REDUCING INSTALLATION ERROR
IN AIRLINE MAINTENANCE

William B. Johnson, Ph.D
Galaxy Scientific Corporation

Jean Watson
FAA Office of Aviation Medicine

December 2000

EXECUTIVE SUMMARY

This project identifies categories of human error related to installation during heavy maintenance. The report offers practices to reduce installation error and to quantify the reduction in error. Two large carriers and one large repair station cooperated in the study. The data collection period provided enlightenment on the challenges associated with standardized data collection and subsequent data sharing. The data also showed the importance of consistent investigation processes within and among airlines. The report shows that the primary contributing factors to maintenance error are rooted in the basic and proper work practices related to: use of information; adequate worker knowledge and skill; organizational, cultural issues and work norms; and a variety of communication issues. For each of the major contributing factors, the report offers corrective actions that are based on 1) The suggestions of the participating industry partners and 2) references to the Web site-available published results and recommendations from FAA Human Factors in Aviation Maintenance and Inspection research reports since 1988. Results suggest that error can be reduced by over 50% if the recommendations are followed.

1.0 BACKGROUND AND REQUIREMENT FOR THE STUDY

The study of human error is not necessarily new[6]. In fact, psychological research from the 50's studied human error in decision-making and troubleshooting[14]. The human error that is the focus of this report is installation error. For this study installation error is defined as mechanic or maintenance system actions or inactions that resulted in reliability, safety, or documentation that was discovered in the final stages of a heavy check or within the first 21 days of operation.

While the works cited above refer to complex tasks, like troubleshooting, it is the every day tasks, like component installation, that are the focus of this study. The study is focusing on every day tasks because many airline studies show that omissions are repeatedly identified as the most common error in aviation maintenance[3,9,7,15]. Since 1988, numerous speakers at the annual FAA Conference on Aviation Maintenance and Inspection have elaborated on the problem of installation error[10,12]. The ATA Maintenance Human Factors Committee completed a human error study in 1999 and installation error was the #1 type of error. Most importantly the FAA Safer Skies initiative has the goal to reduce accidents and incidents caused by human error. Therefore, the lengthy rationale for this study need not be repeated here. Clearly, there is a mandate to reduce such errors during installation and this project is one research response to the mandate.

This report describes a study in which the research team and three industry participants collected data related to installation errors. These errors were discovered near the completion and immediately after a heavy maintenance check. The report categorizes the errors and compares them across the three industry participants. The participants worked with the research team to identify the likely cause of the errors and the best error prevention strategies. The report then maps the industry-derived strategies with research literature from the FAA Human Factors in Aviation Maintenance program, since 1988. Finally, the report describes a straightforward manner to predict the percentage of error reduction that is likely to be achieved by applying the suggested prevention strategies.

2.0 DATA COLLECTION

2.1 A System for Data Collection

Boeing created the Maintenance Error Decision Aid, MEDA, in 1994[3]. Since 1994, Boeing has delivered and trained MEDA to over 150 airlines throughout the world. While MEDA appears to be merely a checklist, as shown in Appendix A, it is really a thorough process for conducting error investigation. MEDA offers a taxonomy to ponder and categorize errors. It is the most popular of the systems to record and share safety data.

2.2 Participants

The project was especially fortunate to engage the participation of three companies with extensive MEDA experience. Because of work associations with the Boeing MEDA team and proximity to the Boeing factory, the participants were the very best qualified in the industry. Additionally, the three companies had corporate commitment from the senior levels of their respective engineering departments.

2.3 Schedule

The project commenced with the ambitious goal of acquiring the data within a six month time period. The plan was to design and implement the interventions, and measure the success. The plan was overly ambitious, providing inadequate time for the variety of logistics issues that would arise during such a study. The proposed schedule did not account for the numerous “real-world’ priorities that drive airline and repair station schedules. The result is that it has taken approximately 14 months for the project to have sufficient data to identify the challenges, suggest alternate corrective actions, and propose a means to quantify the potential error reduction.

2.4 Challenges and Solutions Related to Data

Collection and sharing of safety-related data is an admirable goal. The most formal example of current efforts to share data is the Global Aviation Information Network, GAIN, (http://www.gainweb.org/ or http://www.asy.faa.gov/gain/). According to the Web site, “GAIN promotes and facilitates the voluntary collection and sharing of safety information by and among users in the international aviation community to improve aviation safety.” While the GAIN idea is admirable, the industry application has been very slow. The challenges that face GAIN are identical, although on a larger scale, to the ones encountered for this project. This section describes some of the challenges, how they were overcome, and will continue to be addressed in the future.

2.4.1 Collection Instrument and Standard Format

Ideally, shared data should be similar. As mentioned, MEDA has provided a framework to collect identical data. When the data is identical, the data analysis for MEDA is straightforward. BF Goodrich Aerospace and Galaxy Scientific Corporation both have simple database development and analysis toolkits for the MEDA data. Because of MEDA, the expectation was that the availability of identical data formats should not be a problem. However, that was not the case for this project.

Two of the three participants had internal requirements and needed to alter the MEDA form for data collection. These alterations included shortening the form in one case, and adding an additional contributing factors category in another. Although these changes were minor, they presented challenges in the easy comparison of data among the three participants. For example, a participant company reduced the number of options within each of the contributing factors. “Information” was reduced from seven contributing factors to four. This change had the potential to change the level of investigative specificity among the participants. There was also a large variance in the level of narrative descriptive information on most of the events, making it difficult for one to fully understand the incident unless they were directly involved.

The situation described above did not prevent data analysis, rather increased the challenge of ensuring data was collected properly. The solution to the inconsistencies was to ensure that analysis did not contaminate the data as it was standardized for comparison.

Perhaps the most significant example of a change to MEDA was one participant’s inclusion of a category called “Normative Procedural Noncompliance.” This term refers to a mechanic’s action, or inaction, that appears to be a norm. For example, one may fail to do a specified test because it “takes to long” and “passes 99.9% of the time.” Rather than change the engineering/maintenance procedure to reflect that the test is unnecessary, the group culture can influence a mechanic to skip the procedure. This was labeled as an unacceptable error and categorized as “Normative Procedural Noncompliance.” Since this was not a category on MEDA, the error was classified as an Organizational Factor targeted at Company Work Process for the purposes of this project.

This section would not be complete without discussing the MEDA process itself. The system has not changed in over five years. There are many opportunities to improve MEDA. Boeing has instructed users to change MEDA to meet individual needs and many users have. However, changing the MEDA form to meet individual needs complicates the data sharing process. One alternative is to create a browser-based version of MEDA that would foster immediate changes to MEDA as Boeing creates them. A browser-based MEDA would also encourage the use of a standardized database that an airline could choose to share or retain privately.

2.4.2 Data Quantity

At the outset of the project, the participating companies estimated that there were extensive opportunities to identify maintenance error related to installation and omission. The challenge was to ensure that there were adequate resources to conduct quality investigations of the appropriate incidents. Shortly after the project began, the team delimited the type of incidents that would be the focus of the study. The study was narrowed to review incidents that were found in final check, or in operation within 21 days, of heavy maintenance. This decision helped ensure that the project was comparing the same data among the participants and that reasonable investigative resources were applied to each incident. However, when there were significant installation errors other than those occurring during the final stages of heavy maintenance, that had significant investigation, it was included herein. Additional significant investigation of installation errors other than the final stages of heavy maintenance represented less than 10% of the data.

There was clearly a large difference in the apparent quality of data from the investigations. For example, much of the data for one company consisted of incomplete notes, scribbled on a one-page MEDA-like form. Another company provided tabulated data with brief narratives describing each incident. This vast difference heightened concerns about the company's level of commitment to MEDA-like error investigation and reporting. On a very positive note, a corporate peer pressure was generated, prompting each participant to continually review their database to improve the quality and validity of input.

The authors believe that this data quality challenge was overcome as the participating companies ended up with about 150 incidents. These incidents represent a reasonable sample that characterizes the installation error situation throughout the industry.

2.4.3 *Investigation Resources*

Investigation personnel are critical because the quality of the data hinges on the quality of the investigation. Companies must select investigators that are likely to be respected and trusted by the work force. If investigators present themselves, purposely or not, as “policeman” looking for someone to blame, the investigations are destined to fail. Investigators must be impartial with the ultimate goal being to prevent reoccurrence of the incident.

Training is an important means to ensure consistency among the investigative personnel. This training often begins with a visit from the Boeing Customer Service team, but it can also be delivered internally. The initial training must be consistent. Participants in this project also recommend that investigators be retrained once a year. Proper training is a critical step to ensure the quality and consistency of the investigations.

Communication is also imperative among investigators. Inspectors must be able to discuss the incident and related investigations among themselves to ensure communication and uniformity throughout the investigations. Discussion among investigators may help neutralize the various biases that individuals may adopt. Investigators should also be encouraged to communicate their findings to the working personnel, when appropriate, as much as possible.

In 1999, the FAA published a report by David Marx[7] regarding the rules of causation. The seven rules of causation are an excellent guideline to help investigators with the MEDA-like investigations. The rules are listed in Table 1. Some airlines have placed the emphasis on rules one through five. It is critical that one follow the Marx report to properly explain these concepts to the investigation personnel. Training is offered commercially and available through www.davidmarx.com.

Table 1: Marx's 7 Rules of Causation
1. Causal statements must clearly show the “cause and effect” relationship.
2. Negative descriptors (such as poorly or inadequate) may not be used in causal statements.
3. Each human error must have a preceding cause.
4. Each procedural deviation must have a preceding cause.
5. Failure to act is only causal when there is a pre-existing duty to act.
6. Causal searches must look beyond that which is within the control of the investigator.
7. Statements of culpability must be accompanied by an explanation of the culpable behavior and its link to the undesirable outcome.

2.4.4 *Personnel Issues*

Sometimes field research is challenged depending on the “Available personnel” to conduct a project. This situation can lead to extensive time investment to educate and motivate personnel to complete the project. This project was extremely fortunate to associate with the most knowledgeable MEDA experts in the industry. The participants were always able to add value to the project and were highly motivated to see the project succeed.

2.4.5 *Data Sharing Not a Problem*

When data sharing is discussed, the first issues that arise focus on liability, privacy, security, and such things. However, those issues were not a problem at any time during this study. The true challenges to data sharing, based on this project, are associated with standardization of data format, quality and quantity of data, level of detail in the narrative portions of the data, and timeliness of data delivery. These factors should be considered in advance of the rhetoric of “security.”

As described above, the most significant challenges lie in the corporate commitment to conduct thorough investigations following standard data reporting formats.

3.0 RESULTS

The project used Galaxy Scientifics' software package, Tools for Error Analysis In Maintenance (TEAM), to combine the data from the three companies. This software was directly compatible with the BF Goodrich MEDA data analysis software package. The author selected the TEAM software due to familiarity. Composite data was analyzed to identify the opportunities for the greatest improvement. The composite data was then assigned to the respective company to look at differences among the companies.

This results section merely reports the data collected. Section 4.0 shall address the potential corrective actions. Section 6.0 shall project the likely error reduction based on implementation of the corrective actions.

3.1 Composite Data

Figure 1 summarizes primary contributing factors data for the three participating companies. The highest ranked contributing factors, as shown on Figure 1, are Information, Organizational Factors, and Communication. The next clustered factors include Individual Factors Skills, Technical Knowledge and Skills, Job/Task, A/C Design, and Leadership. These rankings are consistent with previous studies.

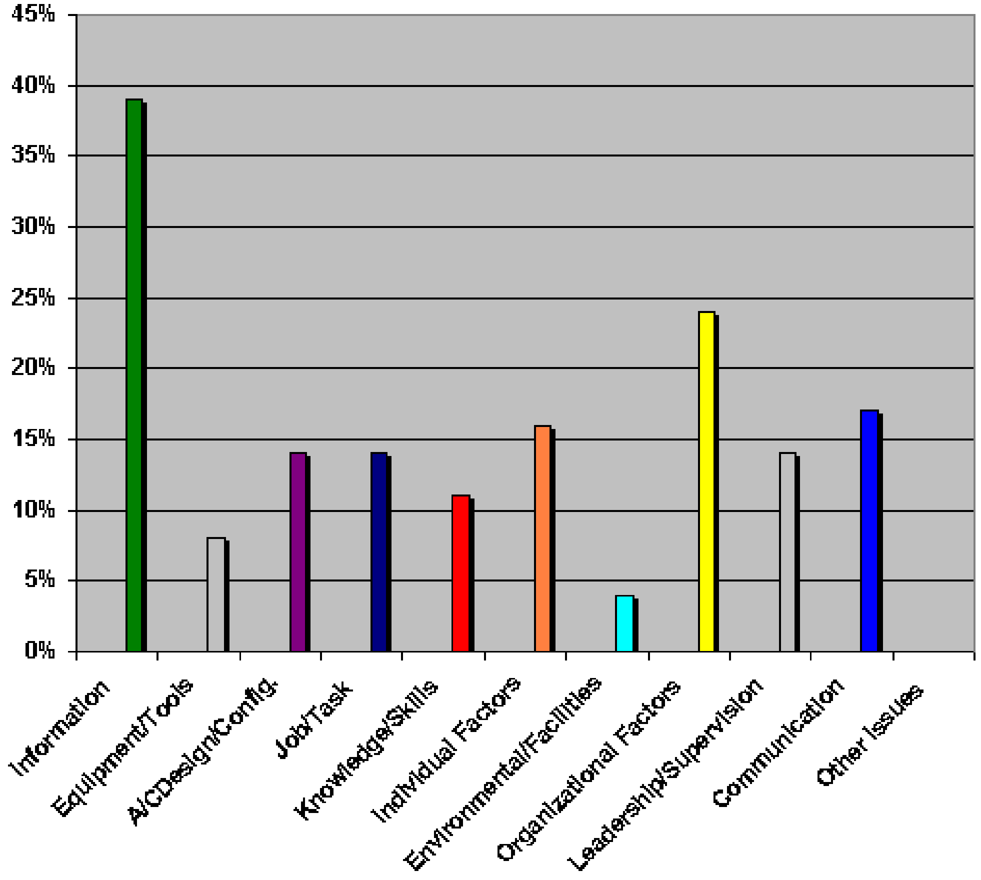


Figure 1: All Contributing Factors for Three Companies (N=125)

Figure 2 shows the breakdown of the three primary contributing factors as they apply to the three companies. Note that Information and Organizational Factors appear as a challenge to all three companies. Communication did not appear as a challenge in any of the 16 total incidents investigated by Company C. However, past studies and the experiences of Company A and Company B qualify it as a topic of discussion in this report. Based on the data, it appears that this agreeable data, independently collected by three companies, is very representative of the industry-at-large. For the purposes of this paper, we shall discuss the top three.

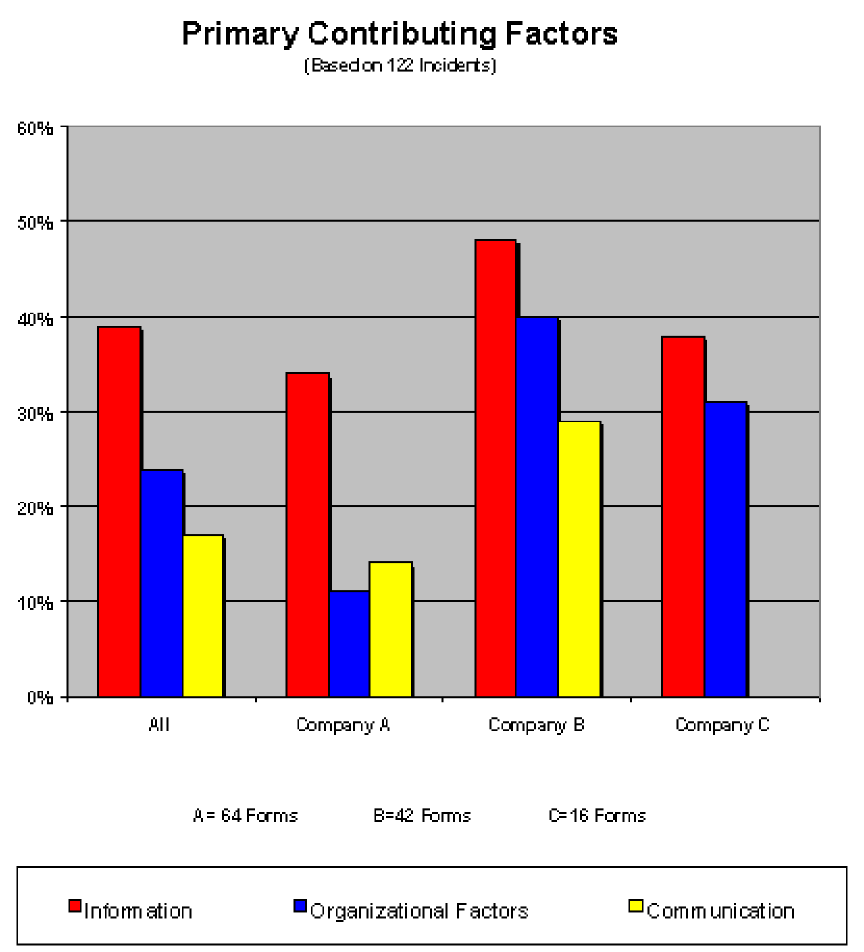


Figure 2: Summary of Three Primary Contributing Factors for All Participants

3.2 Information as a Contributing Factor

Information is an age-old problem in all maintenance, as shown in Figure 2. In all cases, “Information not used” was the most common sub-contributing factor. In fact, 50% of the Information factors were “not used.” Incorrect data was a contributing factor in a minimal number of cases. The participating companies explained that the incorrect information, most likely, referred to incorrect or incomplete write-ups by technicians from other shifts.

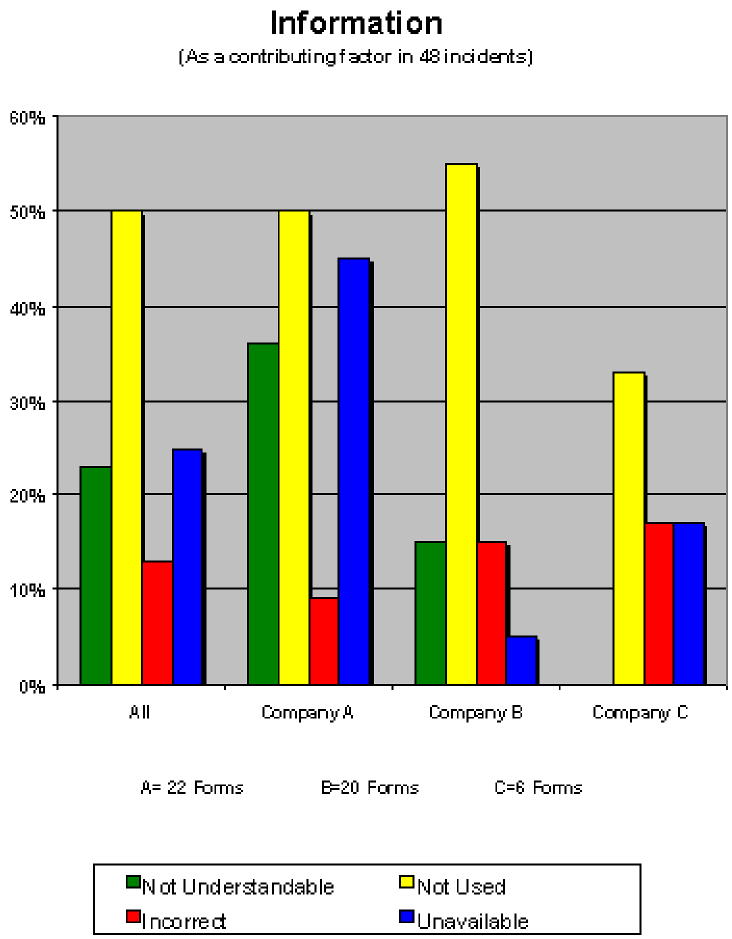


Figure 3: Information as Contributing Factor for Three Companies

3.3 Organizational Factors as a Contributing Factor

The contributing factors related to organization have the least agreement among the three companies, as shown in Figure 4. “Company Work Processes” refers to the manner in which companies conduct their maintenance procedures. It can include many factors, including, but not limited to: scheduling: assigning tasks at start of shift; shift turnover; design and access to work instruction cards; inspection process: work schedules: and more. Company A did not report any contributing factors related to “Company Work Processes.” However, this category was the very highest for Company B and the only factor for Company C’s six incidents. During discussions, the participants indicated that these categories were somewhat nebulous and were likely to be based on any company cultural bias delivered in the training.

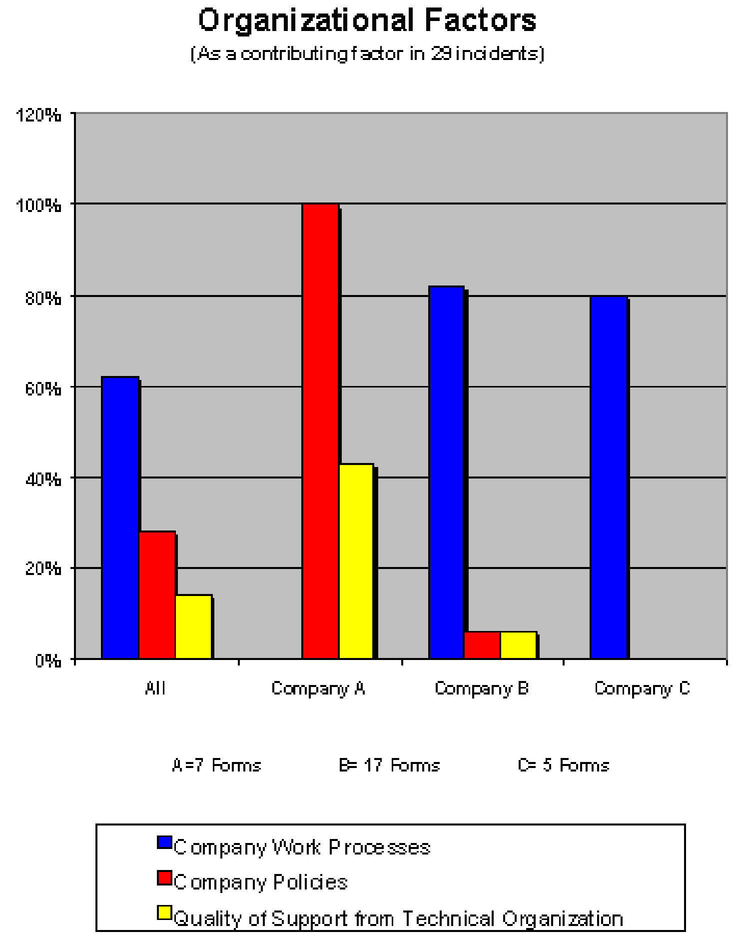


Figure 4: Organizational Factors as Contributing Factor for Three Companies

3.4 Communication as a Contributing Factor

Since the start of the FAA Maintenance Human Factors program, in 1988, the industry has identified “Communication” as one of the most important challenges and potential contributing factors to error. That position is reinforced by this project with “Communication” emerging as one of the top four contributing factors. Again, this category has a significant variance among the three companies. For example, Company C did not identify “Communication” as a contributing factor in its 16 incidents reported for this study. Company C personnel suggest that this zero report is merely a function of its incident selection and did not indicate that they have the “magic” solution to communication. On the other hand, Company A rated communication “Between mechanics” as their greatest communication challenge. Section 4.0 refers to a variety of error prevention strategies related to communication.

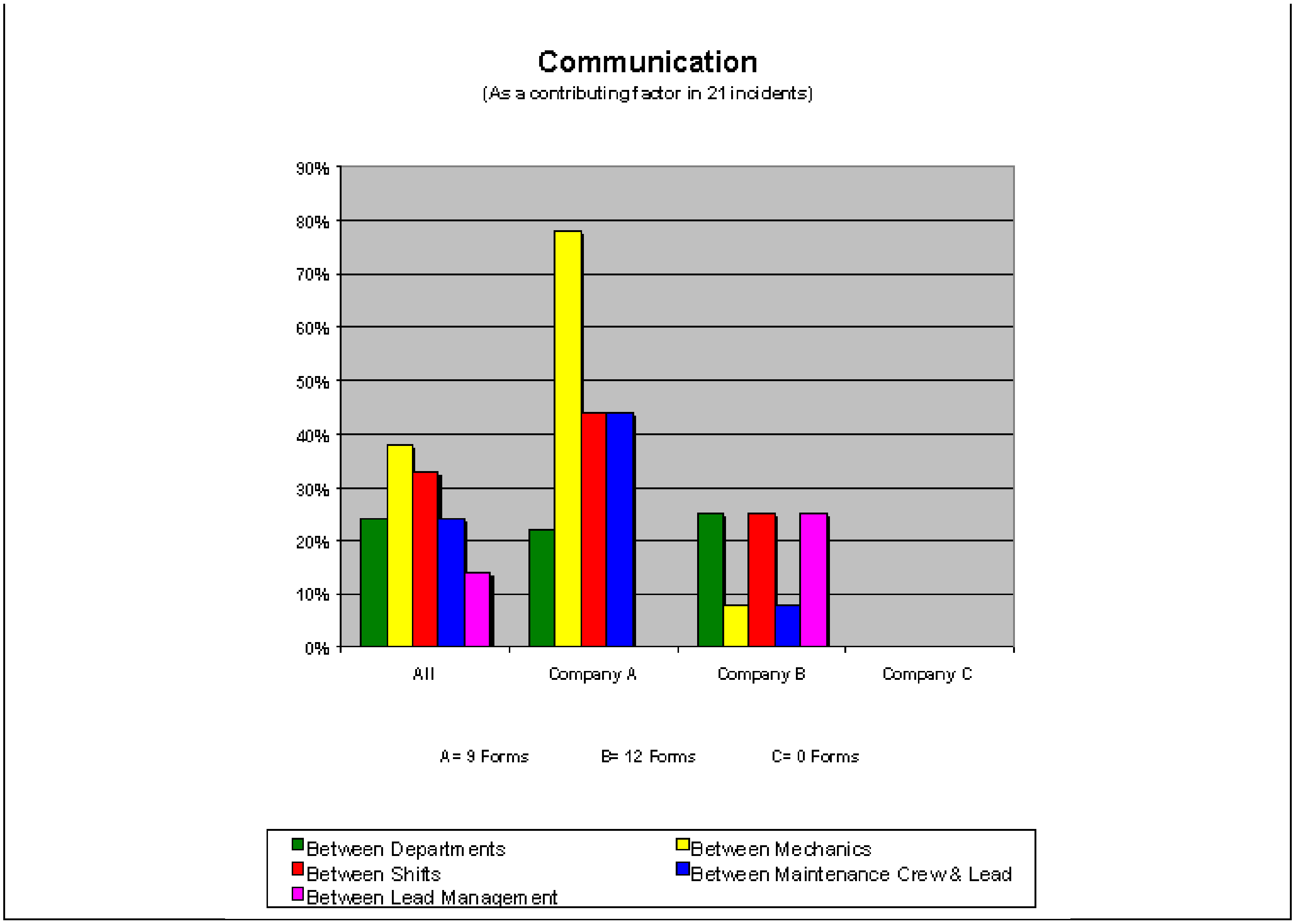


Figure 5: Communication as Contributing Factor for Three Companies

4.0 PREVENTION STRATEGIES

The results reported in Section 3.0 are by no means unanimous. However, they do reinforce the airline maintenance industry's conventional wisdom that there are opportunities for reducing human error. The three primary targets for error reduction include the following: utilization of technical documents; organizational factors that promote/permit error; and, the way maintenance personnel communicate.

Unanimous agreement on most common contributing factors is not necessary for this section to have value. This section shall take the most common contributing factors and describe potential prevention strategies. The strategies come from two primary sources. The first source is based on recommendations and experiences of the three companies involved in this research. The second source is the FAA Office of Aviation Medicine's Web site for Human Factors in Aviation Maintenance and Inspection (http://hfskyway.faa.gov).

4.1 Prevention Strategies: From Participants and Research Results

This section is based on the experiences and advice from the industry project participants as well as the results from FAA research since 1988. The participants included representatives from the two participating airlines and one repair station. In addition, there was one person from Galaxy Scientific and one person from the Boeing Customer Service team responsible for MEDA. The Boeing representative was present to offer insights on MEDA regarding the kind of errors and prevention strategies generally reported by other MEDA users.

Once all of the data was compiled, the team had a two-day round table discussion about all aspects of the project including this report. The primary purpose of the meeting was to agree that the process had identified the most common installation errors as well as the prevention strategies with the highest potential for error reduction. The specific prevention strategies were derived by using the information available in the MEDA data and by discussing specific intervention ideas for each identified installation error. The majority of the interventions below are from the discussions.

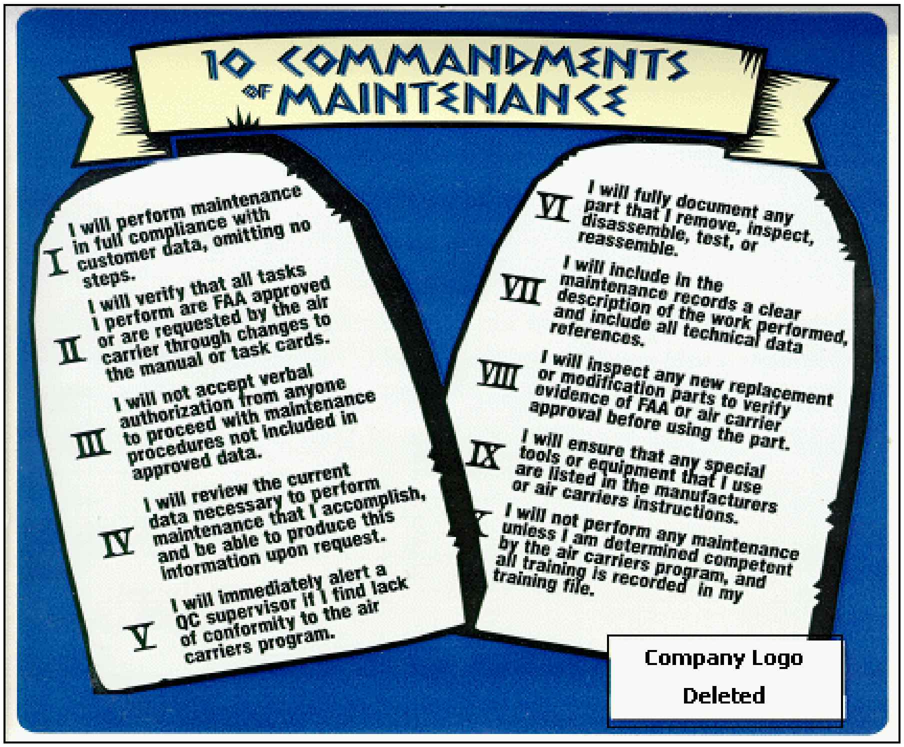
The tables in this section all are complemented by numbered references to research findings available on the FAA Office of Aviation Medicine's Web site, http://hfskyway.faa.gov. That database is comprised of over 10,000 pages of information and presented with a powerful search engine. Therefore, all of the references are readily available to readers of this report. For the convenience of the electronic reader, each reference from this section, has a direct hyperlink to the exact Web site URL. This report does not attempt to derive specific solutions from the 13 years of research, but merely references where that solution is likely to be found. Readers must match their specific situation to the solutions offered in the report references.

Before the specific interventions associated with each error category are detailed, it is valuable to describe two error reduction programs developed by companies that participated in this project.

4.1.1 The 10 Commandments of Maintenance

The 10 Commandments of Maintenance (TCMs) are shown in Figure 6. As shown, the commandments are straightforward and merely reinforce the Federal Aviation Regulations, specifically FAR Part 145. The Commandments also cover many of the regulations of part 43. All maintenance personnel receive initial and recurrent reinforcement training on these 10 Commandments. The company invested in small sticky-backed signs and large signs to reinforce the 10 Commandments. While the commandments seem very basic, they represent the kind of actions that, if not observed, will lead to error.

In the error prevention strategies listed throughout this section, we do not list specific commandments as interventions. However, the group estimates that adherence would eliminate over 50% of the errors that we identified. That is to say, there would be a significant reduction in error if people did what they are supposed to do. One of the companies categorized this failed behavior as normative procedural non-compliance, "everyone does it that way."



I I will perform maintenance in full compliance with customer data, omitting no steps.

II I will verify that all tasks I perform are FAA approved or are requested by the air carrier through changes to the manual or task cards.

III I will not accept verbal authorization from anyone to proceed with maintenance procedures not included in approved data.

IV I will review the current data necessary to perform maintenance that I accomplish, and be able to produce this information upon request.

V I will immediately alert a QC supervisor if I find lack of conformity to the air carriers program.

VI I will fully document any part that I remove, inspect, disassemble, test, or reassemble.

VII I will include in the maintenance records a clear description of the work performed, and include all technical data references.

VIII I will inspect any new replacement or modification parts to verify evidence of FAA or air carrier approval before using the part.

IX I will ensure that any special tools or equipment that I use are listed in the manufacturers or air carriers instructions.

X I will not perform any maintenance unless I am determined competent by the air carriers program, and all training is recorded in my training file.

Figure 6: The 10 Commandments for Error Reduction in Maintenance

4.1.2 Key Behaviors for Aircraft Maintenance and Hangar Inspection

A second company-wide intervention program is called the "Key Behaviors for Aircraft Maintenance & Hangar Inspection." (KBs). The company created a list of key behaviors to reduce maintenance error as a spin-off from this research activity. They used human failure mode and effects/ fault tree assessment methodology to review event data. With this information they identified key behaviors that would have prevented classes of error among the events. The Initial Key Behaviors and Post-Task Checklist Key Behaviors are shown in Tables 2 and 3, respectively.

The Key Behaviors Program is significant in that it provides formal recognition to the existence of unhealthy norms on the hangar floor. One carrier identified that over 50% of its maintenance error events involved some level of normative non-compliance with company policies, such as doing a repetitive task by memory. While compliance is central to the operating philosophy of all air carriers, this carrier found that the system would inadvertently produce obstacles to compliance (such as a complicated procedure) or would simply be unable to spot the local work around on the floor. To support implementation of the Key Behaviors, the carrier is conducting focus groups to identify where the system has become an obstacle to compliance. They wish to determine whether it is tooling availability, procedure availability, or other possible factors.

The Key Behaviors Program is unique in that the program focuses on the accountability for performing the behavior, rather than accountability based solely upon the presence of an error. Whereas, many organizations today may discipline a technician who makes a mistake that permits and aircraft to return to revenue service (in violation of FAR 43.13), this carrier has focused its accountability on the decision to perform the Key Behavior. It recognizes that technicians may make mistakes in performing any task, including the Key Behaviors. The decision by a technician or manager to forego performance of the Key Behavior may invoke some disciplinary sanction.

In developing the Key Behaviors, this carrier has challenged its workforce to 100% compliance with those behaviors directly linked to flight safety, and it has challenged its managers to make sure the technicians and inspectors have the tools and support to remain compliant with the Key Behaviors. The maintenance error data at this carrier shows that full compliance with the Key Behaviors will reduce installation errors out of the check process by 53%. This carrier, through its error investigation system, plans to validate its estimated reduction of errors through the program.

Table 2: The Seven Initial Key Behaviors

1. **When performing principal systems or structures maintenance, we must review the current maintenance instructions before beginning the task.**
2. We must document all disassemblies not specified in the task instructions.
3. We must document job status at the end of shift or when moving to a new task.
4. We must flag all disassemblies that might be inconspicuous to anyone closing the work area.
5. We must confirm the integrity of each adjacent connection upon installation of any LRU.
6. We must complete all required checks and tests.
7. We must, when closing a panel, conduct a brief visual scan for safety-related errors.

Table 3: Key Behaviors Post-Task Checklist

1. **Did I review Instructions before beginning the task?**
2. Did I document additional disassemblies?
3. Have I documented my work?
4. Upon disassembly, have I determined whether the disassembly is inconspicuous and added a flag as appropriate?
5. Upon reassemble of an LRU, did I check assessable, adjacent connections to ensure that they have not been disturbed?
6. At the end of the task, have I reviewed the task to ensure that all required checks and tests have been performed, or documented as to where the check or test will be performed.
7. Upon closing any panel, have I performed a brief visual scan for obvious errors?

4.1.3 *Prevention Strategies related to Information*

Table 4 is a summary of the prevention strategies related to aspects of Information that was either unused or unavailable. In most cases, adherence to basic regulations from FAR Part 43 would prevent incidents. Technicians know they must use the technical documentation, but often fail to comply with this fundamental maintenance principle. The 10 Commandments relating to the use of customer data and approved maintenance data apply to this error category. Key Behavior #1 instructs the mechanic to “review the current maintenance instructions before beginning a task.”

Because failure to use documentation is so fundamental, the Key Behaviors program holds the mechanic accountable for proper use of documentation. Therefore, failure to comply can constitute disciplinary action. For that reason, the Key Behaviors program ensures that the engineering department and all levels of maintenance management have the correct technical documentation readily available for the mechanic. The KB program promotes an awareness of documentation issues to prevent error.

The participating companies discussed the challenge of addressing what they called “Tribal Knowledge.” This term refers to the kind of undocumented knowledge that exists within any working group. Such knowledge often escapes manufacturer or company written procedures. A related challenge is the consensus vote regarding how a task should be completed. As an example, three workers may collectively decide how a component should be reinstalled. Rather than making the decision on their own, they should refer to the maintenance documentation. Again, the solution is to reorient workers to the criticality of the approved maintenance documentation.

Error 3 on Table 4 refers to "Work arounds." These are proven, undocumented methods to complete a task not necessarily aligned with the written work procedures. Unfortunately, sometimes these "accelerated" methods may skip a functional test. The solution, as decided by the research team, is to position engineering departments to approve and formalize such work around procedures. That means that the company culture must change in a manner that mechanics can admit to work around practices and that engineering must be willing to review, approve, and document them in a timely manner. In many cases, this type of action is contrary to the status quo. Error 6 refers to the actions when the mechanic thinks there is a "better way" to perform the job than what is outlined in the manual. This is closely related to Error 3 and has the same Preventative Strategies.

Error 4 refers to the maintenance documentation and to the documentation that mechanics generate. Quite often, geographically located systems are affected by work on other systems or components ("secondary work"). When such systems are moved, loosened, disconnected, or altered, it must be documented. It can be neglected because the written work procedures may refer only to the primary system upon which the work is focused. The KBs and the TCMs both refer to the importance of documenting the "secondary work." As with error 3, engineering departments must step forward and include "secondary work" as part of the primary task. To effectively track "secondary work," maintenance personnel must make Engineering aware of such work activities. In the mean time, there must be programs to document, tag/flag, and otherwise note secondary work.

Error 5 refers to "Information not available." While this was not reported as a significant problem, it was discussed. It is especially important that companies operating under FAR Part 145 make it easy for their personnel to have access to both the customer documentation and the customer's engineering department. Occasionally, when mechanics noted that information was not available, they truly meant that it was not "easily available." The KBs program is taking actions to ensure that the appropriate information is always readily available.

Table 4: Causes and Strategies for Information-related Errors

	Errors	Prevention Strategies	Linked References
1.	**Simply, did not use available information**	• **KB 1, TCM I & TCM IV ,** • Accountability & Discipline • Multi-level management support • Awareness training and reminder programs	2, 3, 10, 13, 16, 17, 21
2.	Technicians used consensus opinion, sometimes called "Tribal Knowledge*." *Term used within the maintenance organization or subgroup referring to their collective corporate knowledge.	• KB1, TCM I &TCM IV	3, 8, 16, 21, 26
3.	Use of "Work-arounds", sometimes this results in skipped tests.	• Identify common 'work-arounds." • Review company procedures to formalize" work-arounds." • Speed up revision process for technical documents.	1, 3, 11, 20, 25,
4.	Failure to document secondary work.	• KB 4, TCM VI & TCM VII • Insure that technical manuals specify all related work for a given task.	1, 2, 3, 4, 5, 7
5.	Information not readily available	• KB 1 & 6, TCM I,& II & IV • Insure that company provides information and engineering support to 3ed party providers and that mechanics take proper advantage of such information and resources. • Make it easy to obtain the information.	4, 5, 7, 11, 20

6.	Technicians think they have a “better” way to do the task.	- Create system to quickly formalize the technician’s “better” way.	4, 5, 7, 11, 20

4.1.4 *Prevention Strategies related to Organizational Issues*

Table 5 depicts the errors, prevention strategies, and Web site references for additional prevention strategies. The first error is termed “Normative Procedural Deviation.” This term, coined by David Marx, was used by one of the airlines to describe error caused by the undocumented workplace actions that are repeated often enough that they become standard procedure, like norms. It especially applies to the norms related to deviation from the written procedure. The Key Behaviors and the Ten Commandments of Maintenance address this type of common procedural deviation. The mechanic knows that the behavior is incorrect, but falls into a type of complacency. The KB and TCM programs refocus on the basics: using the technical documentation, documenting all work, tagging secondary work, and communicating clearly within and between shifts. The KB program has taken the necessary action to raise the level of individual accountability from mechanics and supervisory personnel. Companies must create and foster the error awareness programs that encourage maintenance personnel to comply with the most basic repair principles specified from their first days of mechanical training and reinforced in FAR Part 43.

Error number 2 is much the same as number 1. Gordon Dupont4 describes “Norms” as one of the “Dirty Dozen” errors of maintenance. His suggested safety nets for “Norms” include the following: a) Always work as per the instructions or have the instructions changed and b) Be aware that "norms" don't make it right.

Error number 3 is more of a committee statement than a specific error. The industry group felt that there is an ongoing requirement for the programs to simply reinforce basic safety and compliance. The work environment, including such things as easy access to documentation, access to special tools, and access to safety equipment must make it compliance with safety and regulations easy. Human nature is to find the quickest and easiest way to complete the job. Therefore, the company should strive for ways to make the easy way also the best and safest way. The “Linked References”, numbered 2, 3, 4, 5, 7, and 11 show ways to design the work environment and documentation so that it offers the worker the best solutions.

Table 5: Causes and Prevention Strategies for Organizational Factors-related Errors

	Errors	Prevention Strategies	Linked References
1.	Normative Procedural Deviation	- All Key Behaviors (KBs) - 10 Commandments of Maintenance (TCMs) - Error Awareness programs	1, 2, 3, 4, 6, 8, 12, 13, 16, 17, 22, 23, 24, 27
2.	Norms (Like #1)	- Standardize the Discipline Policy - Reinforce safety & compliance	1, 17, 18, 22
3.	Need additional behavioral reinforcement for basic safety and compliance	- Systems should make it easier to comply than not comply. - Continuous on-the-job and school house training to reinforce: o Safety Awareness o Safety Standards o Skills	2, 3, 4, 5, 7, 11, 17

4.1.5 *Prevention Strategies related to Communication*

The “Communication” errors are divided into sections aligned with the MEDA form. The first category is communication between departments. Error number 1 is incomplete documentation and it is solved with selected Key Behaviors and 10 Commandments. These selected strategies are related to documenting actions before beginning new actions and proper flagging of related disassemblies. One of the Linked References is to #2316, the Communication chapter in the *Human Factors Guide for Aviation Maintenance*. Professor Rifken offers a variety of actions that can be readily applied to clarify written and verbal communication.

Error number 2 is related to lack of communication and “unawareness” between departments. The industry group recommends scheduled meetings between shifts. Again, the Communication chapter in the *Human Factors Guide* offers guidelines on how to schedule and conduct effective meetings.

The group identified one communication error type between mechanics and the engineering department. The challenge is related to mechanic’s occasional uncertainty about written instructions. Two prevention strategies are offered. First, the group reinforced the importance of having engineering department representatives available full time. Such representatives should be easy to contact and have a user-centered, knowledgeable, and responsive attitude. Secondly, the committee recommended that representative mechanics and engineers are present at all meetings where significant events are reviewed. Linked reference # 2517,refers to the teamwork that must exist between departments, engineering, and maintenance.

Shift turnover presents the potential for communication error and is identified as its own error category on the MEDA form. Often, “insufficient time” is blamed for shift turnover communication errors. The shift overlap time could benefit from restructuring and the industry group suggested training to promote improved written handover information. They suggested that poor written communication should be posted as demonstrations of what “Not to do.” These examples should be accompanied by examples of well written handover materials. The group also suggested that teamwork training would remind personnel that the next shift is part of the same team. Renewed pride in workmanship programs would create situations where workers are more likely to clearly document their actions. Further, proud workers would want to be sure that the following shift continued the work at the same level of quality. Linked reference #918, addresses the challenges and solutions related to shift turnover.

The final category of communication error is “between mechanics.” The recurring error in this category is poor written documentation. The industry group suggested increasing training and awareness programs. Again, the communication chapter from the Human Factors Guide is an excellent source to provide information on written and spoken communication between mechanics.

Table 6: Cause and Prevention Strategies for Communication-related Errors

	Between Departments		
	Errors	**Prevention Strategies**	**Linked References**
1.	Incomplete Documentation	• KB2 - 4, TCMs III -VII • Awareness programs to promote importance of documentation	**2, 3, 4, 5, 7, 8, 17, 21, 22, 23, 25**
2.	One department is unaware of what the other Department is doing. Lack of intra-department communication.	• Scheduled and frequent intra-department meetings • Significant event meetings	**1, 2, 3, 4, 7, 8, 13, 23, 24, 27**
	Between Mechanics and Engineers		
	Errors	**Prevention Strategies**	**Linked References**
1.	Mechanics not sure of procedures or work instructions	• Continued full time (7X24) engineering availability to maintenance • Mechanics and Engineering should review significant events together	**3, 4, 7, 8, 23, 27**
	Between Shifts		
	Errors	**Prevention Strategies**	**Linked References**

1.	Insufficient time for clear communication	• Improve “written” handover procedures • Ensure that overlap time is scheduled and structured for efficiency and effectiveness • Formal promotion and training of teamwork skills. • Reinforce Pride in Workmanship • Review FAA “Personal Minimums” for maintenance personnel • Reinforce all KBs and TCMs to floor & line-level managers	2, 3, 7, 8, 9, 12, 15, 21, 23, 24, 26, 27

Between Mechanics

	Errors	**Prevention Strategies**	**Linked References**
1.	Written Documentation causes errors	• Assign high importance to quality of written information and hold writer responsible • Deliver training using good and bad examples • Provide and train criteria for quality write-ups • Ensure that documentation format has room for sufficient write-up • Provide means for writer to receive feedback on the write-up • Create a public board to show where inadequate write-ups caused extra work or created other challenges • Engineering and maintenance should work together on developing documentation sothat engineering can understand how a taskreally gets done.	2, 22, 23, 24, 27
2.	Spoken instructions misunderstood	• Reinforce communication skills with training and promotional programs.	3, 15, 16, 19, 21, 23, 24, 27

5.0 HYPER LINKED REFERNCES FOR POTENTIAL ERROR PREVENTION STRATEGIES

1. Allen, J. and Marx, D.A. (1993). Maintenance Error Decision Aid Project. *The 8th Symposium on Maintenance Human Factors and Inspection: Trends and Advances in Aviation Maintenance Operations.*_Washington, DC FAA.

2. Dupont, G. (1997). The Dirty Dozen Errors in Maintenance. *The 11th Symposium on Human Factors in Maintenance and Inspection: Human Error in Aviation Maintenance*._Washington, DC FAA.

3. Drury, C.G. (1998). Establishing a Human Factors and Ergonomics Program. In M. Maddox (Ed.), *The Human Factors Guide for Aviation Maintenance and Inspection*. Washington, DC: FAA.

4. Drury, C.G. (1998). Work Design. In M. Maddox (Ed.), *The Human Factors Guide for Aviation Maintenance and Inspection*. Washington, DC: FAA.

5. Drury, C G., et al. (1993). Design of Workcards. In Galaxy Scientific (Ed.), *Phase III, Volume 1, Progress Report on Human Factors in Aviation Maintenance and Inspection*. Washington, DC: FAA.

6. Drury, C.G., Levine, C., and Murthy, M. (1996). A Proactive Error Reduction System. *The 11th Symposium on Human Factors in Maintenance and Inspection: Human Error in Aviation Maintenance*. Washington, DC: FAA.

7. Drury, C.G., Wenner, C., and Kritkausky K. (1998). Development of Process to Improve Work Documentation of Repair Stations. *The 12th Symposium on Human Factors in Aviation Maintenance and Inspection*. Washington, DC: FAA.

8. Eiff, G.M., and Lopp, D. (1998). Organizational Culture and Its Affect on Safety. *The 12th Symposium on Human Factors in Aviation Maintenance and Inspection*. Washington, DC: FAA.

9. Gramopadhye, A.K., Kelkar, K., and Watson, J. (1999). Analysis of Shift Change in the Aircraft Maintenance Environment: Findings and Recommendations. Galaxy Scientific (Ed.), *Phase IX Progress Report*. Washington, DC: FAA.

10. Johnson, W.B. (1998). Human Factors in Airline Maintenance: Past, Present, and Future. *The 12th Symposium on Human Factors in Aviation Maintenance and Inspection*. Washington, DC: FAA.

11. Johnson, W.B. and Layton, C.F. (1993). Design, Implementation and Evaluation of a Performance Enhancement System for Aviation Safety Inspectors. *The 8th Symposium on Maintenance Human Factors and Inspection: Trends and Advances in Aviation Maintenance Operations*. Washington, DC: FAA.

12. Johnson, W.B. and Watson, J. (1999). An Assessment of Industry Use of FAA Human Factors Research from 1988 through 1998. Galaxy Scientific (Ed.), *Phase IX Progress Report on Human Factors in Aviation Maintenance and Inspection*. Washington, DC: FAA.

13. King, D. (1998). Learning Lessons the (Not Quite So) Hard Way Incidents, the Route to Human Factors in Engineering. *The 12th Symposium on Human Factors in Aviation Maintenance and Inspection*. Washington, DC: FAA.

14. Maddox, M. (1998). Personal and Job-Related Factors. In M. Maddox (Ed.), *The Human Factors Guide for Aviation Maintenance and Inspection*. Washington, DC: FAA.

15. Maddox, M. (1998). Shift Work and Scheduling. In M. Maddox (Ed.), *The Human Factors Guide for Aviation Maintenance and Inspection*. Washington, DC: FAA.

16. Maddox, M. and Reason, J. (1998). Human Error. In M. Maddox (Ed.), *The Human Factors Guide for Aviation Maintenance and Inspection*. Washington, DC: FAA.

17. Marx, D.A. (1998). *Learning from Our Mistakes: A Review of Maintenance Error Investigation and Analysis Systems (with recommendations to the FAA).* *Phase VIII Progress Report on Human Factors in Aviation Maintenance and Inspection*. Washington, DC: FAA.

18. Marx, D.A. and Watson, J. (1999) Maintenance Error Causation. *Phase IX Progress Report on Human Factors in Aviation Maintenance and Inspection*. Washington, DC: FAA.

19. Miles, B. (1998). Guidelines in Producing an Effective Shift and Task Handover System. In Galaxy Scientific (Ed.) *The 12th Symposium on Human Factors in Aviation Maintenance and Inspection*. Washington, DC: FAA.

20. Patel, S., Pearl, A., Koli, S., and Drury, C. (1995). Design of Portable Computer-Based Work Cards for Aircraft Inspection. In Galaxy Scientific (Ed.), *Phase IV Progress Report on Human Factors in Aviation Maintenance and Inspection*. Washington, DC: FAA.

21. Prabu, P. (1998). Information Transfer. In M. Maddox (Ed.), *The Human Factors Guide for Aviation Maintenance and Inspection*. Washington, DC: FAA.

22. Reason, J. (1997). Approaches to Controlling Maintenance Error. *The 11th Symposium on Human Factors in Maintenance and Inspection: Human Error in Aviation Maintenance*. Washington, DC: FAA.

23. Rifkind, L. (1998). Communication. In M. Maddox (Ed.), *The Human Factors Guide for Aviation Maintenance and Inspection*. Washington, DC: FAA.

24. Robertson, M.M., and Ensley, M.R. (1997). Creation of Team Situation Awareness Training for Maintenance Technicians. In Galaxy Scientific (Ed.). *Phase VII Progress Report on Human Factors in Aviation Maintenance and Inspection*. Washington, DC: FAA.

25. Scoble, R. (1993). Aircraft Maintenance Production and Inspection: Team Work + Empowerment + Process Simplification = Quality. *The 8th Symposium on Maintenance Human Factors and Inspection: Trends and Advances in Aviation Maintenance Operations*. Washington, DC: FAA.

26. Sian, I.B. and Hastings, P. (1998). A Study of AMT Norms and Work Habits. *Phase VIII Progress Report on Human Factors in Aviation Maintenance and Inspection*. Washington, DC: FAA.

27. Sian, I.B., Robertson, M, and Watson, J. (1998). *Maintenance Resource Management Handbook.* Washington, DC: FAA.

6.0 POTENTIAL FOR ERROR REDUCTION

It is a challenge to assign the probability of whether a particular prevention strategy will reduce error. However, it is straightforward and reasonable to say, "If the mechanic would have performed X check, the event would not have occurred." It is with this pragmatic, and not necessarily tested approach, that this report offers a means to consider the potential for error reduction. The method has been very successful for one of the participating companies. They have used this method to predict to the FAA and their senior management how they intend to reduce error.

The system is straightforward and does not have to be complex. The data reported herein has demonstrated that the most prevalent errors fall into three or four major categories, as discussed. These categories represent about 90% of the installation errors reported herein. Past studies have also shown that installation errors are the most common of all human errors in maintenance. Table 7 uses the same format as Section 4 of this report. The "Linked Reference " Section is replaced with a section called "P of Reduction," probability of reduction. Currently, the P is based on the opinions of the participating companies and/or the research team. All numbers presented are purposely conservative.

This presentation is quite generic. For the calculation to be precise, evaluators would have to carefully analyze each incident, including the narrative statements. Our analysis did not permit extensive knowledge of each incident. The examples below select an error from each of the three major categories.

Table 7: Errors, Prevention Strategies, and Probability of Error Reduction

	Errors	Prevention Strategies	P of Reduction
	Use of Information		
1.	**Simply, did not use available information**	• **KB 1, TCM I & TCM IV ,** • Accountability & Discipline • Multi-level management support	• 90% • 20% • 20%
	Organizational Factors		
2.	Norms (Like #1)	• Standardize the Discipline Policy • Reinforce safety & compliance	• 40% • 60%
	Communication		
1.	Mechanics not sure of procedures or work instructions	• Continued full time (7X24) engineering availability to maintenance • Mechanics and Engineering should review significant events together	• 30% • 40%

Table 7, therefore, has selected the most frequent errors in the most common categories and estimated that organizations can impact error by retreating to the basics. Those basics are the fundamental principles of maintenance. They include such activities as following: the technical manuals, avoiding the everyday short cuts that have become conventional bad practice, and working hard to communicate clearly in verbal and written communication. While terms and campaigns entitled "Back to the Basics" seemed to be overused, it is clear that it is failure of basic regulatory good practice that leads to most error.

7.0 CONCLUSION

Minor maintenance mishaps, significant incidents, and accidents are usually a combination of errors that could have been avoided by more careful adherence to good operating practice and maintenance regulations as defined in FAR Part 43. The data presented herein merely reinforces this notion. The major opportunities to reduce maintenance error are associated with the use of information, organizational work practices, and communication.

The FAA Human Factors In Aviation Maintenance and Inspection Research Program has spent over 13 years to find ways to improve human performance in maintenance. The research and development program has had an impact on the US Domestic and international aviation maintenance industry. A large portion of the international airline maintenance community now has some kind of active maintenance human factors initiative. Examples include the MEDA process, training programs, safety awareness programs, documentation improvement programs, and more. The FAA has published over 10,000 pages of useable technical reports (http://hfskyway.faa.gov) and made a variety of software available to the industry and to the FAA. Because of the research efforts, led by the FAA, many international regulatory agencies are mandating human factors programs in maintenance.

The crusade to promote human factors in maintenance is ongoing. Each year, the international airline maintenance community devotes more money to maintenance human factors. This report has demonstrated that there can be a significant error reduction and return on investment. It remains the responsibility of airline industry human factors personnel to continue to measure the impact of the investment and ensure that it continues as long as humans maintain airplanes.

8.0 ACKNOWLEDGEMENTS

The authors kindly acknowledge Delta Air Lines, Northwest Airlines, and BF Goodrich Aerospace for their contributions to this effort. They have demonstrated a commitment to identify and reduce human error to maintain highest quality and safety within their respective organizations. Further, the author acknowledges Boeing Commercial Airplane Company for their leadership in human error reduction in maintenance by supporting the Maintenance Error Decision Aid (MEDA). Specifically, the authors kindly acknowledge the following personnel: Jeff Bongard, Jerry P. Allen, Tim Killion, David Marx, Tommy Smith, John Westphal, William Rankin, and Bryan Kesterson.

9.0 REFERENCES

1. Allen, J.P, Jr, & Rankin, W.L. (1997). Use of the maintenance error decision aid (MEDA) to enhance safety and reliability and reduce costs in the commercial aviation industry. *The 10th Annual FAA Conference on Aviation Maintenance and Inspection*. FAA: Washington, DC. 1996. (http://hfskyway.faa.gov).

2. Allen, J. P. Jr., and Rankin, W. L. (1995). A Summary of the use and impact of the maintenance error decision aid (MEDA) on the commercial aviation industry. *Proceedings of the Flight Safety Foundation International Federation of Airworthiness 48th Annual Air Safety Seminar*. Seattle, WA: November 7-9, 1995.

3. Boeing. (1994). Maintenance Error Decision Aid. Seattle, WA: Boeing Commercial Airplane Group.

4. Dupont, G. (1997). The Dirty Dozen Errors in Maintenance. *The 11th Symposium on Human Factors in Maintenance and Inspection: Human Error in Aviation Maintenance.* Washington, DC: FAA.

5. International Civil Aviation Organization (ICAO) (1984). *Accident prevention manual (1st Edition)*. ICAO Document Number 9422-AN/923. Montreal, CN: Author.

6. Johnson, W.B. (1981). Computer simulations for fault diagnosis training: An empirical study of learning transfer from simulation to live system performance (Doctoral dissertation, University of Illinois). *Dissertation Abstracts International*, 41 (11) 4625-A. (University Microfilms No. 8108555)

7. Marx, D.A. & Graeber, R.C. (1994). Human error in aircraft maintenance. In N. Johnston, N. McDonald, and R. Fuller’s (Eds.). *Aviation Psychology in Practice*. Brookfield, VT: Ashegate Publishing.

8. Norman, D.A. (1988). *The design of everyday things*. New York, NY: Doubleday.

9. *Open Cowl*. (1992). Pratt & Whitney, March Issue.

10. Rankin, W.L., Allen, J.P. Jr., and Sargent, Robert A. (1998). Maintenance Error Decision Aid: Progress Report. *The 11th Annual FAA Conference on Aviation Maintenance and Inspection.* Washington, DC.: FAA 1998. (http://hfskyway.faa.gov).

11. Reason, J. (1995). *Comprehensive Error Management in Aircraft Engineering: A Manager's Guide.* London, Heathrow: British Airways Engineering.

12. Reason, James (1998). Approaches to Controlling Maintenance Error. *The 11th Annual FAA Conference on Aviation Maintenance and Inspection*. FAA: Washington, DC. 1998. (http://hfskyway.faa.gov).

13. Senders, J.W., and Moray, N.P. (Eds.) (1991). *Human Error: Cause, prediction, and reduction*. Hillsdale, NJ: Lawrence Erlbaum Associates.

14. Standlee, L.S.; Popham, W.J.; and Fattu, N.A. (1956). *A Review of Troubleshooting Research* (Research Report No. 3). Bloomington, IN: Indiana University.

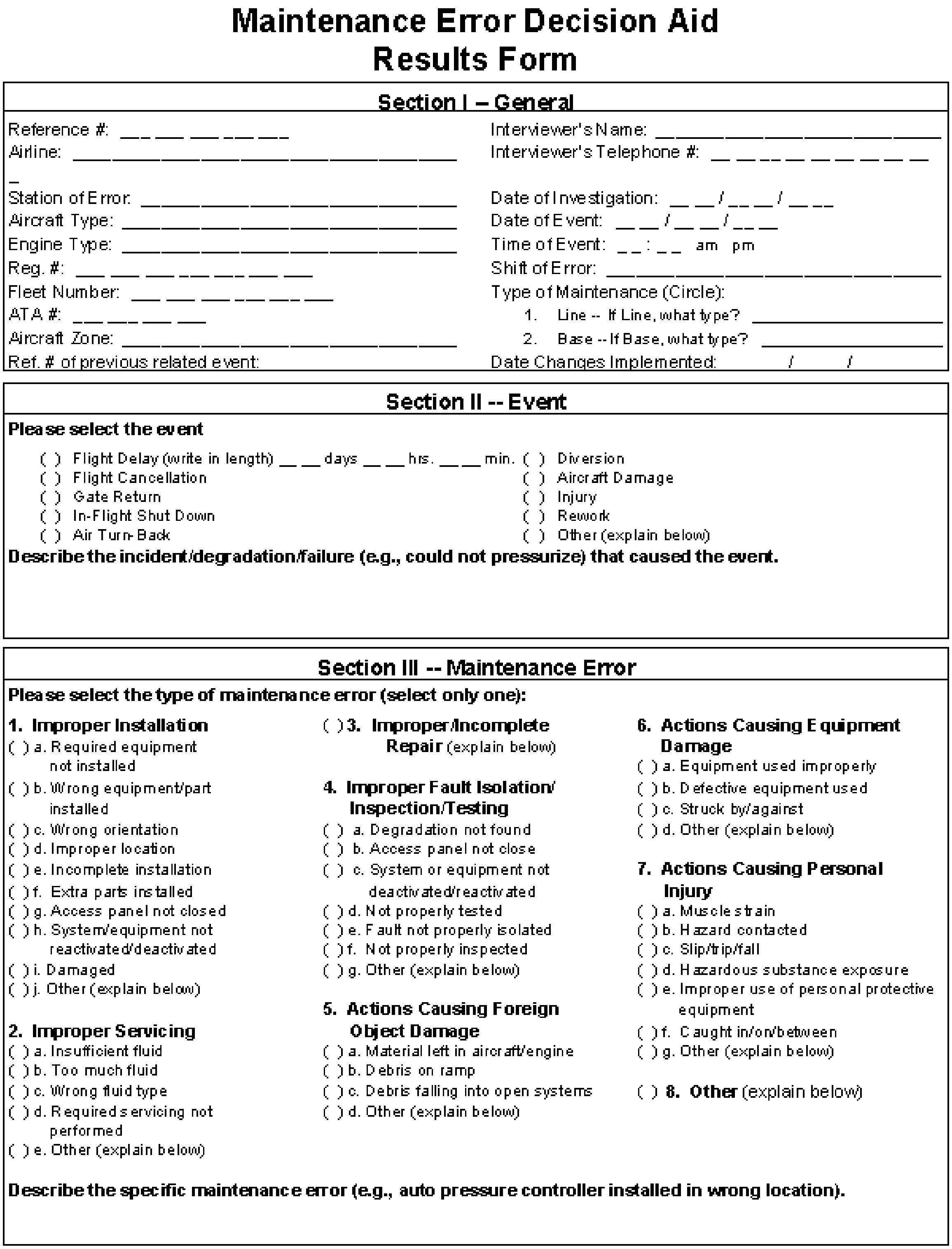
15. United Kingdom Civil Aviation Authority (1992). *Maintenance Error. Asia Pacific Air Safety*. September issue.

16. Rifkind, L. (1998). Communication. In M. Maddox (Ed.), *The Human Factors Guide for Aviation Maintenance and Inspection*. Washington, DC: FAA.

17. Scoble, R. (1993). Aircraft Maintenance Production and Inspection: Team Work + Empowerment + Process Simplification = Quality. *The 8th Symposium on Maintenance Human Factors and Inspection: Trends and Advances in Aviation Maintenance Operations*. Washington, DC: FAA.

18. Gramopadhye, A.K., Kelkar, K., and Watson, J. (1999). Analysis of Shift Change in the Aircraft Maintenance Environment: Findings and Recommendations. Galaxy Scientific (Ed.), *Phase IX Progress Report*. Washington, DC: FAA.

10.0 APPENDIX A: MAINTENANCE ERROR DECISION AID



Maintenance Error Decision Aid
Results Form

Section I – General

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

( ) Flight Delay (write in length) __ __ days __ __ hrs. __ __ min.
( ) Flight Cancellation
( ) Gate Return
( ) In-Flight Shut Down
( ) Air Turn-Back
( ) Diversion
( ) Aircraft Damage
( ) Injury
( ) Rework
( ) Other (explain below)

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

Section III -- Maintenance Error

Please select the type of maintenance error (select only one):

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

2. Improper Servicing
( ) a. Insufficient fluid
( ) b. Too much fluid
( ) c. Wrong fluid type
( ) d. Required servicing not performed
( ) e. Other (explain below)

( ) **3. Improper/Incomplete Repair** (explain below)

4. Improper Fault Isolation/ Inspection/Testing
( ) a. Degradation not found
( ) b. Access panel not close
( ) c. System or equipment not deactivated/reactivated
( ) d. Not properly tested
( ) e. Fault not properly isolated
( ) f. Not properly inspected
( ) g. Other (explain below)

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

6. Actions Causing Equipment Damage
( ) a. Equipment used improperly
( ) b. Defective equipment used
( ) c. Struck by/against
( ) d. Other (explain below)

7. Actions Causing Personal Injury
( ) a. Muscle strain
( ) b. Hazard contacted
( ) c. Slip/trip/fall
( ) d. Hazardous substance exposure
( ) e. Improper use of personal protective equipment
( ) f. Caught in/on/between
( ) 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

N/A __

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 information factor(s) contributed to the error.

N/A __

B. Equipment/Tools

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

Describe specifically how the selected equipment/tool factor(s) contributed to the error.

N/A __

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 aircraft design/configuration/parts factor(s) contributed to error.

N/A __

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 job/task factor(s) contributed to the error.

N/A __

E. Technical Knowledge/Skills

__ 1. Inadequate skills
__ 2. Inadequate task knowledge
__ 3. Inadequate task planning
__ 4. Inadequate airline process knowledge
__ 5. Inadequate aircraft system knowledge
__ 6. Other (explain below)

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

N/A __

F. Individual Factors

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

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

N/A __

G. Environment/Facilities

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

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

N/A __

H. Organizational Factors

__ 1. Quality of support from technical organizations (e.g., engineering, planning, technical pubs) __ 4. Union action
__ 5. Corporate change/restructuring
__ 2. Company policies __ 6. Other (explain below)
__ 3. Company work processes

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

N/A __

I. Leadership/Supervision

__ 1. Inadequate planning/organization of tasks __ 4. Unrealistic attitude/expectations
__ 2. Inadequate prioritization of work __ 5. Amount of supervision
__ 3. Inadequate delegation/assignment of task __ 6. Other (explain below)

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

N/A __

J. Communication

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

Describe specifically how the selected communication factor(s) 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.