the amount of research performed on human factors (Shappell and Wiegmann 2004).

Despite the lack of GA maintenance human factors research, most of the research that has been performed at commercial air carriers can be applied to GA simply because the basic functions and responsibilities of a GA AMT and a commercial air carrier AMT are very similar. Because of this, the statistic that installation errors accounted for 29.3% of skill-based errors may also apply in premise to general aviation. For this reason, a system that works to investigate the contributing factors in a commercial air carrier setting could also feasibly be applied to general aviation.

### *2.3 – Maintenance Error Decision Aid (MEDA)*

The aforementioned references, and others, have shown that there are contributing factors that lead to human errors. There was an obvious need to investigate errors and identify contributing factors with the goal of eliminating those factors. This may prevent future errors and the accidents they cause. In the mid-1990s, a group of Boeing

representatives and other interested parties met over the course of 18 months to develop a system that would investigate these errors (Rankin 2000). The outcome of these meetings led to the Maintenance Error Decision Aid (MEDA) process to investigate errors at airlines.

The MEDA process differs from error prevention programs because it is designed as an investigation tool to uncover contributing factors. There is also a difference in the philosophy behind MEDA:

> "The Maintenance Error Decision Aid process was developed based on the philosophy that maintenance technicians do not make errors on purpose, that errors result from a series of related contributing factors, and that these factors are largely under management control and, therefore, can be changed." (Rankin 2000)

This philosophy that contributing factors can be corrected is the core idea behind MEDA system development. This differs from other maintenance error programs called Aviation Safety Action Programs (ASAPs) mainly because the FAA is not directly involved. Most ASAPs use an Error Review Committee (ERC) to gather information that can be used to determine the contributing factors of an error and the FAA is usually represented on these committees. Many AMTs are reluctant to voluntarily come forward and admit errors when they know that the FAA will be part of an ERC.

Another error related system is the Aviation Safety Reporting System (ASRS) that was developed as a means for aircrew and maintenance technicians to report errors. The person filing the report is given limited immunity as long as no criminal acts were involved and no accident occurred in return for voluntarily reporting errors. The

downfall of the ASRS system is that it is generally considered an aircrew reporting system with very few AMTs making reports and there is no attempt to identify the contributing factors that led to the error. The MEDA process does both of these.

*2.3.1 – The MEDA Process*

The MEDA process is based on the MEDA Error Model shown in Figure 4. This model shows the order in which an error causes an event and the probabilistic relationship between each of the steps. This means that after a contributing factor occurs there is a probability that it may or may not cause an error and an error has a probability of leading to an event. However, some probabilities are higher than others and can almost be assured to lead to the next step. For example, if an engine is drained of oil and the oil is mistakenly not refilled, then it is almost certain to lead to an engine failure.

There are four major events and a number of intermediate steps in the MEDA process. First, an investigation is conducted after an incident occurs to determine if maintenance error was the cause, and if so, the person responsible for the error. Second, an interview of the responsible individual determines the contributing factors to the error and corrective action that needs to be taken to eliminate these factors. This information is

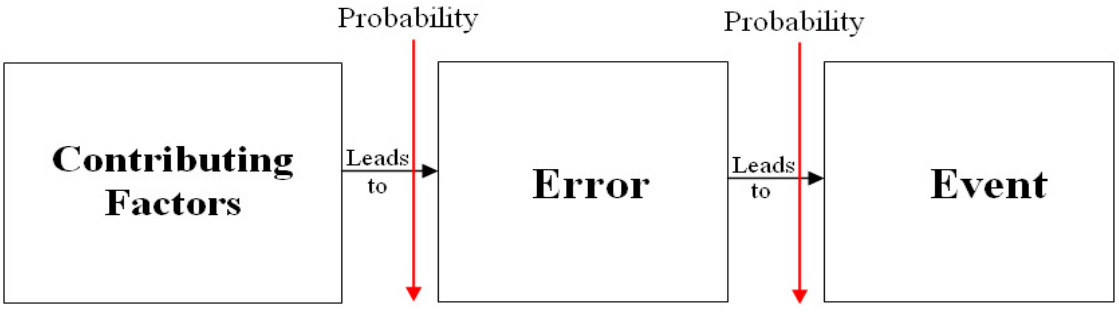



Figure 4. MEDA Error Model. Source: MEDA User's Guide. 2003

entered into the MEDA Results Form and subsequently a database. Third, the corrective action is put in place and monitored for effectiveness. Lastly, the person that committed the error and all other employees are provided feedback about the corrective action. This shows that the process is being used to make improvements and it is not being used to punish maintenance technicians (MEDA User's Guide 2003). Figure 5 shows the complete MEDA process in contrast to a typical airline investigation process.

The most important part of the MEDA process is the interview with the responsible technician. This is perhaps the most difficult part of the investigation. At the time of the interview the maintenance technician responsible is "probably the world's expert on the contributing factors to that specific error" and "on what changes need to be

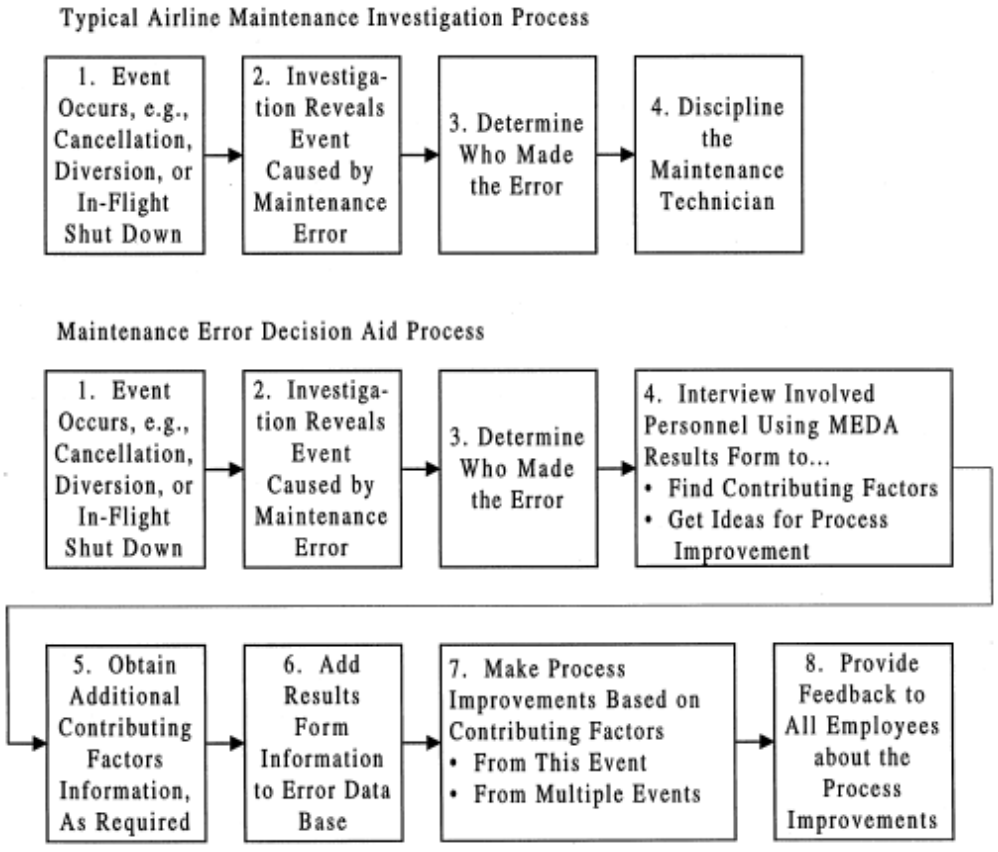



Figure 5. MEDA Process flow chart. Source: Rankin 2000.

made to the contributing factors in order to keep them from contributing to future, similar errors." (MEDA User's Guide 2003). It is the job of the interviewer to use the interview to determine both the contributing factors and the corrective actions that need to be taken from the technician's perspective.

The MEDA Results Form is the most critical piece of paperwork that is part of the MEDA process. This form is used to identify the error, contributing factors, and corrective actions. To make the MEDA system truly effective, the Results Form should be archived in a database that is shared company wide and ideally industry wide. This will help other technicians and companies implement measures to eliminate the contributing factors that can cause this specific error. Over time this database should help to significantly reduce the number of errors that occur.

*2.3.2 – MEDA System Implementation*

The MEDA system was field tested in 1994 and 1995 at eight airlines and one repair station. The system was implemented at these companies for a trial period and questionnaires were sent to the new MEDA investigators both before and after implementation of the system. Questionnaires were also given to the maintenance technician(s) involved in the investigations and management personnel. Completed Results Forms from the field test were also analyzed for correct completion and the data from the forms was compiled and summarized. Finally, meetings were held with the test organizations to get their feedback on their experience with MEDA (Rankin 2000). For detailed results of these methods of analyzing implementation, consult the paper *Development and evaluation of the Maintenance Error Decision Aid (MEDA) process* as

published in the “International Journal of Industrial Ergonomics” in the year 2000. From this test evaluation, there were many positive reports of the success of the MEDA process. In general, investigators, managers, and technicians all agreed that the MEDA process was helpful and would reduce future errors. It was also noted that the system did not create much more work for those involved. Overall, the consensus was that MEDA should be permanently implemented at all airlines and it was a useful tool to everyone involved in the process (Rankin 2000).

The acceptance of the MEDA process at the airlines was overwhelming. In fact, by 1997 over 60 additional maintenance programs had begun implementing MEDA (Rankin 2000). Therefore, acceptance was not considered to be a large problem with MEDA once the system was implemented. However, the implementation of MEDA has proven to be very difficult in some cases. Initial resistance by management, fear of punishment by technicians, and resistance to more paperwork have all been difficulties in implementing MEDA. Companies with a history of punishing technicians for errors find technicians extremely hesitant to volunteer information about errors. This greatly reduces the effectiveness of the MEDA process.

# 3. EXPERIMENT AND APPROACH

*3.1 – Application of the MEDA process to General Aviation*

The success of the Maintenance Error Decision Aid in a scheduled air carrier atmosphere suggests that this system could be beneficial if applied to general aviation. Since GA has a much higher maintenance related accident rate as compared to the airlines, it is apparent that something must be done to reduce this rate. While the MEDA system was designed to be used with airline maintenance organizations, the fundamental principles behind MEDA also apply to GA. Human error is the same whether it happens in the airline setting, GA setting, or any other industry. The principle that AMTs do not purposely make mistakes is as true for general aviation as it is for anyone else.

Given that the term "general aviation" encompasses such a wide variety of organizations, it is most likely that a system such as MEDA may not apply to the entirety of this segment of aviation. The small maintenance shops that employ a handful of technicians would probably not see much benefit from a maintenance error investigation system, because the managers of these small shops are typically aware of errors that are made and the reasons behind them. If an error is made at a small shop, it is most likely corrected by direct action immediately following the error. An error investigations system, with all of its paperwork, would probably be seen as more of burden than a help. For this reason, it is expected that only large maintenance shops employing at least 25 technicians would be receptive to implementing MEDA. Therefore, this paper only addresses the feasibility of applying the MEDA process to these large shops.

*3.2 – Research Methods*

Numerous scholarly papers, text books, and conversations with industry experts were used to gather the preliminary data for this paper. Research performed by Dr. Scott Shappell, formerly of the FAA Civil Aeromedical Institute; Dr. Douglas A Wiegmann, professor of psychology and aviation at the University of Illinois in Urbana-Champaign; Dr. William Rankin, Technical Fellow at Boeing; and many others provided much of the data used to analyze the feasibility of the MEDA system's application to general aviation.

A questionnaire was created and sent to Directors of Maintenance/General Managers at large general aviation maintenance shops, which is very similar to the way that Boeing determined the effectiveness of MEDA in the airline setting. These questionnaires were designed to utilize these industry professionals' opinions to determine acceptability of the MEDA system in GA. The questionnaire consisted of 32 opinion questions with multiple choice answers ranging from "strongly disagree" to "strongly agree". These questions were followed by a list of contributing factors that are ranked by the respondent from 1 to 11 in order of what the respondent believes is the most likely contributing factors to cause maintenance errors. Finally, two short answer questions were asked, along with a comments section, to determine the respondent's opinion of various aspects of maintenance error investigation systems. Refer to Appendix A for an example of the questionnaire.

The 32 opinion questions were divided into four categories: current shop conditions, punishment/corrective action, error probability/control, and error investigation system acceptability. These categories were further broken down to reflect whether a positive answer resulted in a positive outcome or negative outcome. All of the

question responses were averaged to give an overall opinion of the four questionnaires. The ranking list of contributing factors was also averaged to determine a consensus of the order of most influential contributing factors. From comments made by the questionnaire respondents, the ranking of contributing factors was the most difficult part of the questionnaire. This is because there are often contributing factors to an error that are not easily identifiable. Despite this, all of the respondents were in general agreement as to the order of which factors contribute to errors the most.

The questionnaires were sent to 23 medium to large GA maintenance shops, however only 6 questionnaires were returned. The response rate of 26% was lower than expected and was due to a host of factors, the most common was simply time constraints that did not allow the respondents the time to fill out a questionnaire. In spite of the low number of responses, the trends allowed the formation of an educated opinion on the feasibility of applying the MEDA system to general aviation.

### *3.2.1 – Short Answer Question One: Benefits and Difficulties*

The first short answer question was: "What positive benefits and difficulties could you foresee that implementing an error investigation system would create?" This question was asked to give the respondents a chance to state their opinion about the foreseeable pros and cons of an error investigation system. From this, it was hoped that the respondent's first overall opinion of the MEDA system could be determined.

### *3.2.2 – Short Answer Question Two: Limited Immunity*

The second short answer question was: "Do you believe that granting technicians

limited immunity from punitive action for errors they report would increase the likelihood of them admitting errors? (Immunity from non-malicious, non-criminal acts)" This questions addresses fear of punishment as a major factor that may prevent technicians from admitting errors. The respondents probably know their mechanics better than anyone, and therefore would know if granting limited immunity would spark more error reports.

# 4. RESULTS

*4.1 – Contributing Factors*

The average of the result for each of the contributing factors list responses were ranked, in order of likeliness to contribute to an error, as follows:

1. Communication between people, shifts, and organizations
2. Job/task (e.g., monotonous, too complex, different from similar tasks, etc.)
3. Qualifications/skills of technician, lead, or supervisor regarding task, process, or system issues
4. Factors specific to an individual (e.g., size, fatigue, task interruption, time constraints, etc.)
5. Supervision (e.g., poor planning/organization, inadequate prioritization, delegation of work, etc.)
6. Information (e.g., manuals, work cards, and procedures) available to the technician (e.g., not understandable, not available, not used, etc.)
7. Equipment/tools/parts (e.g., unsafe, unavailable, mis-calibrated, wrong tool, etc.)
8. Airplane design/configuration (e.g., complex, accessibility problems, configuration variability, etc.)
9. Organizational factors (e.g., support from other organizations, company policies, processes and procedures, morale, etc.)
10. Facility factors (e.g., lighting, ventilation, hazardous/toxic substances, etc.)
11. Environmental factors (e.g., heat, humidity, snow, vibration, etc.)

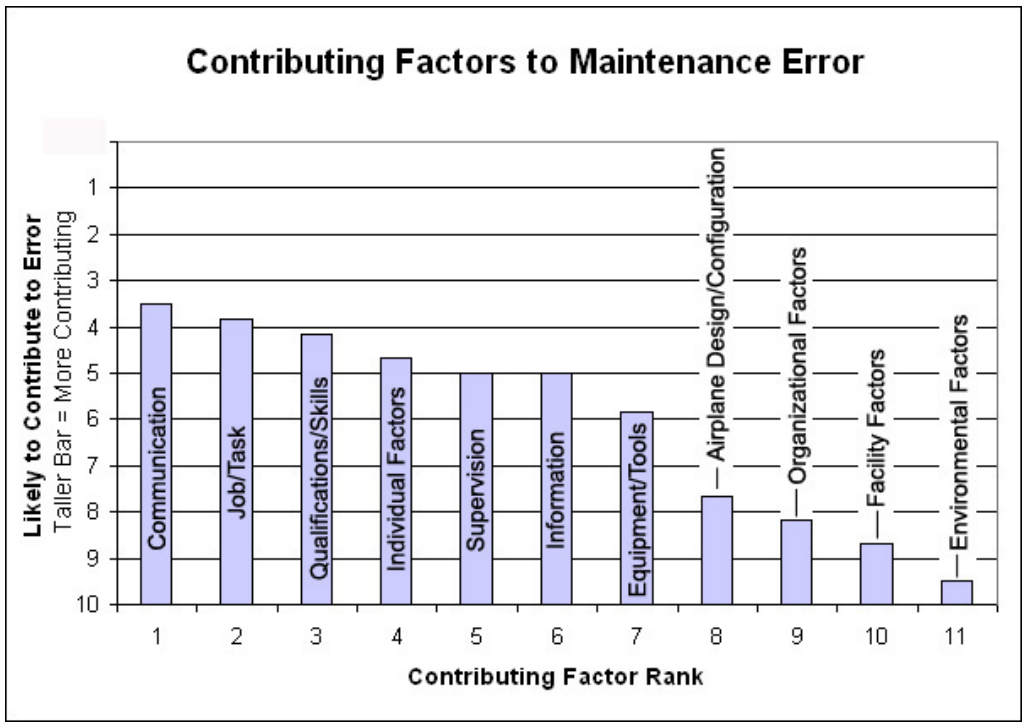



Figure 6. Contributing factors to maintenance error in order of likely to contribute to error.

Figure 6 shows the rank of each contributing factor which from left to right is likely to contribute to error. Communication was found to be the factor most likely to cause maintenance error, while environmental factors were the least likely.

*4.2 – Opinion Questions*

The following charts were generated by assigning categories and points for each of the responses to the opinion questions. The answers available were: "strongly disagree", "disagree", "no opinion", "agree", and "strongly agree". Table 2 shows the point system that was used. For each opinion question, the total numbers of points were summed and each point category was calculated for its percentage of the total number of points. These charts show the percent of each category over a 100% scale. The raw data for each of the charts can be found in Appendix B.

Table 2. Opinion Question Point System

| Opinion Question Point System | | | |
|---|---|---|---|
| Answer | Category | | |
| | Disagree | No Opinion | Agree |
| Strongly Disagree | 2 | | |
| Disagree | 1 | | |
| No Opinion | | 1 | |
| Agree | | | 1 |
| Strongly Agree | | | 2 |

*4.2.1 – Current Shop Conditions*

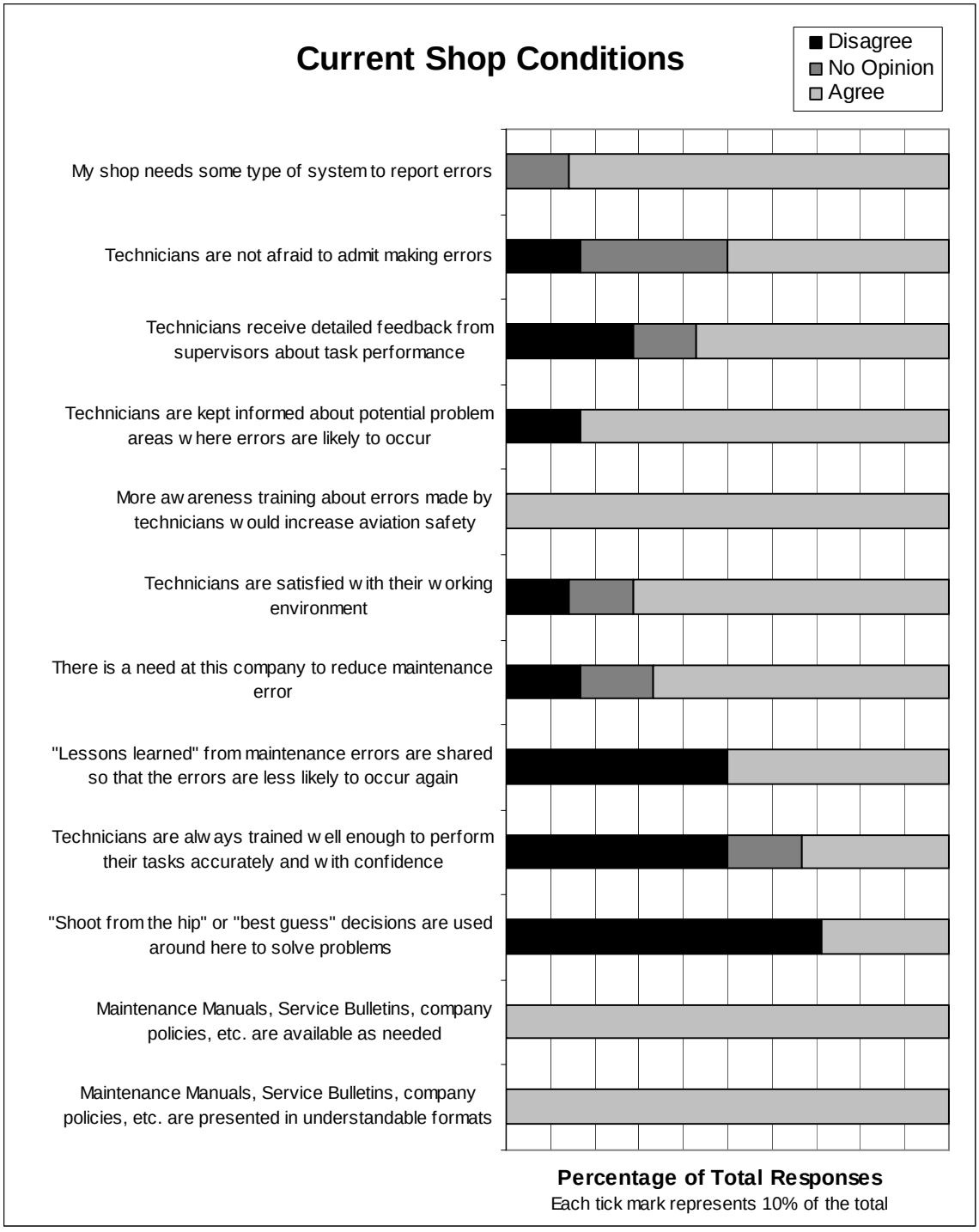



Figure 7. Current Shop Condition Questions Results.

*4.2.2 – Punishment/Corrective Action*

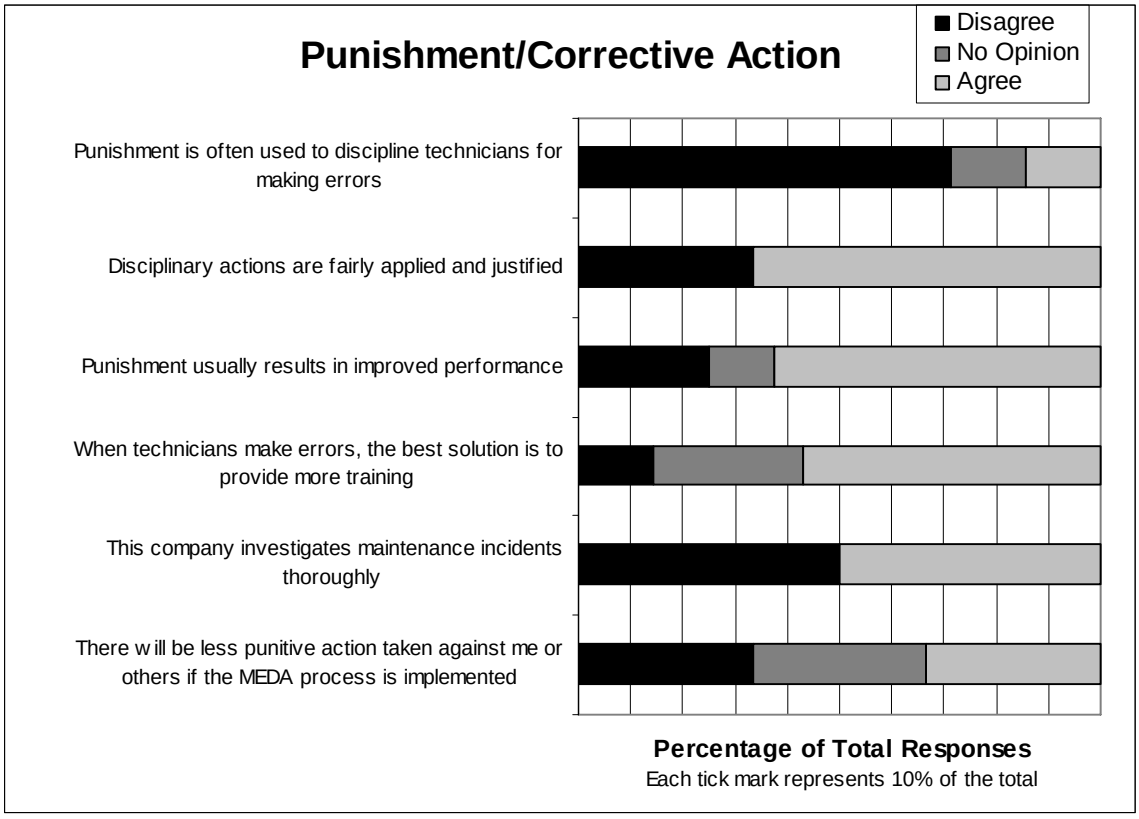



Figure 8. Punishment and Corrective Action Questions Results.

*4.2.3 – Error Probability/Control*

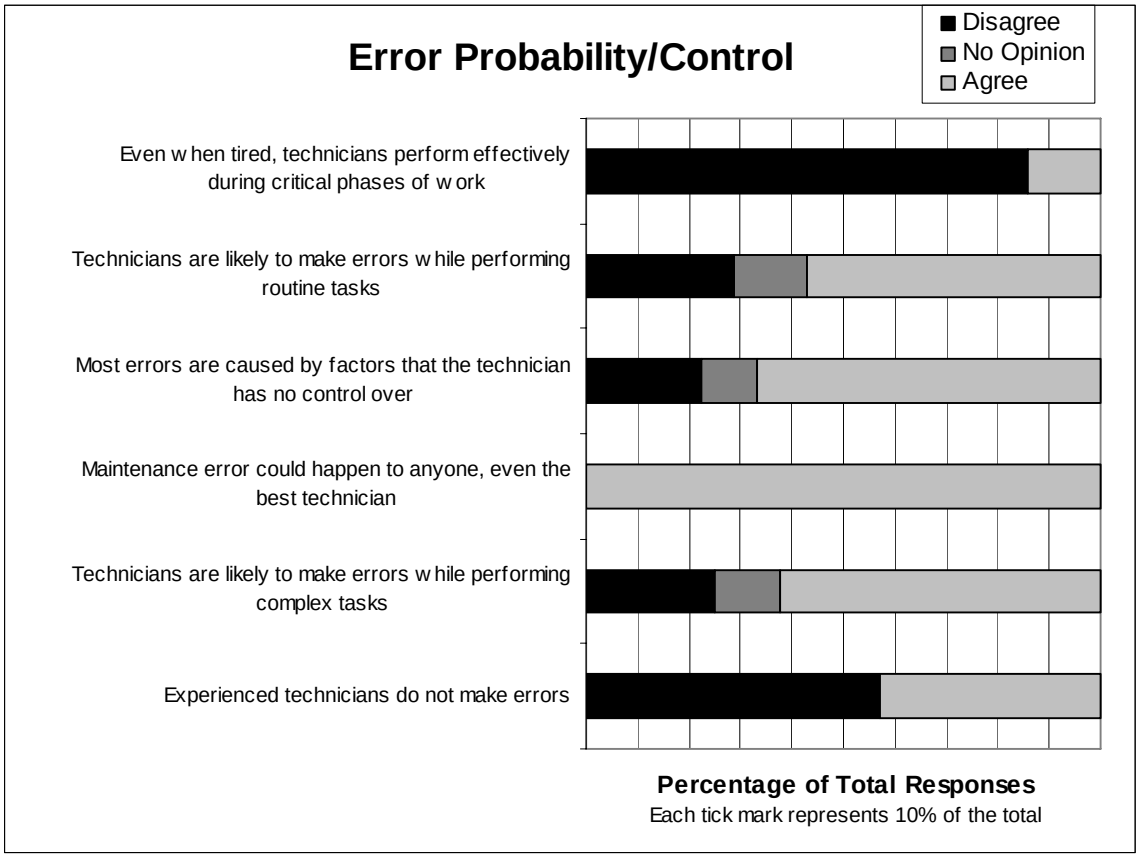



Figure 9. Error Probability and Error Control Questions Results.

*4.2.4 – Error Investigation System Acceptability*

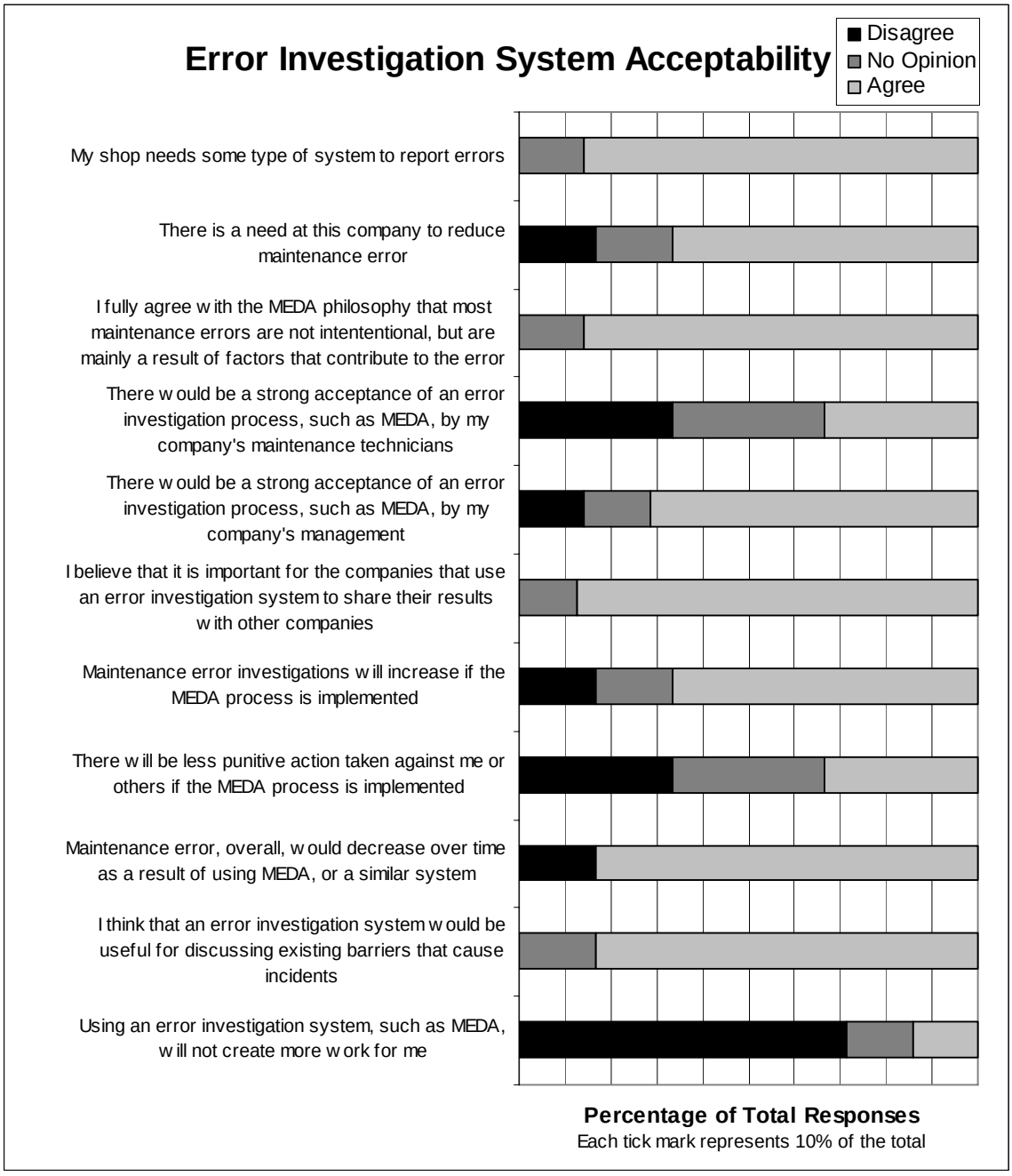



Figure 10. Error Investigation System Acceptability Questions Results.

*4.3 – Short Answer Questions*

*4.3.1 – Short Answer Question One: Benefits and Difficulties*

From the first short answer question, regarding benefits and difficulties, the respondents were split between the number of benefits and difficulties. Most felt that it would be beneficial to implement an error investigation system, but that there would certainly be some challenges. From the results, the benefits were seen to be: constant overview of errors, development of discrete steps and expectations which would in turn help eliminate errors, information about contributing factors would benefit the entire industry if shared and an increase in awareness that would result in a reduced risk of an incident. The most common difficulty that was foreseen by the respondents was time constraints. They felt that it would be difficult to find time to implement an error investigation system, but that it was not impossible. One respondent said that it would be hard to get their company to accept the system. It was also felt that some businesses would be reluctant to make their errors common knowledge whether they would be identified or not. Proper execution of the error investigation system was also a concern of one of the managers.

*4.3.2 – Short Answer Question Two: Limited Immunity*

When asked if the managers believed that granting technicians' limited immunity from punitive action for errors they reported would increase the likelihood of them admitting errors, so long as they were non-malicious or non criminal acts, they responded unanimously that it would help foster reporting. This would be similar to the ASRS system where those that report incidents are granted limited immunity from FAA

prosecution. In this case, it would be immunity from action by the company itself. One of the respondents said that, "in reality there will always be some fall out to making an error, even if limited immunity was granted." Another was quoted as saying, "a true aircraft technician that is dedicated to our industry would care enough to admit when he or she has made an error." The others simply stated "yes" that it would help increase error reports.

*4.3.3 – Comments and Suggestions*

Comments and suggestions were made by a number of the respondents. One said that simplicity was important, while another said that a global system instead of just a company system would be more beneficial to general aviation safety. One of the comments in particular agreed with the philosophy behind MEDA by saying,

> "The key is to address root cause and not symptom. This may appear to be an over-simplification, but too often we forget that most issues occur when two or more issues line up in a situation. There is often a rush to take action and little in-depth review to prevent/eliminate background issues such as equipment, worker movement between projects, or tooling issues."

# 5. DISCUSSION OF RESULTS

*5.1 – Contributing Factors*

See figure 6 for a graphical representation of the contributing factors as ranked by the respondents in order of most likely to occur. The most influential contributing factor was considered to be communication between people, shifts, and organizations. This agrees with a survey of senior US maintenance mechanics who stated that the most challenging part of their job was "human relations or dealing with people" (Reason and Hobbs 2003). Oftentimes, technicians make assumptions that someone else has already completed work, because they were not told that it was uncompleted. A case study reported by the MEDA evaluation group discussed how a technician left rags in a fuel tank for the next technician to use to finish the job. However, the technician that followed believed the job to be completed and returned to the aircraft to service with the rags still in the fuel tanks. These errors lead to a fuel system blockage in flight and subsequent aircraft diversion to the nearest airport (Rankin 2000). From the results, the respondents believe that communication is a major problem in the aircraft maintenance industry.

Following closely behind communication, the respondents believed that job/task difficulties are the most influential contributing factors. This category includes difficulties due to the task being repetitive, too complex, or very different from other tasks that are normally performed by the technician. Many technicians will attempt to perform a task that is too complex for their experience without asking for assistance just to avoid embarrassment. Sometimes the technician may be well qualified for the complex task, but makes an error because of extreme difficulty of the job. Another error

in which the job/task is a causal factor is when a technician has been performing a task and suddenly has to change procedure to complete another task that is very similar. For instance, if a technician has been inflating the tires of a certain model airplane and then has to inflate the tires of another model, this can lead to the technician accidentally over/under filling the tires.

Rounding out the top three contributing factors as ranked by the respondents are the qualification and skills of the technician, lead, or supervisor. This means that the respondents feel that experience and skill factor into the ability of a person to prevent errors to a great degree. This is a particularly strong factor when the task at hand is one that the technician has not performed in the past. James Reason and Alan Hobbs describe this situation: "Most maintenance personnel have had the experience of carrying out a new task, while not being entirely sure whether they were doing it correctly. Such trial-and-error performance is by definition prone to being unreliable" (2003). Unfortunately, this happens very often in aviation maintenance because AMTs perform such a wide variety of tasks.

The remaining contributing factors are basically self-explanatory. Despite this, there are a few things that are important to note about these results. One of these is that the contributing factor "factors specific to an individual" was reported to be only the fourth most likely factor to contribute to an error. One of the definitions listed with this factor was time constraints and it has been shown from previous studies that time constraints are one of the leading contributing factors to maintenance errors. In their study *Aircraft Maintenance Safety Survey – Results*, Hobbs and Williamson found that "time pressure was the most frequently mentioned factor leading to incidents." They also

found that 32% of technicians surveyed reported not performing a functional check due to time constraints and an astonishing 76.5% reported having turned a blind eye to a minor defect to prevent delaying an aircraft (Hobbs and Williamson 1998). It is probable that time pressure is more likely to cause an error than the respondents perceived.

Another noteworthy result from the respondents was that organizational, facility, and environmental factors ranked as the three least likely factors to contribute to maintenance error. These factors probably ranked low because they are normally secondary contributing factors, meaning that they are combined with other "primary" factors before they result in an error. While this is normally the case, one of these factors will almost always be included in a list of contributing factors of an error that is analyzed to determine its causal factors. Overall, the respondents agreed with prior studies that have been performed on the subject of contributing factors, apart from these few exceptions. Because of the low spread in all of the responses, the standard deviation from these results is very small and there is little concern about bias since this was a random sample.

### *5.2 – Opinion Questions*

#### *5.2.1 – Current Shop Conditions*

For a graphical representation of opinions on the current shop conditions, refer to figure 7. The first opinion question asked the respondents if they felt that their shop was in need of a system to report errors. The respondents unanimously agreed that their shop needed some type of system to report errors. Also, 67% said that there was a need to reduce maintenance errors at their company. However, most of those surveyed believed

that their organization did not use “shoot from the hip” or “best guess” decisions to solve problems that might arise, which means that they try to make effective decisions, but they believe errors will still occur. These results show that it is probable that a maintenance error/investigation system would be beneficial to general aviation organizations that are trying to be as professional as possible.

Most of those polled felt that technicians were kept informed about potential problem areas, but they strongly agreed that more awareness training would help to improve aviation safety. The respondents said that technicians did not receive enough training to perform all of their tasks accurately and with confidence. The solution to this that sounds the easiest is that more training should be provided, however the consistent problem with increasing training is that it imposes serious time constraints, because it takes time away from a paying job. If training levels go up, productivity will go down, at least in the short term. In the long run, though, more training would mean fewer errors and less rework, so productivity would probably rise.

Two of the most strongly agreed upon questions were about written information availability and understandability. The respondents were unanimous in their agreement that maintenance manuals, service bulletins, and company policies were available to the technicians as needed. They also agreed that these documents were presented in understandable formats. However, a study of European airlines “found that unclear task cards or vague procedures were among the main reasons for deviations from maintenance procedures” (Reason and Hobbs 2003). Therefore, it is possible that, since management was the target of this questionnaire, it may appear to management that written information is understandable, but to the technician who actually has to read them, they

may appear confusing.

83% of the maintenance managers surveyed felt that the AMTs working for their company were satisfied with their working environment. However, only 50% felt that technicians were not afraid to admit making errors. It is notable that these two were linked together for the most part. The stronger that the respondent felt the technicians were satisfied, the less afraid they were to admit making errors. This shows the close tie between trust of management and willingness to admit mistakes. This will be a key to the implementation effectiveness of an error investigation system.

*5.2.2 – Punishment/Corrective Action*

For a graphical representation of opinions on the punishment and corrective actions questions refer to figure 8. One of the greatest obstacles to successfully implementing an error investigation system will be getting technicians to admit errors if the organization has a history of punishing technicians. According to answers to questions about punishment, 83% of the respondents said that their company did not normally use punishment to discipline technicians for making errors even though 67% of the managers believed that punishment did result in improved performance. This is in contrast to the study that was performed by the MEDA evaluation group in which only 9% believed that punishment improved performance (Rankin 2000). When asked if they felt that implementing the MEDA system would result in more punitive action against them or others, the respondents were mixed in their opinions with 33% feeling it would result in more punitive action, 33% did not know, and 33% felt that it would not lead to punitive action.

Instead of using punishment, the majority of the respondents felt that training was the best solution to prevent errors from happening again. However, as mentioned before, training requires time and resources. It is far easier to simply punish a technician than it is to take the time and money to train them more effectively. Although, the training could be as simple as having a senior technician show a younger one how to properly perform a task or demonstrate areas that are prone to error. It would be difficult, though, to have a formal system to train technicians for every error that is made. An informal approach would probably work better.

*5.2.3 – Error Probability and Error Control*

For a graphical representation of opinions on the error probability and error control questions refer to figure 9. The maintenance managers were asked multiple questions regarding error probability and error control. All but one of the respondents believed that fatigue played a significant factor in the ability of technicians to perform effectively. According to Reason and Hobbs, "Recent research has shown that moderate sleep deprivation of the kind experienced by shift workers can have consequences that are very similar to those produced by alcohol" (2003). From this, a technician that has been awake for an extended period of time can show degradation in performance similar to a drunken person. Most general aviation maintenance shops do not run multiple shifts and it is not unusual for technicians to be asked to work longer than a normal eight hour shift. This situation often leads to fatigued technicians working on complex tasks. Therefore, it is likely that fatigue would be a contributing factor to error that could be identified by an error investigation system.

Interestingly, the respondents recognized that technicians not only committed errors during complex tasks, but also while performing routine tasks. This means that they realize that errors can happen at any time, although they are probably more likely to occur during complex tasks. Along the same lines, the maintenance managers believed that maintenance error could happen to anyone and even experienced technicians committed errors. There were no questions asked to determine what factor experience played in the likeliness of errors, but since qualifications and skills ranked number three on the list of contributing factors discussed earlier, it definitely plays a major role.

Perhaps the most important question that was asked of the respondents was if they believed that most errors were caused by factors that the technicians had no control over. The overwhelming majority of respondents agreed that the technician was not in control of the contributing factors to maintenance error. This is an extremely important viewpoint, because it shows that something out of the realm of the technicians control needs to be corrected to prevent future errors. This is the exact philosophy of the MEDA system. The very purpose of the system is to try and identify these contributing factors in order to correct them.

### *5.2.4 – Error Investigation System Acceptability*

For a graphical representation of opinions on the error investigation system acceptability questions refer to figure 10. The final category of opinion questions that were asked related to how the maintenance managers believed an error investigation system would be accepted in general aviation. As mentioned before, the managers polled believed that their shop needed to reduce maintenance errors and a system to report

errors. They also all agreed with the MEDA philosophy that errors were not committed intentionally, but instead were the result of a number of contributing factors. During interviews, the managers agreed that technicians did not come to work with an intention of making an error and the technicians themselves would like to never make an error.

The respondents were mixed in their opinions of whether the maintenance technicians would strongly accept an error investigation process. However, they felt that management was likely to strongly accept a system such as MEDA. Managers believed that the technicians might be afraid of a system that was investigating errors that they committed. They felt that technicians would fear punishment to them or others as a result of any investigation. Trust in management is critical. Without trust it is unlikely that technicians would accept an error investigation system. However, a strong acceptance by the company's management would enhance implementation of an error investigation system.

The overwhelming majority of maintenance managers believed that it was important for companies that use an error investigation system to share their results with other companies. This would allow for other companies to learn from errors made somewhere else and hopefully prevent the same thing from happening at their organization. The Aviation Safety Reporting System (ASRS) that was developed by NASA is similar in that it shares incident information through a published database. While the respondents did not necessarily believe that a public database would be the best solution, they did agree that general aviation companies needed a way to share their results from error investigations.

One of the most positive results from the error investigation system acceptability

questions was that the respondents felt that maintenance error investigations would increase if the MEDA process was implemented and over time maintenance error would decrease as a result of using MEDA, or a similar system. They also strongly agreed that an error investigation system would be useful in discussing existing barriers that cause incidents. This shows that there is a strong favorable opinion of the benefit of using an error investigation system in general aviation.

Most of the respondents felt very strongly that a system such as MEDA would result in more work for them, on top of their already great burden of work. This is a very legitimate concern, because despite the fact that errors overall would decrease, there would be more paperwork associated with the errors that did occur. This is one of the few reasons that a system such as MEDA might be difficult to implement in general aviation. There are usually not as many levels of management and supervision at general aviation shops as there are at airline maintenance facilities, therefore those in management perform at the peak constantly.

### *5.2.5 – Short Answer Questions*

From the responses to the short answer questions, it would appear that, overall, the respondents believe that the implementation of an error investigation system, such as MEDA, in general aviation would be beneficial by reducing future errors and increasing safety. None of the respondents expressed a negative opinion about the idea of implementing MEDA in general aviation. This leads to the assumption that maintenance managers at larger general aviation shops will be receptive to the idea of an error investigation system at their organization.

# 6. CONCLUSIONS

It is probable that the implementation of an error investigation system will be met with resistance because of fears of more work, punishment, and the effectiveness of the system. However, from the questionnaire results, it was found that maintenance managers agreed that a system was needed to reduce the number of errors at their shop and they saw communication as a major problem. They also agreed fully with the MEDA philosophy that technicians did not intentionally commit errors. It was felt that strong acceptance by management and trust in management by technicians would be key factors in the implementation of an error investigation system. However, time constraints would be a major problem in implementing MEDA because most general aviation managers are already stretched to their maximum.

Overall, aviation is a very safety minded industry, which is shown by the general opinion, according to the respondents, that general aviation companies need a way to share their results from error investigations. In addition, most felt that the system would be strongly accepted by management at their company, although the technicians may be reluctant. It will not be surprising if there is some initial resistance to the system. However, the results from this study have shown that an error investigation system can be implemented in general aviation.

# 7. RECOMMENDATIONS

*7.1 – Modification of the MEDA Process to Suit General Aviation*

To better suit general aviation, the MEDA system needs to be modified. This would include altering the results form to reflect the general aviation environment (see Appendix C for an example MEDA results form). References to airline procedures in the results form would need to be modified to reflect general aviation. These include references to ATA #, airline name, fleet number, aircraft zone, and type of maintenance (line or base). These items are not needed, because they do not represent elements of general aviation maintenance.

From the results of this study, limited immunity needs to be granted to the technicians that report errors. This would increase the number of error reports and would likely increase the acceptance of the MEDA system by technicians. As noted before, limited immunity would not protect the technicians against criminal acts and should therefore not result in a rise in violations.

*7.2 – Further Research*

Further research is needed in several areas before the MEDA system could be applied to general aviation. First, a detailed study of how to adapt the system to general aviation should be conducted. This would include, among other things, an in-depth look at the differences between airline maintenance and general aviation to determine if items should be added or removed from the results form. Second, an implementation plan for general aviation needs to be designed, including how to create a database that can be shared freely amongst the industry. Finally, a number of pilot programs should be

conducted by implementing the MEDA system at a number of large general aviation maintenance shops and analyzing the results of the system over an extended period of time. Once these studies have been conducted, implementation of the MEDA process could begin in general aviation.

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# LIST OF REFERENCES


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# APPENDICES

# APPENDIX A

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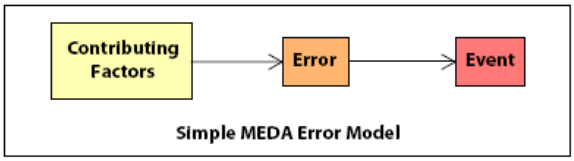
Print Form | Submit by Email

**Feasibility of the Application of the MEDA Process to General Aviation Maintenance**
Questionnaire

The Maintenance Error Decision Aid (MEDA) was developed by Boeing in an attempt to create a process that could be used to investigate the causes of maintenance errors that lead to aircraft events (like flight cancellations and in-flight engine shutdowns). MEDA was designed to be implemented by major airlines and it has been successfully tested in the airline atmosphere. Because of the success of MEDA in the airlines, it stands to reason that such a system might also be beneficial to General Aviation. The goal of this questionnaire is to determine if the MEDA system is a feasible system to use in General Aviation.

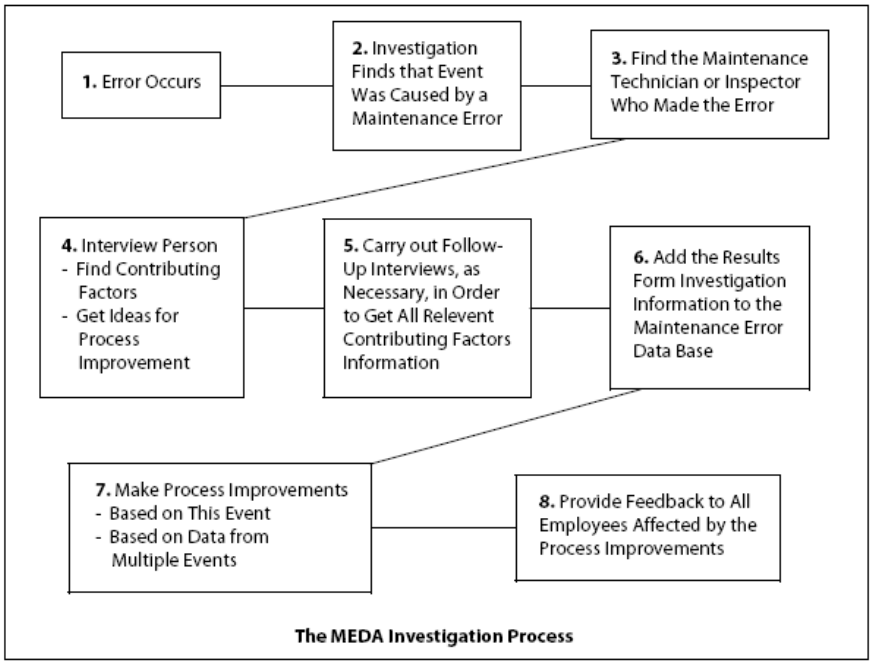
The fundamental philosophy behind MEDA is:

- Maintenance errors are not committed on purpose
- Maintenance errors result from a series of contributing factors in the work place (e.g., fatigue, inadequate lighting, and poorly written maintenance manuals.
- Most of these contributing factors are part of a company process, and, therefore, can be improved so that they do not contribute to future, similar errors
- The maintenance organization must be viewed as a system where the maintenance technician is but one part of the system
- Addressing the contributing factors to lower level events helps prevent more serious events




**Simple MEDA Error Model**

Once again, the purpose of the MEDA investigation is to identify contributing factors and improve them to reduce the chance that they will contribute to future errors. Please take just a few minutes and fill out this questionnaire carefully. Your responses to the questions will be extremely beneficial in this study. Thank you for your time.




**The MEDA Investigation Process**

*Source: Boeing Maintenance Error Decision Aid (MEDA) User's Guide. Revised 2003.*

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**Feasibility of the Application of the MEDA Process to General Aviation Maintenance**
Questionnaire

| | | Strongly Disagree | Disagree | No Opinion | Agree | Strongly Agree |
|---|---|---|---|---|---|---|
| 1 | My shop needs some type of system to report errors. | ○ | ○ | ○ | ○ | ○ |
| 2 | Technicians are not afraid to admit making errors. | ○ | ○ | ○ | ○ | ○ |
| 3 | Technicians receive detailed feedback from supervisors about task performance. | ○ | ○ | ○ | ○ | ○ |
| 4 | Even when tired, technicians perform effectively during critical phases of work. | ○ | ○ | ○ | ○ | ○ |
| 5 | Technicians are likely to make errors while performing routine tasks. | ○ | ○ | ○ | ○ | ○ |
| 6 | Most errors are caused by factors that the technician has no control over. | ○ | ○ | ○ | ○ | ○ |
| 7 | Technicians are kept informed about potential problem areas where errors are likely to occur. | ○ | ○ | ○ | ○ | ○ |
| 8 | More awareness training about errors made by technicians would increase aviation safety. | ○ | ○ | ○ | ○ | ○ |
| 9 | Technicians are satisfied with their working environment. | ○ | ○ | ○ | ○ | ○ |
| 10 | Maintenance error could happen to anyone, even the best technician. | ○ | ○ | ○ | ○ | ○ |
| 11 | There is a need at this company to reduce maintenance error. | ○ | ○ | ○ | ○ | ○ |
| 12 | "Lessons learned" from maintenance errors are shared so that the errors are less likely to occur again. | ○ | ○ | ○ | ○ | ○ |
| 13 | Technicians are always trained well enough to perform their tasks accurately and with confidence. | ○ | ○ | ○ | ○ | ○ |
| 14 | "Shoot from the hip" or "best guess" decisions are used around here to solve problems. | ○ | ○ | ○ | ○ | ○ |
| 15 | Punishment is often used to discipline technicians for making errors. | ○ | ○ | ○ | ○ | ○ |
| 16 | Disciplinary actions are fairly applied and justified. | ○ | ○ | ○ | ○ | ○ |
| 17 | Punishment usually results in improved performance. | ○ | ○ | ○ | ○ | ○ |
| 18 | When technicians make errors, the best solution is to provide more training. | ○ | ○ | ○ | ○ | ○ |
| 19 | This company investigates maintenance incidents thoroughly. | ○ | ○ | ○ | ○ | ○ |
| 20 | Technicians are likely to make errors while performing complex tasks. | ○ | ○ | ○ | ○ | ○ |
| 21 | Experienced technicians do not make errors. | ○ | ○ | ○ | ○ | ○ |
| 22 | Maintenance Manuals, Service Bulletins, company policies, etc. are available as needed. | ○ | ○ | ○ | ○ | ○ |
| 23 | Maintenance Manuals, Service Bulletins, company policies, etc. are presented in understandable formats. | ○ | ○ | ○ | ○ | ○ |
| 24 | I fully agree with the MEDA philosophy that most maintenance errors are not intententional, but are mainly a result of factors that contribute to the error. | ○ | ○ | ○ | ○ | ○ |

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**Feasibility of the Application of the MEDA Process to General Aviation Maintenance**
Questionnaire

| | | Strongly Disagree | Disagree | No Opinion | Agree | Strongly Agree |
|---|---|---|---|---|---|---|
| 25 | There would be a strong acceptance of an error investigation process, such as MEDA, by my company's maintenance technicians. | ○ | ○ | ○ | ○ | ○ |
| 26 | There would be a strong acceptance of an error investigation process, such as MEDA, by my company's management. | ○ | ○ | ○ | ○ | ○ |
| 27 | I believe that it is important for the companies that use an error investigation system to share their results with other companies. | ○ | ○ | ○ | ○ | ○ |
| 28 | Maintenance error investigations will increase if the MEDA process is implemented. | ○ | ○ | ○ | ○ | ○ |
| 29 | There will be less punitive action taken against me or others if the MEDA process is implemented. | ○ | ○ | ○ | ○ | ○ |
| 30 | Maintenance error, overall, would decrease over time as a result of using MEDA, or a similar system. | ○ | ○ | ○ | ○ | ○ |
| 31 | I think that an error investigation system would be useful for discussing existing barriers that cause incidents. | ○ | ○ | ○ | ○ | ○ |
| 32 | Using an error investigation system, such as MEDA, will not create more work for me. | ○ | ○ | ○ | ○ | ○ |

Based upon your training and experience, please rank the following factors on how likely it is that the factor contributes to maintenance error.
- Select a 1 in front of the factor that you think contributes most to maintenance error.
- Then select a 2 in fron of the factor that you think contributes second most to maintenance error.
- Continue to rank the factors until you place a 11 in from of the factor that you think contributes least to maintenance error.

After you have finished, each number 1 through 11 should be used once and only once.

[ ] Information (e.g., manuals, work cards, and procedures) available to the technician (e.g., not understandable, not available, not used, etc.)

[ ] Equipment/tools/parts (e.g., unsafe, unavailable, mis-calibrated, wrong tool, etc.)

[ ] Job/task (e.g., monotonous, too complex, different from similar tasks, etc.)

[ ] Airplane design/configuration (e.g., complex, accessibility problems, configuration variability, etc.)

[ ] Qualification/skills of technician, lead, or supervisor regarding task, process, or system issues

[ ] Factors specific to an individual (e.g., size, fatigue, task interruption, time constraints, etc.)

[ ] Environmental factors (e.g., heat, humidity, snow, vibration, etc.)

[ ] Facility factors (e.g., lighting, ventilation, harzardous/toxic substances, etc.)

[ ] Organizational factors (e.g., support from other organizations, company policies, processes and procedures, morale, etc.)

[ ] Supervision (e.g., poor planning/organization, inadequate prioritization, delegation of work, etc.)

[ ] Communication between people, shifts, and organizations

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**Feasibility of the Application of the MEDA Process to General Aviation Maintenance**
Questionnaire

1. What positive benefits and difficulties could you foresee that implementing an error investigation system would create?

2. Do you believe that granting technicians limited immunity from punitive action for errors they report would increase the likelihood of them admitting errors? (Immunity from non-malicious, non-criminal acts)

3. Please write any suggestions or comments below that you would like to make regarding the implementation of an error investigation system in your company or general aviation in general.

# APPENDIX B

| Current Shop Conditions<br>Opinion Questions – Responses | | | | | |
|---|---|---|---|---|---|
| Question | Strongly Disagree | Disagree | No Opinion | Agree | Strongly Agree |
| My shop needs some type of system to report errors | 0 | 0 | 1 | 4 | 1 |
| Technicians are not afraid to admit making errors | 0 | 1 | 2 | 2 | 1 |
| Technicians receive detailed feedback from supervisors about task performance | 1 | 0 | 1 | 4 | 0 |
| Technicians are kept informed about potential problem areas where errors are likely to occur | 0 | 1 | 0 | 5 | 0 |
| More awareness training about errors made by technicians would increase aviation safety | 0 | 0 | 0 | 4 | 2 |
| Technicians are satisfied with their working environment | 0 | 1 | 1 | 3 | 1 |
| There is a need at this company to reduce maintenance error | 0 | 1 | 1 | 4 | 0 |
| "Lessons learned" from maintenance errors are shared so that the errors are less likely to occur again | 1 | 2 | 0 | 2 | 1 |
| Technicians are always trained well enough to perform their tasks accurately and with confidence | 0 | 3 | 1 | 2 | 0 |
| "Shoot from the hip" or "best guess" decisions are used around here to solve problems | 1 | 3 | 0 | 2 | 0 |
| Maintenance Manuals, Service Bulletins, company policies, etc. are available as needed | 0 | 0 | 0 | 2 | 4 |
| Maintenance Manuals, Service Bulletins, company policies, etc. are presented in understandable formats | 0 | 0 | 0 | 4 | 2 |

Current Shop Conditions - Responses

| Punishment/Corrective Action<br>Opinion Questions - Responses | | | | | |
|---|---|---|---|---|---|
| Question | Strongly Disagree | Disagree | No Opinion | Agree | Strongly Agree |
| Punishment is often used to discipline technicians for making errors | 1 | 3 | 1 | 1 | 0 |
| Disciplinary actions are fairly applied and justified | 0 | 2 | 0 | 4 | 0 |
| Punishment usually results in improved performance | 0 | 2 | 1 | 1 | 2 |
| When technicians make errors, the best solution is to provide more training | 0 | 1 | 2 | 2 | 1 |
| This company investigates maintenance incidents thoroughly | 1 | 2 | 0 | 2 | 1 |
| There will be less punitive action taken against me or others if the MEDA process is implemented | 0 | 2 | 2 | 2 | 0 |

Punishment/Corrective Action Responses

| Error Probability/Control<br>Opinion Questions - Responses | | | | | |
|---|---|---|---|---|---|
| Question | Strongly Disagree | Disagree | No Opinion | Agree | Strongly Agree |
| Even when tired, technicians perform effectively during critical phases of work | 1 | 4 | 0 | 1 | 0 |
| Technicians are likely to make errors while performing routine tasks | 0 | 2 | 1 | 2 | 1 |
| Most errors are caused by factors that the technician has no control over | 0 | 2 | 1 | 1 | 2 |
| Maintenance error could happen to anyone, even the best technician | 0 | 0 | 0 | 4 | 2 |
| Technicians are likely to make errors while performing complex tasks | 0 | 2 | 1 | 1 | 2 |
| Experienced technicians do not make errors | 1 | 2 | 0 | 3 | 0 |

Error Probability/Control Respnses

| Error Investigation System Acceptability<br>Opinion Questions - Responses | | | | | |
|---|---|---|---|---|---|
| Question | Strongly Disagree | Disagree | No Opinion | Agree | Strongly Agree |
| My shop needs some type of system to report errors | 0 | 0 | 1 | 4 | 1 |
| There is a need at this company to reduce maintenance error | 0 | 1 | 1 | 4 | 0 |
| I fully agree with the MEDA philosophy that most maintenance errors are not intentional, but are mainly a result of factors that contribute to the error | 0 | 0 | 1 | 4 | 1 |
| There would be a strong acceptance of an error investigation process, such as MEDA, by my company's maintenance technicians | 0 | 2 | 2 | 2 | 0 |
| There would be a strong acceptance of an error investigation process, such as MEDA, by my company's management | 0 | 1 | 1 | 3 | 1 |
| I believe that it is important for the companies that use an error investigation system to share their results with other companies | 0 | 0 | 1 | 3 | 2 |
| Maintenance error investigations will increase if the MEDA process is implemented | 0 | 1 | 1 | 4 | 0 |
| There will be less punitive action taken against me or others if the MEDA process is implemented | 0 | 2 | 2 | 2 | 0 |
| Maintenance error, overall, would decrease over time as a result of using MEDA, or a similar system | 0 | 1 | 0 | 5 | 0 |
| I think that an error investigation system would be useful for discussing existing barriers that cause incidents | 0 | 0 | 1 | 5 | 0 |
| Using an error investigation system, such as MEDA, will not create more work for me | 1 | 3 | 1 | 1 | 0 |

Error Investigation System Acceptability Responses

# APPENDIX C

## Maintenance Error Decision Aid (MEDA) Results Form

### Section I -- General Information

Reference #: ___ ___ ___ ___ ___
Airline: _____
Station of Error: _____
Aircraft Type: _____
Engine Type: _____
Reg. #: ___ ___ ___ ___ ___ ___ ___
Fleet Number: ___ ___ ___ ___ ___ ___
ATA #: ___ ___ ___ ___
Aircraft Zone: _____
Ref. # of previous related event: ___ ___ ___ ___ ___

Interviewer's Name:_____
Interviewer's Telephone #: __ __ __ __ __ __ __ __ __ __
Date of Investigation: __ __ / __ __ / __ __
Date of Event: __ __ / __ __ / __ __
Time of Event: _ _ : _ _ am pm
Shift of Error: _____
Type of Maintenance (Circle):
1. Line -- If Line, what type? _____
2. Base --If Base, what type? _____
Date Changes Implemented: __ __ / __ __ / __ __

### Section II -- Event

**Please select the event (check all that apply)**

**1. Operations Process Event**
( ) a. Flight Delay (write in length) _ days _ _ hrs. _ _ min.
( ) b. Flight Cancellation
( ) c. Gate Return
( ) d. In-Flight Shut Down
( ) e. Air Turn-Back
( ) f. Diversion
( ) g. Other (explain below)

**( ) 2. Aircraft Damage Event**
**( ) 3. Personal Injury Event**
**( ) 4. Rework**
**( ) 5. Other Event (explain below)**

**Describe the incident/degradation/failure (e.g., could not pressurize) that caused the event.**

### Section III -- Maintenance Error

**Please select the maintenance error(s) that caused the event:**

**1. Installation Error**
( ) a. Equipment/part not installed
( ) b. Wrong equipment/part installed
( ) c. Wrong orientation
( ) d. Improper location
( ) e. Incomplete installation
( ) f. Extra parts installed
( ) g. Access not closed
( ) h. System/equipment not reactivated/deactivated
( ) i. Damaged on installation
( ) j. Cross connection
( ) k. Other (explain below)

**2. Servicing Error**
( ) a. Not enough fluid
( ) b. Too much fluid
( ) c. Wrong fluid type
( ) d. Required servicing not performed
( ) e. Access not closed
( ) f. System/equipment not deactivated/reactivated
( ) g. Other (explain below)

**( ) 3. Repair Error** (e.g., component or) structural repair)

**4. Fault Isolation/Test/Inspection Error**
( ) a. Did not detect fault
( ) b. Not found by fault isolation
( ) c. Not found by operational/ functional test
( ) d. Not found by inspection
( ) e. Access not closed
( ) f. System/equipment not deactivated/reactivated
( ) g. Other (explain below)

**5. Foreign Object Damage Error**
( ) a. Material left in aircraft/engine
( ) b. Debris on ramp
( ) c. Debris falling into open systems
( ) d. Other (explain below)

**6. Airplane/Equipment Damage Error**
( ) a. Tools/equipment used improperly
( ) b. Defective tools/equipment used
( ) c. Struck by/against
( ) d. Pulled/pushed/drove into
( ) e. Other (explain below)

**7. Personal Injury Error**
( ) a. Slip/trip/fall
( ) b. Caught in/on/between
( ) c. Struck by/against
( ) d. Hazard contacted (e.g., electricity, hot or cold surfaces, and sharp surfaces)
( ) e. Hazardous substance exposure (e.g., toxic or noxious substances)
( ) f. Hazardous thermal environment exposure (heat, cold, or humidity)
( ) g. Other (explain below)

**( ) 8. Other** (explain below)

**Describe the specific maintenance error (e.g., auto pressure controller installed in wrong location).**

## Section IV -- Contributing Factors Checklist

**A. Information (e.g., work cards, maintenance manuals, service bulletins, maintenance tips, non-routines, IPC, etc.)**

__ 1. Not understandable
__ 2. Unavailable/inaccessible
__ 3. Incorrect
__ 4. Too much/conflicting information
__ 5. Update process is too long/complicated
__ 6. Incorrectly modified manufacturer's MM/SB
__ 7. Information not used
__ 8. Other (explain below)

**Describe specifically how the selected <u>information</u> factor(s) contributed to the error.**

**B. Equipment/Tools/Safety Equipment**

__ 1. Unsafe
__ 2. Unreliable
__ 3. Layout of controls or displays
__ 4. Mis-calibrated
__ 5. Unavailable
__ 6. Inappropriate for the task
__ 7. Cannot use in intended environment
__ 8. No instructions
__ 9. Too complicated
__ 10. Incorrectly labeled
__ 11. Not used
__ 12. Incorrectly used
__ 13. Other (explain below)

**Describe specifically how selected <u>equipment/tools/safety equipment</u> factor(s) contributed to the error.**

**C. Aircraft Design/Configuration/Parts**

__ 1. Complex
__ 2. Inaccessible
__ 3. Aircraft configuration variability
__ 4. Parts unavailable
__ 5. Parts incorrectly labeled
__ 6. Easy to install incorrectly
__ 7. Other (explain below)

**Describe specifically how the selected <u>aircraft design/configuration/parts</u> factor(s) contributed to error.**

**D. Job/Task**

__ 1. Repetitive/monotonous
__ 2. Complex/confusing
__ 3. New task or task change
__ 4. Different from other similar tasks
__ 5. Other (explain below)

**Describe specifically how the selected <u>job/task</u> factor(s) contributed to the error.**

**E. Technical Knowledge/Skills**

__ 1. Skills
__ 2. Task knowledge
__ 3. Task planning
__ 4. Airline process knowledge
__ 5. Aircraft system knowledge
__ 6. Other (explain below)

**Describe specifically how the selected <u>technical knowledge/skills</u> factor(s) contributed to the error.**

**F. Individual Factors**

__ 1. Physical health (including hearing and sight)
__ 2. Fatigue
__ 3. Time constraints
__ 4. Peer pressure
__ 5. Complacency
__ 6. Body size/strength
__ 7. Personal event (e.g., family problem, car accident)
__ 8. Workplace distractions/interruptions during task performance
__ 9. Memory lapse (forgot)
__ 10. Other (explain below)

**Describe specifically how the selected factors affecting individual performance contributed to the error.**

**G. Environment/Facilities**

__ 1. High noise levels
__ 2. Hot
__ 3. Cold
__ 4. Humidity
__ 5. Rain
__ 6. Snow
__ 7. Lighting
__ 8. Wind
__ 9. Vibrations
__ 10. Cleanliness
__ 11. Hazardous/toxic substances
__ 12. Power sources
__ 13. Inadequate ventilation
__ 14. Other (explain below)

**Describe specifically how the selected environment/facilities factor(s) contributed to the error.**

**H. Organizational Factors**

__ 1. Quality of support from technical organizations (e.g., engineering, planning, technical pubs)
__ 2. Company policies
__ 3. Not enough staff
__ 4. Corporate change/restructuring
__ 5. Union action
__ 6. Work process/procedure
__ 7. Work process/procedure not followed
__ 8. Work process/procedure not documented
__ 9. Work group normal practice (norm)
__ 10. Other (explain below)

**Describe specifically how the selected organizational factor(s) contributed to the error.**

**I. Leadership/Supervision**

__ 1. Planning/organization of tasks
__ 2. Prioritization of work
__ 3. Delegation/assignment of task
__ 4. Unrealistic attitude/expectations
__ 5. Amount of supervision
__ 6. Other (explain below)

**Describe specifically how the selected leadership/supervision factor(s) contributed to the error.**

**J. Communication**

__ 1. Between departments
__ 2. Between mechanics
__ 3. Between shifts
__ 4. Between maintenance crew and lead
__ 5. Between lead and management
__ 6. Between flight crew and maintenance
__ 7. Other (explain below)

**Describe specifically how the selected communication factor(s) contributed to the error.**

**K. Other Contributing Factors (explain below)**

**Describe specifically how this other factor contributed to the error.**

## Section V – Error Prevention Strategies

**A. What current existing procedures, processes, and/or policies in your organization are intended to prevent the incident, but didn't?**

( ) **Maintenance Policies or Processes** (specify)_____

( ) **Inspection or Functional Check** (specify) _____

**Required Maintenance Documentation**

( ) Maintenance manuals (specify) _____
( ) Logbooks (specify) _____
( ) Work cards (specify)_____
( ) Engineering documents (specify) _____
( ) Other (specify) _____

**Supporting Documentation**

( ) Service Bulletins (specify)_____
( ) Training materials (specify)_____
( ) All-operator letters (specify) _____
( ) Inter-company bulletins (specify) _____
( ) Other (specify) _____

( ) **Other** (specify)_____

**B. List recommendations for error prevention strategies.**

| Recommendation # | Contributing Factor # | |
|---|---|---|
| | | |

(Use additional pages, as necessary)

## Section VI – Summary of Contributing Factors, Error, and Event

**Provide a brief summary of the event.**

(Use additional pages, as necessary)

# VITA

Mark Thomas Blanks was born on June 3, 1982 in Nashville, Tennessee and raised in the same area. He was home schooled from 5th grade through high school and graduated in 1999 at the age of 16. From there, he went to Middle Tennessee State University in Murfreesboro, Tennessee and received a Bachelor of Science in Aerospace Maintenance Management in the spring of 2004.

An avid aviation enthusiast for his entire life, Mark is a licensed pilot and holds an Airframe & Powerplant certificate. His favorite pastimes include: flying, hunting, fishing, backpacking, and camping.