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Procedural error analysis in aircraft maintenance operations

Kirsten Nord
San Jose State University

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PROCEDURAL ERROR ANALYSIS IN AIRCRAFT MAINTENANCE OPERATIONS

A Thesis

Presented to

The Faculty of the Graduate Program in Human Factors/Ergonomics

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Kirsten Nord

May 1998

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APPROVED BY THE MASTER'S THESIS COMMITTEE

Dr. Kevin Jordan, Thesis Chairperson

Dr. Barbara Kanki, Thesis Committee member

Dr. Louis Freund, Thesis Committee member

APPROVED FOR THE UNIVERSITY

ABSTRACT

PROCEDURAL ERROR ANALYSIS IN AIRCRAFT MAINTENANCE OPERATIONS

by Kirsten Nord

Procedural errors were identified as the major cause of aircraft maintenance incidents (Veinott & Kanki, 1995). They examined 83 ASRS reports and found that these errors accounted for approximately 60% of all error types. In this paper, we examined more recent ASRS reports, those after 1996, for procedural errors, and analyzed them according to recently developed error analysis tools such as FRANCIE and MEDA. We evaluated reports on four levels: error type, written support information (document type, aspect of the document), verbal support information (communication type, aspect of the communication), and contributing factors (written, verbal). Awareness and task execution errors were the most frequent error type. Document type errors included maintenance manual and aspect of the document included completeness as the most frequent. The majority of communication type errors were between superior and subordinate and aspect of the communication involved problem solving/decision making. Written contributing factors had two errors in the majority: part design/tools/equipment and task related and verbal contributing factors had one, organizational culture.

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PROCEDURAL ERROR ANALYSIS IN AIRCRAFT MAINTENANCE OPERATIONS

Kirsten Nord

San Jose State University

PROCEDURAL ERROR ANALYSIS

ABSTRACT

Procedural errors were identified as the major cause of aircraft maintenance incidents (Veinott & Kanki, 1995). They examined 83 ASRS reports and found that these errors accounted for approximately 60% of all error types. In this paper, we examined more recent ASRS reports, those after 1997, for procedural errors, and analyzed them according to recently developed error analysis tools such as FRANCIE and MEDA. We evaluated reports on four levels: error type, written support information (document type, aspect of the document), verbal support information (communication type, aspect of the communication), and contributing factors (written, verbal). Awareness and task execution errors were the most frequent error type. Document type errors included maintenance manual and aspect of the document included completeness as the most frequent. The majority of communication type errors were between superior and subordinate and aspect of the communication involved problem solving/decision making. Written contributing factors had two errors in the majority: part design/tools/equipment and task related and verbal contributing factors had one, organizational culture.

PROCEDURAL ERROR ANALYSIS IN AIRCRAFT MAINTENANCE OPERATIONS

With the Airline Deregulation Act of 1978, the airline industry was forever changed. Instead of guaranteed routes and passengers, airlines were forced into a competitive free market. In order to survive, the industry had to modify procedures so as to become cost-effective.

Hub and spoke systems are a popular and efficient way to operate an air carrier. In this system, an airline has a few major “hubs” or main cities in which they fly. “Spokes” are minor cities the airline flies where passengers are fed to the larger hubs. Similar to a bicycle wheel, the spokes lead to a large center hub. Flights out of the hub are frequent. Instead of a single flight from A to B, the hub and spoke system allows infinite combinations of flights. By operating in this manner, airlines are able to provide service to many more passengers.

Not every system is perfect, and with the advent of the hub and spoke system, the need for ground crew significantly increased. A typical turn around time (the time it takes to refuel, unload baggage, and reload new baggage) is approximately 45 minutes. During this 45 minute time period, crew workload is high. However, the time in between flights is slow and ground crews have little to do. This lag time creates an ineffective use of company time.

Maintenance crews face similar problems. The time that is spent maintaining an aircraft, although necessary, is viewed as down-time to the company. Airlines do not make money when the aircraft is in the maintenance bay.

Maintenance of aircraft can be divided into two categories: routine (or scheduled) and unscheduled. Federal Aviation Regulations (FARS) require that aircraft be maintained at regular intervals (FAR Part 135.425), such as a routine inspection after 100 hours of flight. Manufacturers can also specify scheduled maintenance intervals. A scheduled event, such as engine change procedure, can require up to three days to perform, (on Boeing 737's) but is performed only a few times in the life of an aircraft (Repp, 1995).

Unscheduled maintenance is dependent upon where the aircraft is when the incident occurs, the time of the incident, and the crew available at the time. Managers, then, face the task of balancing crews in order to keep “turn-around time” to a minimum.

Aircraft Maintenance Technicians (AMT) face time-management problems on a daily basis. They are involved in a process of crew interaction every day and, in fact, communication within and between crews is a critical function of how well an AMT can do his or her job. Research on flight crew interaction and management and its improvement has been the topic of many studies (see Foushee & Helmreich, 1988). However, similar research which focuses on maintenance crews is still somewhat rare.

Crew Resource Management

Crew Resource Management (CRM) began as an industry response to crew problems implicated in several crashes. For example, the L-1011 crash in the Florida Everglades was caused, as determined by NTSB investigators, by lack of communication between aircraft crew members and air traffic controllers (ATC). The crew was focusing on an incidental cautionary landing light, and did not establish who was in charge of flying the aircraft. They did not realize that they were slowly losing altitude. The ATC who was monitoring their position did not clearly communicate the fact that the aircraft had gone severely below glide slope and was in danger of impacting with the ground. Unfortunately, the crew did not become aware of the situation in time and 99 passengers and crew members lost their lives (NTSB, 1972).

After the NTSB ruled that the accident occurred because of a lack of communication between crew members and ATC, the aviation community response included a variety of initiatives. Among them, was the development of a new area of human factors research in which communication between pilots was studied (e.g. Kanki & Foushee, 1989).

Airlines heeded the call to train their personnel. Many airlines, such as KLM and Royal Dutch (Helmreich & Foushee, 1993), initiated programs using lectures and videotape presentations to train pilots on how to communicate effectively with crew

members. Line Oriented Flight Training (LOFT) and CRM training programs were the American counterparts. Some pilots have always responded to the training negatively, but after these early training initiatives, CRM has become widely accepted.

At first, CRM focused on group processes and included training in “advocacy, communicating, proposed action and conflict resolution, decision making, critique and review action taken and decisions reached” (Foushee & Helmreich, 1988). Later, CRM training focused attention on organizational cultures as well as group and individual factors (Foushee & Helmreich, 1988). Currently, these elements, and others such as situational awareness and error management, are now included in pilot CRM training.

Crew Resource Management is a proven success in some cases. For example, while flying over Sioux City, Iowa, a United DC-10's turbine blade failed, severing all hydraulic lines to the flight controls. The pilot, Captain Al Haynes, faced one of the most disturbing scenarios of his life; no way to maneuver an aircraft with several hundred people onboard. Determined to keep all his passengers safe, he used all available resources in an attempt to safely land the aircraft. Thanks to Captain Haynes' training in CRM, 175 passengers and crew members survived an almost certain deadly situation (NTSB, 1989). He spends his retirement as a continuing proponent of CRM training.

Maintenance Resource Management

With this success in mind, CRM researchers and their industry partners began to explore the idea that CRM principles could be applied to other arenas such as nuclear power engineers, surgery teams, and aviation maintenance crews. Maintenance Resource Management (MRM) began as such an application.

MRM is a burgeoning field. As a new field, data collection of accidents and incident reports is key to identifying “problems” within the system. Unfortunately, the basic data to which most CRM researchers have access is not available to the MRM researcher. For instance, the data collection process of studying the errors induced by a pilot is relatively simple. The “input” the pilot enters into the system can be recorded and

analyzed instantly. The result (or “output”) is the manipulation, in some way, of the aircraft. The data collection process in maintenance operations, however, is quite different. An erroneous input from an AMT might not be detected for years. Instant analysis, then, is not always possible.

For this reason, data collection requires creativity on the part of the MRM researcher. One extensive database that is available for analysis is the Aviation Safety Reporting System (ASRS). This database which is managed by Battelle, supported by NASA and the FAA, collects incident information reported by aircraft personnel including pilots, flight attendants, ground crew, air traffic controllers, and maintenance crew. In 1997, ASRS introduced reporting forms specifically designed to accommodate maintenance crew incidents. All information reported is confidential and, under specified conditions, reporters receive immunity from FAA prosecution.

Error Analysis Tools

Analysis of maintenance data has been conducted in various forms. Fault analysis tools are common. Maintenance Error Decision Aid (MEDA) and Framework Assessing Notorious Contributing Influences for Error (FRANCIE) are two such analysis tools. The FRANCIE methodology can identify specific types of errors that occur in any environment and MEDA supports aircraft maintenance.

Maintenance Error Decision Aid

MEDA began as a collaborative effort initiated by Boeing with airline partners United Airlines, Continental Airlines, and British Airways. This team formulated a decision aid error analysis tool to help those people untrained in human factors to evaluate events. The decision-aid is an event-driven tool; it is only used when a perceived event has occurred. The aid is also an “error management tool” expected to help prevent accidents by systematically examining causal factors (MEDA, 1994).

MEDA has several levels to consider. After the initial incident occurs, it defines the sequence of events to analyze. First cut analysis is explored by the AMT’s immediate

trained analyst, and data collection begins. For example, if a tool is left inside an aircraft, the analyst must first collect data about who was involved and where the incident occurred. Error scenario development pieces together all the events that are likely to have contributed to the error. Continuing with the previous example, the mechanic stepped away from the task and when he or she returned, they did not remember the tool was still in the aircraft. After the scenario is set, contributing factors analysis considers other factors that might have also contributed to the error. Contributing factors might include fatigue, distraction, and motivation. Finally, an intervention strategies analysis indicates preventative measures for the future.

MEDA's error analysis describes the event in concrete terms. The Results Form (see Appendix A on Results Form) includes five sections: general, operation event, maintenance error, contributing factors checklist, corrective actions. In this manner, the location and type of error is evident.

Framework Assessing Notorious Contributing Influences for Error

FRANCIE is another paper-based error analysis tool. This tool was created by Idaho National Engineering Labs to analyze a hierarchical system of events analysis. FRANCIE differs from MEDA in that the breakdown of the task is done at a more detailed level. After the error is detected, several levels of the incident are analyzed.

FRANCIE'S first level determines if the error was an omission or commission (see Appendix B on System/Component/Part to be Maintained). An example of an error of omission is when an AMT skips a procedure (non-intentionally). When this type of error has been determined, the tool defines potential error types. Such error types, if a procedure was skipped, might include improper repair. General Performance Shaping Factors (PSF) indicate the general area of concern, for example a procedural error. Once the General PSF's have been defined, an analysis of intermediate PSF's takes place. The AMT could have skipped the procedure because it was not "easy to use". Finally, a Specific PSF test is conducted on the suspected error. In this way, a "branching effect" occurs in which the

investigator can follow an event tree diagram from the error to the specific PSF (Ostrom, Nelson, Haney, Richards, Wilhelmsen, & Owen, 1997).

Error Types in Aircraft Maintenance

A study by Veinott and Kanki (1995) specified types of maintenance errors which occurred within the environment. They analyzed ASRS data to determine three things “(a) What types of errors occur? (b) What are the contributing factors to these errors? (c) What are the results of these errors in terms of aircraft damage and operational impact?”. Out of the 83 valid cases, 60% of the errors were found to be procedural in nature, 27% involved practices, 8% were attributed to parts, and 5% were due to airport operations. The large number of procedural errors was of principle interest to this investigator.

Procedural Error Analysis, The Present Study

Procedural errors are typically assumed to be errors that involve written documents. However, procedural errors can also include verbal instruction and communication. For example, when a lead maintenance technician explains to an AMT how to disassemble a casing, the explanation is a verbal procedure. Most error analysis tools, however, do not include an extensive amount of attention to both verbal and written communication in their analyses. By combining and arranging sections of FRANCIE and MEDA, while adding a verbal communication section, a more extensive analysis tool is created. The present study examined ASRS maintenance reports to understand more about: (a) the error types included in procedural errors (b) the involvement of written and verbal information (c) the types of contributing factors involved in procedural errors.

ASRS Incident Database

ASRS has collected nearly 350,000 incident reports from pilots, flight attendants, air traffic controllers, ground crew, and maintenance personnel (Aviation Safety Reporting System, 1997). These confidential reports help researchers identify important issues in aviation. By utilizing this vast database, scientists are able to improve aviation safety.

In recent years, ASRS has developed several new reporting forms to help identify

non-pilot related incidents. One type of new reporting form is the Maintenance Form (see Appendix C on Maintenance Form). Consequently, the present data set primarily included reports from 1997 onward. The Veinott and Kanki (1995) study differed from the present study in that their ASRS data set was sampled prior to the new Maintenance Reporting Form implementation in 1997.

Reports also met the previous criteria of Veinott and Kanki (1995), specifically: “(a) It involved an aircraft operating under the Title 14, Code of the Federal Regulations Part 121, (b) It cited an error that involved maintenance personnel, (c) It was not a ground incursion.” Following their criteria, the reports were selected (see Appendix D on the Veinott and Kanki Coding System).

METHOD

Measures

The present study used two coding schemes. The first defined which ASRS reports were included in the study. The second coding scheme identified procedural errors. The investigator moved through the coding sheets and circled appropriate characteristics of the incident as delineated by the scheme. The experiment involved several levels of coding as illustrated in the Flowchart (see Appendix E on Flowchart).

Design

In Veinott and Kanki’s study (1995), four types of errors were used including: parts, procedures, practices, and airport operations. Parts was defined as: “installing a bad or wrong part”. Procedures was defined as “not finishing a procedure, misinterpreting instructions, signing off on work that has not been completed, and not inspecting work that requires an inspection”. Practices was defined as “incorrect action, no written procedures are available, deferring items when could not legally do so, and signing off on items when could not perform required check”. Airport Operations are defined as “airport problems (e.g. no sand on the runway equipment in the safety zone”. Of these four types, only the procedures and practices sections will be included in the research data set as these meet the

requirements of being procedural errors by definition.

First Level Coding

The reports were coded on all aspects of the Veinott and Kanki Coding System. This system included: AC Type (aircraft type), a description of the error, the cause of the error, the result of the error, and an anomaly description (see Appendix D on the Veinott & Kanki Coding System). Such information helped to predict consequences (if any) of aircraft maintenance procedural incidents. Only those reports which contained procedural errors were included in the data set.

Second Level Coding

The second level of coding used only those reports selected by the first level coding. The second level coding sheet was divided into four headings: error types, written support information, verbal support information, and contributing errors for both written and verbal support information. The researcher included all information that was involved in the incident. Multiple errors were possible, although each ASRS report was coded independently.

The first section of coding in the second level specified error types. There were eight error types as delineated in FRANCIE (Ostrom, Nelson, Haney, Richards, Wilhelmsen, & Owen, 1997). Each type of error was listed with examples (see Appendix F on Error Type).

Once the investigator had coded error types, the second section in the second level was the written support information section. This section allowed an examination of errors that were within the maintenance document. Written support information consisted of three main subheadings: error does not involve the use of a document (from FRANCIE, 1997), error involves the use of a document (from MEDA, 1994), and aspect of the document (altered from FRANCIE, 1997). Below each heading was a section describing errors that was classified under each heading (see Appendix G on Written Support Information).

The first part of written support information was "error does not involve the use of

a document". Here, if the error did not involve the use of a document, the investigator was instructed to continue to the verbal support information section and continue coding. If the error did involve a document, the investigator coded "aspect of the document".

While procedural errors can involve written information, they can also involve verbal information. The verbal support information was the third section and investigated this topic. As in written support information, the first subheading of verbal support information was "error does not involve verbal communication" (adapted from FRANCIE, 1997, see Appendix I on Verbal Support Information). In Part A (see Appendix E on Flowchart), when an error did not involve the use of verbal communication, the investigator was instructed to continue to the contributing factors section and continue coding. If the error "involves verbal communication" (altered from MEDA, 1994), the investigator specified where the communication lay in "aspects of the communication" (altered from FRANCIE, 1997).

In addition to written and verbal support information, "contributing factors" (from FRANCIE, 1997) can augment potential errors. Contributing factors were broken into two categories: (a) written support information contributing factors (see Appendix H on Written Contributing Factors), or those that are associated with a written error, and (b) verbal support information contributing factors (see Appendix J on Verbal Contributing Factors), or those that involve the verbal aspect of the error. In this section multiple error types were common. Descriptions are included in each of these sections.

RESULTS

Three issues were addressed directly in this study: (a) the error types included in procedural errors (b) the involvement of written and verbal information (c) the types of contributing factors involved in procedural errors. The following is a descriptive exploration of those issues.

Data

In this study, several variables were permitted to have up to three responses. By allowing three responses, the ASRS reporter's comments on multiple error factors were addressed. For example, if a reporter states that it was raining, she or he was tired, and she or he could not find a part, these responses would be coded separately although they are from a single report. The variables that were permitted multiple responses were: aspect of the document, aspect of the communication, written contributing factors, and verbal contributing factors. Valid cases were those responses which have a separate identified response within a variable. Therefore, valid cases can be greater than the actual number of reports.

Coding System

The reports were coded on two levels. The first level was the Veinott and Kanki Coding System which included: AC Type (aircraft type), a description of the error, the cause of the error, the result of the error, and an anomaly description. The second level coding sheet was divided into four headings: error types, written support information, verbal support information, and contributing errors for both written and verbal support information.

First Level Coding

As a continuation of the previous work by Veinott and Kanki (1995), 207 reports were queried from the ASRS database under the title "Maintenance Reports" (ASRS Report # 5036) to determine the percentage of procedural types of errors. In the present study, a broader definition of procedural errors was included. Practices errors were defined as errors related to procedures which were not available, while procedural errors were defined as errors tied to procedures which were not completed or misinterpreted. Therefore, procedural errors in the present study are roughly equivalent to the combined procedural and practices errors from the previous study.

From the 207 reports (see Figure 1), 23 were not from Part 121 operations and

Figure 1

Organizational Chart

Reports=Actual ASRS Reports
Cases=Multiple Response Variables
* These variables are not exclusive

were not included. Nineteen cases could not be classified with respect to type of error, making the total reports 165. Of these 165, 123 reports were determined to be procedural in nature (see Table 1).

Second Level Coding

The second level of coding involved three areas: error types in procedural errors, the involvement of written and verbal information, and written and verbal contributing factors. The following are the results for these three areas.

Error Type in Procedural Errors

The first question asked was what error types occur in procedural errors. In this study, error type included 123 reports (see Figure 1). Awareness and task execution errors were among the most common types (33%), as opposed to procedural omission, error of intent, selection error, fault identification/diagnosis/indicators, inspection and verification, and maintenance repair (see Table 2). Examples of awareness and task execution errors include leaving foreign material in aircraft, leaving aircraft in the wrong configuration, or damaging a component or part being maintained. The next highest category was maintenance repair inadequate with 26% of the reports. This category was a generic "catch all" in which an error type was mentioned, but could not be included in another category. The third highest category was procedural omission. These errors were attributed to 21% of the reports. An example of procedural omission includes unintentionally skipping a step in the procedure.

Involvement of Written and Verbal Information

The second question that was considered was how written and verbal information were involved in procedural errors. Written information included: document type (maintenance manual, logbook/minimum equipment list (MEL), and workcard/jobcard) and aspect of the document (correctness, completeness, usability, and inspection/verification). Verbal information involved: communication type (between departments, between crew members, and between subordinate and superior) and aspect of the communication

Table 1

Frequency and Distribution of Types of Error (Valid Cases=165)

Parts	Procedures	Airport Ops
37	123	5
22%	75%	3%

Table 2

Frequency and Distribution of Error Type (Valid Cases=123)

Procedural Omission	Selection Error	Awareness and Task Execution Error	Fault Identification, Diagnosis, and Indicators	Inspection and Verification	Error of Intent	Maintenance Repair Inadequate
26	5	40	6	3	11	32
21%	4%	33%	5%	2%	9%	26%

(problem solving decision making, interpersonal relationships, attention to task, and communication as a management tool).

Document Type. Of the 123 reports, 97 reports involved the use of a document (see Figure 1). Of these 97 reports, 35% involved the maintenance manual (see Table 3). The logbook/MEL category was the next highest category with 24% of the reports, and workcard/jobcard was prevalent in 22% of the reports. The "other" category accounted for 19% of the reports. In this category, use of a document was mentioned, but not specifically identified and, therefore, conclusions can not be made from that data.

Aspect of the Document. Aspect of the document had 91 valid cases and it was a multiple response variable (see Figure 1). Thirty-one percent attributed aspect of the document errors to the completeness of the document (see Table 4). An example of completeness is an individual step not included in the written procedure. The second most prevalent aspect of the document was no inspection/verification with 29%. Examples of no inspection/verification errors are no walk around inspection provision in document or no signoff procedure in document. Another type of aspect if the document error was correctness and warnings/cautions/notes with 24% of the errors. Steps in the improper order, as well as consequences which were inadequately stated are examples of correctness and warnings/cautions/notes errors. Sixteen percent of the aspect of the document were usability related errors. Usability issues includes non-adherence to writer's guide and non-minimization of multiple procedures/tasks.

Communication Type. Of the 123 reports, 29 involved verbal communication (see Figure 1). Forty-one percent were between superior and subordinate related errors (see Table 5). Examples of communication between superior and subordinate were management personnel speaking to lead AMT's or a lead speaking to AMT's. The between departments category accounted for 28% of reports and between crew member was attributable to 24% of reports. Between department communication can include communication such as between engineering and maintenance departments, while between crew members can be

Table 3

Frequency and Distribution of Document Type (Valid Cases=97)

Maintenance Manual	Logbook/ MEL	Workcard/ Jobcard	Other
35	23	21	18
35%	24%	22%	19%

Table 4

Frequency and Distribution of Aspect of the Document (Valid Cases=91)

Correctness/ Warnings/Cautions/ Note	Completeness/ Supporting Information	Usability	No Inspection/ Verification
22	28	15	26
24%	31%	16%	29%

Table 5

Frequency and Distribution of Communication Type (Valid Cases=29)

Between Departments	Between Crew Members	Between Shifts	Between Superior and Subordinate
8	7	2	12
28%	24%	7%	41%

communication between two AMT's. The between shifts category was only reported in two reports.

Only 14 reports out of 123 were solely attributed to verbal communication. Of those fourteen, ten were because the procedure was not used, and four were due to the procedure not existing.

Aspect of the Communication. Aspect of the communication had 34 valid cases and was a multiple response variable (see Figure 1). Forty-three percent of aspect of the communication cases were problem solving/decision making in nature (see Table 6). An example of this type of error is: recognizing a problem, gathering information, or explaining the situation. The next highest category was attention to task/monitoring with 24% of the cases. An example of this error is an interrupted task or incomplete task. Communication as a management tool was included in 21% of the cases. Examples of these errors are not integrating tasks in an ordered timely fashion or poor leadership style. Interpersonal relationships were the lowest ranking aspect of the communication with 12% of cases. Examples of interpersonal relationships errors are personality conflicts or strain between co-workers.

Contributing Factors

In the third question, written and verbal contributing factors were explored in procedural errors. Both written and verbal contributing factors used the same categories: parts design/tools/equipment, AMT skill/training/attributes, environment, organizational culture/stress/fatigue, workload/resources.

Written Contributing Factors. Written contributing factors was a multiple response variable, although there were only 86 valid cases (see Figure 1). One third of written contributing factors was due to both part design/tools/equipment and task related (see Table 7). For example, parts not available or tools not available are examples of part design/tools/equipment. Examples of task related are disproportionate workload for available time or staff and stress and fatigue negatively affecting performance. AMT skill,

Table 6

Frequency and Distribution of Aspect of the Communication (Valid Cases=34)

Problem Solving/ Decision Making	Interpersonal Relationships	Attention to Task	Communicaton as a Management Tool
15	4	8	7
43%	12%	24%	21%

Table 7

Frequency and Distribution of Written Contributing Factors (Valid Cases=86)

Part Design, Tools, and Equipment	AMT Skill, Training, and Attitude	Environment	Organizational Culture	Task Related
28	16	5	9	28
33%	19%	6%	10%	33%

training and attitude were prevalent in 19% of cases. This category included errors such as maintenance personnel are not trained or experienced and maintenance personal are not motivated.

Verbal Contributing Factors. Verbal contributing factors was involved in 27 valid cases (see Figure 1). The main verbal contributing factor (67%) was organizational culture (see Table 8). Organizational culture included such errors as management is uninformed or non-supportive in maintenance activity and peer pressure negatively affecting performance. The second type of verbal contributing factor is part design/tools/equipment with 19% of errors. Examples of part design/tools/equipment are a part not available or a tool not available. AMT skill, training and attitude were prevalent in 15% of cases. This category included errors such as maintenance personnel are not trained or experienced and maintenance personal are not motivated. There were no reported cases of environment or task related verbal contributing factors.

Cross Tabulations

In the previous study by Veinott and Kanki, Pearson chi-square and cross tabulation descriptive statistics were explored in the context of maintenance error. As this study is also exploratory in nature, Pearson chi-square and cross tabulations were also employed (Norusis, 1994).

Two-way cross tabulations were performed on several variables. In each cross tabulation, the total number of events does not reflect the frequency of the distribution, but includes only those events sampled in the test. For example, error type by document type includes only 55 events, because the number of sampled reports are those which must contain both an error type and a document type. This number is significantly less than the total number of reports in either category alone. However, we can comment about those errors types which are associated with particular document types.

Cross Tabulations of Error Type Combinations

Examinations by Pearson's chi-square focused on error type by several other

Table 8

Frequency and Distribution of Verbal Contributing Factors (Valid Cases=27)

Part Design, Tools, and Equipment	AMT Skill, Training and Attitude	Organizational Culture	Organizational Culture	Task Related
5	4	18	0	0
19%	15%	66%	0%	0%

variables, document type, aspect of the document, communication type, aspect of the communication, written contributing factors, and verbal contributing factors.

Error Type by Document Type

There were 55 events that included both error type and document type. The interaction of error type and document type (maintenance manual, logbook/MEL, and workcard/jobcard) was tested for significance ($\chi^2=10.33$, $df=8$, $p>.24$) and was found to have no interaction.

Of the events, 26 out of 55 (47%) were maintenance manual related. Sixteen out of fifty-five (29%) were workcard/jobcard related. Thirteen out of fifty-five events (24%) were logbook/MEL related.

Fourteen events out of the twenty-six maintenance manual errors (54%) were found to be a part of maintenance manual errors. Eight of the sixteen workcard/jobcard related errors (50%) were a part of procedural omission errors. Ten out of thirteen of logbook/MEL errors (77%) were found to contain awareness and task execution errors.

Error Type by Aspect of the Document

The number of sampled error type and aspect of the document events was 64. The interaction of error type and aspect of the document (correctness, completeness, usability, and no inspection/verification) was not significant ($\chi^2=16.03$, $df=12$, $p>.18$).

No inspection/verification errors had the largest category with 20 out of 64 events (31%). Seventeen out of sixty-four events (27%) were attributed to correctness and warning/cautions/notes. Similarly, 16 out of 64 events (25%) accounted for completeness and supporting information. Only 11 out of 64 events (17%) were related to usability.

Eleven out of twenty no inspection/verification events (55%) were related to awareness and task execution errors. Nine out of seventeen events (53%) of correctness and warning/cautions/notes were related to awareness and task execution errors. Twelve out of sixteen events (75%) involved completeness aspect of the document and awareness and task execution errors. Four out of eleven events (36%) were associated with usability

aspect of the documents and awareness and task execution errors.

Error Type by Communication Type

Error type and communication type had 16 events. The interaction of error type and communication type (between departments, between crew members, and between superiors and subordinates) was calculated ($\chi^2=5.65$, $df=6$, $p>.46$), and was found not significant.

The largest category was between superior and subordinate with eight events out of sixteen. Between crew member had five events. Between departments had three events.

Five out of eight events (63%) of between superior and subordinate were related to awareness and task execution errors. Three events out of the five (60%) between crew members were related to procedural omission. Two out of three (67%) between departments events related to procedural omission, as well.

Error Type by Aspect of the Communication

Errors that included both error type and aspect of the communication had 19 events. The interaction of error type and aspect of the communication (problem solving/decision making, interpersonal relationships, attention to task, and communication as a management tool) did not show a strong interaction ($\chi^2=15.35$, $df=9$, $p>.08$).

Nine out of nineteen aspect of the communication events (47%) were related to problem solving/decision making. Five out of nineteen events (26%) were related to attention to task. Communication as a management tool was prevalent in three out of nineteen events (16%), and interpersonal relationships accounted for two out of nineteen events (11%).

Problem solving/decision making had only two out of nine events (22%) that involved fault identification and diagnosis. Three of the five attention to task errors (60%) were attributed to awareness and task execution errors. Communication as a management tool were evenly associated with procedural omission, selection error, and awareness and task execution errors. Two out of two (100%) interpersonal relationship errors were

fault identification/diagnosis errors.

Error Type by Written Contributing Factors

Errors that involved both error type and written contributing factors totaled 70 events. The interaction of written contributing factors (part design/tools/equipment, AMT skill/training/attributes, environment, organizational culture, and task related) did not show a strong interaction ($\chi^2=24.01$, $df=16$, $p>.08$).

Part design/tools/equipment was the largest category with 24 out of 70 errors (34%). The second largest was task related with 22 out of 70 events (31%). AMT skill/training/attitude was third with 15 out of 70 events (21%).

Of the part design/tools/equipment written contributing factors, 17 out of 24 events (71%) were related to awareness and task execution errors. Nine out of twenty-two events (41%) were related to task related errors and procedural omission. AMT skill/training/attitude had six out of fifteen events (40%) that were awareness and task execution related.

Error Type by Verbal Contributing Factors

Error type and verbal contributing factors had 15 valid events. The interaction of verbal contributing factors (part design/tools/equipment, AMT skill/training/attributes, environment, organizational culture, and task related) showed no interaction ($\chi^2=1.52$, $df=6$, $p>.96$).

Ten events out of fifteen events (67%) were related to organizational culture. Three out of fifteen events (20%) were related to AMT skill/training/attitude, and two out of fifteen events (13%) were related to part design/tools/equipment. The distribution across error type was roughly the same for each of the verbal contributing factors.

Cross Tabulations of Written and Verbal Information

Pearson's chi-square tests were calculated for written and verbal information. Written information included the combination of document type by aspect of the document, while verbal information included communication type by aspect of the communication.

Document Type by Aspect of the Document

Events for the combination of document type and aspect of the document was 76. The interaction of document type compared and aspect of the document did not show significance ($\chi^2=2.63$, $df=6$, $p>.85$).

Completeness and supporting information was the largest category with 26 out of 76 events (34%). No inspection/verification had 20 out of 76 events (26%). Correctness and warnings/cautions/notes was third with 16 out of 76 events (21%), and usability was fourth largest with 14 out of 76 events (18%).

Twelve of the twenty-six completeness and supporting information events (46%) were related to the maintenance manual. Eight out of twenty events (40%) from the no inspection/verification category were related to the maintenance manual. Similarly, seven out of sixteen events (44%) from correctness and warnings/cautions/notes were related to maintenance manual. Six out of fourteen usability events (43%) were related to the workcard/jobcard category.

Communication Type by Aspect of the Communication

Communication type and aspect of the communication included only 34 events. The interaction of communication type versus aspect of the communication, ($\chi^2=15.76$, $df=9$, $p>.07$) did not show significance.

Problem solving and decision making were attributed to 15 out of 34 (44%) of the events. Attention to task accounted for eight out of thirty-four events (24%). Communication as a management tool was attributed to seven out of thirty-four events (21%), and interpersonal relationships accounted for four out of thirty-four events (12%).

The distribution of events was roughly equal for problem solving and decision making. Four out of eight events (50%) from attention to task were related to between superior and subordinate. Similarly, four out of seven events (57%) were related to superior and subordinate for communication as a management tool. Four out of four events (100%) were related to interpersonal relationship aspect of the communication and between

superior and subordinate category.

Cross Tabulations for Contributing Factors

Tests of Pearson's chi-square were done for contributing factors. Document type and written contributing factors, as well as communication type and verbal contributing factors were tested.

Document Type by Written Contributing Factors

Document type and written contributing factors were sampled in 67 events. The interaction of document type compared to written contributing factors showed no interaction ($\chi^2=7.98$, $df=8$, $p>.44$). Task related amounted to 23/67 (34%) of events. Part design/tools/equipment accounted for 20 events, and AMT skill/training/attitude was in 13 events. The distribution was roughly equal for task related. Sixty percent of parts design/tools/equipment related written contributing factors were also included in maintenance manual errors. Similarly, six out of 13 AMT skill/training/attitude events were related the to maintenance manual category.

Communication Type by Verbal Contributing Factors

The number of events for communication type and verbal contributing factors was 27. The interaction of communication type versus verbal contributing factors showed no significance, ($\chi^2=7.40$, $df=6$, $p>.29$).

Organizational culture accounted for 18 out of 27 of errors (67%). Five out of eighteen events (19%) were related to part design/tools/equipment, and four out of eighteen events (15%) were related to AMT skill/training/attitude.

Eleven out of 18 events (61%) were related to errors in the organizational culture and between superior and subordinate. The distribution of communication type was roughly the same for both part design/tools/equipment and AMT skill/training/attitude.

DISCUSSION

In a continuation of the work done by Veinott and Kanki (1995), we first analyzed error types. As procedural errors was the largest category in both studies, we

focused on classifying those types of errors. Previously, Veinott and Kanki suggested that procedural errors could be improved through technical training and documentation, and practical errors could be modified through on the job training. We considered those improvements in maintenance errors.

Coding System

Reports were coded on two levels. The first was the Veinott and Kanki Coding System. The second was a combination of the MEDA and FRANCIE coding systems with new material added.

First Level Coding

In the previous study, procedural errors were the main type of errors (60%) and practices errors were also significant at 27%. As explained in the previous section, we included both of these errors in a general category of procedural errors, which accounts for 75% of the errors. The percentage of both of Veinott and Kanki's types of errors is greater (87%) than the present study's combined category (75%), even though the number of reports was approximately half (83) of the present one (165). The difference between the two is accompanied by an increase in the parts related errors, which rose from 8% to 22%.

Second Level Coding

The second level of coding involved the three issues: error types in procedural errors, the involvement of written and verbal information, and written and verbal contributing factors (see Figure 1). These three issues can help identify how reporters identified errors in procedural errors.

Error Type in Procedural Errors

The first issue identified error types in procedural errors. In the present study, we determined that the most common error type was awareness and task execution errors (33%). Examples of awareness and task execution errors are leaving foreign material in aircraft, leaving aircraft in the wrong configuration, or damaging a component or part being maintained. The next highest category was maintenance repair inadequate. Since this

category became a generic “catch all” in which an error type was mentioned, but could not be described in detail, further analysis was not possible. The third highest category was procedural omission. An example of procedural omission includes unintentionally skipping a step in the procedural. These error types could be attributed to both technical training and on-the-job-training issues. In addition, it could point to deficiencies in the procedure itself.

Error Type by Document Type. Both maintenance manual and seventy-seven logbook/MEL events were found to have a large percentage of awareness and task execution errors. The ASRS responses suggest that the maintenance manual written procedures could be improved by providing better guidance to AMT's. For example, it is common for the maintenance manual to finalize a repair by stating “Return aircraft to original condition”. Instead, by writing the steps of returning the aircraft to operational condition, or reversing the order of the repair, the maintenance manual and logbook/MEL procedures would better describe the task. Revision of this system could prove valuable.

Improved teamwork could also improve awareness of tasks. AMT's comment that “another set of eyes” could catch mistakes in progress. Revision of maintenance manual and logbook documents, which remind or warn AMT's as to how many people need to complete a job or to check over work, could reduce errors.

Error Type by Communication Type. Error type and the aspect of the verbal communication did not show interaction. However, communication between superiors and subordinates was most often related to awareness and task execution errors. The between crew members category and the between departments category both had a high percentage of procedural omissions errors, suggesting that information is being lost in transfer. This finding suggests that communication skills of the crew, lead, and management can be improved with team training, as suggested by researchers (Helmreich & Foushee, 1993; Foushee & Helmreich, 1988). In addition, standardized company wide training in active listening and participation could diminish errors.

Error Type by Verbal Contributing Factors. Error type and verbal contributing

factors were tested, but was not significant. Due to the small number of valid cases in each category, however, it is difficult to draw conclusions. A redesign of the reporting system, (e.g., one in which an AMT's is prompted to express verbal communication issues), could improve future analyses.

Involvement of Written and Verbal Information

In the second question, we addressed the involvement of written and verbal information in procedural errors. This analysis focused on document type, communication type, aspect of the document, and aspect of the communication.

Document Type. We found that a large number of errors (123) were attributed to written information. The majority of written information errors involved the maintenance manual. Of those reports involving the maintenance manual, it was clear from respondents that the problem lay in the completeness of the documents.

Aspect of the Document. Completeness of the document is where an individual step is not included in the written procedure. The second most common aspect of the document was no inspection/verification. Examples of no inspection/verification errors are no walk around inspection provision in document or no signoff procedure in document. Another type of aspect of the document error was correctness and warnings/cautions/notes. Steps in the improper order, as well as consequences which were inadequately stated are examples of correctness and warnings/cautions/notes errors. Usability related errors were the least common aspect of the document and involve issues including non-adherence to writer's guide and non-minimization of multiple procedures/tasks. When reviewing the cases of aspect of the document, there were significantly more errors in documents than communication errors. This could indicate the greater need for documentation-related interventions. In order to prevent such written errors, review of maintenance manual documents, and all maintenance related documents should be evaluated for effectiveness on-the-job. On the other hand, it may also indicate it is easier to report document problems than communication issues.

Communication Type. Only 29 cases out of 123 indicated verbal communication as a problem. It is difficult to determine why such a small number of reporters did not view verbal communication as a procedural or practical error. Communication is so commonplace that is hard to identify a problem unless it is extremely obvious. Perhaps with a more structured reporting form, ASRS could improve the description of the incident. Due to the small number of valid cases in each category, it is difficult to draw conclusions.

Communication Type by Aspect of the Communication. The most common aspect of the communication errors were problem solving/decision making related. An example of problem solving/decision making errors are: recognizing a problem, gathering information, or explaining a situation. A possible correlation between communication type and aspect of the communication was found. This correlation could be a result of all of the interpersonal relationships aspects of the communication relating to communication between a superior and subordinate. Hence, communication skills of the crew, lead, and management can be improved through team training and standardized company wide training in active listening and participation (Helmreich & Foushee, 1993; Foushee & Helmreich, 1988).

Contributing Factors

In the third question, we explored written and verbal contributing factors as they related to procedural errors. The following is a discussion of those findings.

Written Contributing Factors. Written contributing factors was another area that indicated areas for improvement. A majority of the errors was related to both part design/tools/equipment and task related contributing factors.

Part design/tools/equipment errors are those which involve parts or tools not being accessible to the AMT. Reporters stated having to "rob" parts from other aircraft or wait for another AMT to finish using a tool before they are able to complete their task. These types of problems add significant time to a scheduled departure. By addressing and integrating these errors, a functional system can be achieved.

Examples of task related contributing factors are workload outweighing available

time or staff and stress and fatigue negatively affecting performance. Reporters comment that the nature of the job is stressful, working graveyard shifts for 15 hour stretches to get an aircraft out on time. There are two ways to reduce staffing problems: (a) evaluate all job tasks for personnel and time involved in order to plan tasks effectively, then match skill to personnel as suggested researchers (MEDA, 1994 and Ostrom, Nelson, Haney, Richards, Wilhelmsen, & Owen, 1997) and (b) increase or redistribute skilled employees in the workforce.

Verbal Contributing Factors. The most frequent verbal contributing factor was organizational culture, which has been studied previously (Foushee & Helmreich, 1988). Examples of organizational culture are: management administration, communication between peers, and peer pressure. Reporters comment that many times supervisors are not available or do not have time to focus on one person. Lead mechanics must achieve a delicate balance of assuring that quality work is done in a timely manner. Sometimes one-on-one interaction is not possible. For this reason, more detailed written procedures or better access to information resources could help AMT's when they need more guidance.

Summary

In general, this study explored errors in maintenance by classifying procedural errors. In coding this study, the combination of the FRANCIE, MEDA, and new verbal section covered many areas, but many classification categories overlapped, e.g. organizational culture. However, the extensiveness of the categories allowed a fine detail, that with a larger database of records could provide an extremely accurate portrayal of maintenance errors.

Although the data set was twice as large as the previous study, more data was needed since many categories of errors were infrequently reported. This problem will likely be eliminated as time progresses and more technicians use the new ASRS reporting form. A more structured reporting form could improve data collection. These changes could help further analysis.

This study identified procedural errors and indicated that most of those types of errors involved written communication. Future analysis of written procedures, especially those involved with maintenance manual and logbook/MEL procedures would give us a clearer picture of where further research should be directed.

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Appendix A

Results Form

MAINTENANCE ERROR DECISION AID RESULTS FORM

(See User's Guide for more information)

SECTION I - GENERAL

REFERENCE #: _____
AIRLINE: _____
AIRCRAFT TYPE: _____
ENGINE TYPE: _____
TAIL/FLEET #: _____
TIME/SHIFT OF INCIDENT: _____
DATE OF INCIDENT: _____
STATION OF INCIDENT: _____

ANALYST'S FIRST NAME: _____
ANALYST'S LAST NAME: _____
ANALYST'S PHONE #: _____
ATA #: _____
AIRCRAFT ZONE: _____
REF # OF PREVIOUS EVENT, IF APPLICABLE: _____

SECTION II - OPERATIONAL EVENT

A. PLEASE INDICATE THE OPERATIONAL EVENT:

- ☐ FLIGHT DELAY _____ MINUTES/TIME
☐ FLIGHT CANCELLATION
☐ GATE RETURN
☐ IN-FLIGHT SHUT DOWN
☐ AIR TURN-BACK
- ☐ AIRCRAFT DAMAGE
☐ INJURY
☐ DIVERSION
☐ REWORK
☐ OTHER _____

B. PLEASE PROVIDE A SHORT NARRATIVE DESCRIPTION OF INCIDENT, DEGRADATION OR FAILURE.
(eg. a/p could not pressurize, air turnback)

SECTION III - MAINTENANCE ERROR

A. PLEASE INDICATE THE MAINTENANCE ERROR TYPE:

- ☐ 1. IMPROPER INSTALLATION
☐ a. 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 or equipment not reactivated / deactivated
☐ i. Damaged
- ☐ 2. IMPROPER SERVICING
☐ a. Insufficient fluid
☐ b. Too much fluid
☐ c. Wrong fluid type
☐ d. Required servicing not performed
☐ e. Improper cleaning of parts
☐ f. Incorrectly closing system
☐ g. Access panel not closed
☐ h. System or equipment not deactivated / reactivated
- ☐ 3. IMPROPER/INCOMPLETE REPAIR
- ☐ 4. IMPROPER FAULT ISOLATION / INSPECTION / TESTING
☐ a. Degradation not found
☐ b. Access panel not closed
☐ c. System or equipment not deactivated / reactivated
☐ d. Not properly tested
- ☐ 5. FOREIGN OBJECT DAMAGE
☐ a. Material left in airplane/engine
☐ b. Debris on ramp
☐ c. Debris falling into open systems (protecting open systems)
- ☐ 6. SURROUNDING EQUIPMENT DAMAGE
☐ a. Damage to surrounding area during repair
☐ b. Spilling fluids
- ☐ 7. PERSONAL INJURY
- ☐ 8. OTHER, Explain _____

B. PLEASE PROVIDE A SHORT NARRATIVE DESCRIPTION OF THE MAINTENANCE ERROR. (eg. auto pressure controller, pn xx-xxx installed incorrectly)

CONTRIBUTING FACTORS CHECKLIST

(See User's Guide and Supplemental Assessment Material for more information)

N/A		F. FACTORS AFFECTING INDIVIDUAL PERFORMANCE ☐ 1. Physical health (including hearing and sight) ☐ 2. Fatigue ☐ 3. Time constraints ☐ 4. Peer pressure ☐ 5. Body size/strength ☐ 6. Significant life changes ☐ 7. Other, explain _____ How did these factors lead to the incident?
N/A		G. ENVIRONMENT/FACILITIES ☐ 1. High noise levels ☐ 2. Hot ☐ 3. Cold ☐ 4. Humidity ☐ 5. Rain ☐ 6. Snow ☐ 7. Dark ☐ 8. Wind ☐ 9. Vibration ☐ 10. Distraction/Interruptions during task performance ☐ 11. Cleanliness ☐ 12. Hazardous/toxic substances ☐ 13. Power sources ☐ 14. Inadequate ventilation ☐ 15. Unsafe work stand/etc. ☐ 16. Other, explain _____ Give specific location (eg. station, bldg., bay, etc.) and how it led to the incident.
N/A		H. ORGANIZATIONAL ENVIRONMENT ISSUES ☐ 1. Quality of support from technical Organizations (e.g., Engineering, Planning, Tech Pubs, etc) ☐ 2. Inadequate Company policy ☐ 3. Unions ☐ 4. Morale ☐ 5. Other, explain _____ How did these factors lead to the incident?
N/A		I. SUPERVISION ☐ 1. Poor planning/organization of tasks ☐ 2. Inadequate prioritization of work ☐ 3. Inadequate delegation/assignment of task ☐ 4. Unrealistic attitude/expectations ☐ 5. Excessive supervision ☐ 6. Other, explain _____ How did these factors lead to the incident?
N/A		J. COMMUNICATION ISSUES ☐ 1. Between departments ☐ 2. Between people ☐ 3. Between shifts ☐ 4. Between crew and lead ☐ 5. Between lead and management ☐ 6. Other, explain _____ How did these factors lead to the incident?
N/A		K. OTHER How did these factors lead to the incident?

CONTRIBUTING FACTORS CHECKLIST

(See User's Guide and Supplemental Assessment Material for more information)

SECTION IV

INSTRUCTIONS:

1. Check the appropriate contributing factors
2. For each factor not involved, please check N/A.
3. Provide brief, descriptive narrative for each contributing factor identified.

N/A A. INFORMATION (e.g., Workcards, Procedures, Maintenance Manuals, Service Bulletins, Maintenance Tips, Non-routines, IPC, etc.)

☐ 1. Not understandable	☐ 6. Incorrectly modifying manufacturer's MM/SB
☐ 2. Unavailable/Inaccessible	☐ 7. Information not used
☐ 3. Incorrect	☐ 8. Other, explain _____
☐ 4. Too much information/conflicting	
☐ 5. Update process is too long/complicated	

Give specific details (eg. manual, workcard, section, page, etc.) as to how this led to the incident:

N/A B. EQUIPMENT/TOOLS/PARTS

☐ 1. Unsafe	☐ 7. Inappropriate for task
☐ 2. Inaccessible	☐ 8. Can't use in intended environment
☐ 3. Unreliable	☐ 9. No instructions
☐ 4. Poor layout of controls and displays	☐ 10. Too complicated
☐ 5. Mis-calibrated	☐ 11. Incorrectly labeled
☐ 6. Unavailable	☐ 12. Other, explain _____

Specify exactly what tool, effectivity, part #, equipment, etc. and how it led to the incident:

N/A C. AIRPLANE DESIGN/CONFIGURATION

☐ 1. Complex
☐ 2. Not accessible
☐ 3. Not user friendly
☐ 4. Configuration variability between models and airplanes
☐ 5. Other, explain _____

Specify A/C type, effectivity, zone, etc. and how that led to the incident:

N/A D. JOB/TASK

☐ 1. Repetitive/monotonous	☐ 5. Technician's inadequate planning/prioritization of tasks
☐ 2. Complex/confusing	☐ 6. Different from other similar tasks
☐ 3. New task or task change	☐ 7. Other, explain _____
☐ 4. Boredom/complacency	

Which specific job/task and how it led to the incident (eg. routine job #, non-routine job #, etc.)?

N/A E. QUALIFICATIONS/SKILLS

☐ 1. Proficiency/experience level	☐ 6. Lead
☐ 2. Inadequate task knowledge	☐ 7. Supervisor
☐ 3. Inadequate airline process knowledge	☐ 8. Manager
☐ 4. Inadequate airplane system knowledge	☐ 9. Other, explain _____
☐ 5. Technician	

What specific skill deficiency and how it led to the incident?

CORRECTIVE ACTIONS

(See User's Guide and Supplemental Assessment Material for more information)

SECTION V

A. ARE THERE CURRENT EXISTING PROCEDURES, PROCESSES, AND POLICIES IN YOUR ORGANIZATION INTENDED TO PREVENT THE INCIDENT BUT DIDN'T?

() Maintenance procedures, specify: _____

() Inspection or functional check, specify: _____

Required Maintenance Documentation

() Maintenance manuals, specify: _____

() Logbooks, specify: _____

() Workcards, specify: _____

() Engineering documents, specify: _____

() Other, specify: _____

Supporting Documentation

() Service Bulletins, specify: _____

() Training materials, specify: _____

() All-operator letters, specify: _____

() Inter-company bulletins, specify: _____

() Company or maintenance policies, specify: _____

Other, specify: _____

B. LIST CORRECTIVE ACTIONS SUGGESTED OR TAKEN AT THE LOCAL LEVEL**C. OTHER CORRECTIVE ACTIONS SUGGESTED.**

FRamework Assessing Notorious Contributing Influences for Error (FRANCIE)

SYSTEM/ COMPONENT/ PART TO BE MAINTAINED OR MAINTENANCE TASK

Appendix C

Maintenance Form

TELEPHONE NUMBERS where we may reach you for further details of this occurrence

HOME Area _____ No _____ Hours _____

WORK Area _____ No _____ Hours _____

NAME _____

TYPE OF EVENT/SITUATION _____

ADDRESS/PO BOX _____

DATE OF OCCURRENCE _____

CITY _____ STATE _____ ZIP _____

LOCAL TIME (24 hr. clock) _____

DO NOT REPORT AIRCRAFT ACCIDENTS AND CRIMINAL ACTIVITIES ON THIS FORM.
ACCIDENTS AND CRIMINAL ACTIVITIES ARE NOT INCLUDED IN THE ASRS PROGRAM AND SHOULD NOT BE SUBMITTED TO NASA.
ALL IDENTITIES CONTAINED IN THIS REPORT WILL BE REMOVED TO ASSURE COMPLETE REPORTER ANONYMITY.

PLEASE FILL IN APPROPRIATE SPACES AND CHECK ALL ITEMS WHICH APPLY TO THIS EVENT OR SITUATION

EXPERIENCE	
Describe your qualifications	☐ A & P ☐ A ☐ P ☐ repairman ☐ inspection authority ☐ FCC other _____
What is your technician/maintenance experience in years?	lead technician _____ technician _____ repairman _____ avionics _____ other _____

FACTORS																					
Location _____																					
Was training a factor?	☐ yes ☐ no ☐ I was instructing ☐ I was receiving training																				
What other factors may have contributed?	☐ lighting ☐ work cards ☐ briefing ☐ weather ☐ manuals ☐ other _____																				
Check items which were involved in the event	<table border="0"> <tr> <td>inspection</td> <td>☐ yes ☐ no</td> <td>installation</td> <td>☐ yes ☐ no</td> </tr> <tr> <td>testing</td> <td>☐ yes ☐ no</td> <td>scheduled maintenance</td> <td>☐ yes ☐ no</td> </tr> <tr> <td>repair</td> <td>☐ yes ☐ no</td> <td>MEL</td> <td>☐ yes ☐ no</td> </tr> <tr> <td>logbook entry</td> <td>☐ yes ☐ no</td> <td>* other</td> <td></td> </tr> <tr> <td>fault isolation</td> <td>☐ yes ☐ no</td> <td colspan="2">("Describe in the 'Describe Event/Situation' section")</td> </tr> </table>	inspection	☐ yes ☐ no	installation	☐ yes ☐ no	testing	☐ yes ☐ no	scheduled maintenance	☐ yes ☐ no	repair	☐ yes ☐ no	MEL	☐ yes ☐ no	logbook entry	☐ yes ☐ no	* other		fault isolation	☐ yes ☐ no	("Describe in the 'Describe Event/Situation' section")	
inspection	☐ yes ☐ no	installation	☐ yes ☐ no																		
testing	☐ yes ☐ no	scheduled maintenance	☐ yes ☐ no																		
repair	☐ yes ☐ no	MEL	☐ yes ☐ no																		
logbook entry	☐ yes ☐ no	* other																			
fault isolation	☐ yes ☐ no	("Describe in the 'Describe Event/Situation' section")																			

Component/System/Subsystem involved: _____	
Was maintenance deferred? ☐ yes ☐ no	When was problem detected? ☐ routine inspection ☐ while aircraft was in service at gate ☐ in-flight ☐ pre-flight ☐ taxi ☐ other _____

CONSEQUENCES/OUTCOME			
flight delay	☐ gate return	☐ aircraft damage	☐ improper service
flight cancellation	☐ in-flight shut down	☐ rework	☐ air turn back
			☐ other _____

AIRCRAFT/AIRWORTHINESS STATUS	MISSION	OPERATOR
☐ aircraft released for service ☐ aircraft records completed ☐ aircraft required documents aboard ☐ not released for service ☐ unknown	☐ passenger ☐ cargo ☐ business ☐ training ☐ pleasure ☐ other _____	(Check all that apply) ☐ air carrier ☐ government ☐ commuter ☐ military ☐ corporate ☐ part 121 ☐ air-taxi ☐ part 135 ☐ charter ☐ repair station ☐ FBO ☐ self employed ☐ flight school ☐ other _____

TYPE OF AIRCRAFT (MAKE/MODEL) AND ENGINE TYPE		
Type of aircraft _____	series _____	ATA Code _____
Aircraft zone _____	engine model _____	other _____

DESCRIBE EVENT/SITUATION
Explain in detail the topics shown below. Discuss those which you feel are relevant and anything else you think is important. Include what you believe really caused the problem and what can be done to prevent a recurrence, or correct the situation. (CONTINUE ON THE OTHER SIDE AND USE ADDITIONAL PAPER IF NEEDED)

CHAIN OF EVENTS		HUMAN PERFORMANCE CONSIDERATIONS
How the problem arose (Contributing factors)	How it was discovered Corrective actions	Perceptions, judgments, decisions Actions or inactions Factors affecting the quality of human performance

Appendix D

Veinott and Kanki Coding System

Level One, Section One

B-1 AC type

- 1 MLRG
- 2 LRG
- 3 HVT
- 4 WDB

B-2 Who reported:

- 1 GRD
- 2 FLC
- 3 Other

B-3 What was the cause:

- 1 indiv.
- 2 team
- 3 xteam
- 4 proced
- 5 tools
- 6 Uknwn
- 7 Other _____

B-4 Anomaly description (severity):

- 1 AC_Eqp/critical
- 2 AC_Eqp./less severe
- 3 Grd Conft/ critical
- 4 Grd Conf/less severe
- 5 Non adh-Proc.
- 6 Non_Ad-FAR
- 7 _____

Appendix E

Flowchart

Level One, Section One

Veinott and Kanki Coding System

Level Two, Section One

Error Type

Level Two, Section Two, Part A

Written Support Information

Yes

No

Aspects of the Document

Level Two, Section Two, Part B

Written Contributing Factors

Level Two, Section Three, Part A

Verbal Support Information

Yes

No

Aspects of the Communication

Level Two, Section Three, Part B

Verbal Contributing Factors

END

Appendix F

Error Types**Level Two, Section One****K-1 Procedural Omission**

- Skip a task/procedure
- Skip a step
- Skip a warning/caution/note

K-2 Error of Intent

- Ignore a warning caution note
- Mechanic intentionally performs activity in a manner other than specified in procedures
- Improper use of tool

K-3 Selection Error

- Select wrong procedure/step
- Select wrong system/component/part/area
- Load wrong software
- Install wrong equipment/part
- Use wrong fluid type
- Use wrong/improper tool

K-4 Awareness and Task Execution Error

- Fail to properly install tag/placard
- Inadequate/improper maintenance safety equipment installation
- Allow/cause debris to fall into open systems
- Damage component/part being maintained
- Cause collateral damage
- Spill hazardous fluids
- Place/leave in wrong configuration
- Leave foreign material in airplane/engine
- Leave debris on ramp

K-5 Fault Identification/Diagnosis Inadequate

- Improper fault isolation
- Improperly adjust/calibrate
- Inadequately/improper performance of functional/operational/system/safety test

K-6 Inspection/Verification Incomplete

- Degradation/fault not found during inspection/fault isolation
- Inadequately ensure/check (includes QC check)
- Inadequately inspect

K-7 Values/Units/Scales/Indicators Related Error

- Fail to notice system indication
- Fail to respond to system indication
- Add insufficient fluid
- Add too much fluid
- Read value/unit wrong
- Set/initiate value/unit wrong
- Mistime a timed duration event

K-8 Maintenance/Repair Inadequate

- Inadequate/incomplete compliance with warning/caution/note
- Perform sequenced steps in wrong order
- Improperly remove/replace/install/clean/lubricate/modify
- Inadequate/improper cleaning of parts
- Improperly repair
- Improperly load software
- Use wrong orientation of equipment/part
- Incomplete installation
- Install extra parts
- Misuse of force (too little/too much)
- Inadequate/improper installation of in service securing/locking device

Appendix G

Written Support Information**Level Two, Section Two, Part A****K-9 Error involves the use of a document**

- 1 Maintenance manual
- 2 Logbook
- 3 Workcard
- 4 Engineering
- 5 Service Bulletin
- 6 Training Mat'l
- 7 All-operator letter
- 8 Inter-company bulletin
- 9 Company or Maintenance Policy
- 10 Other_____

K-10 Error does not involve the use of a document

- 1 Written Procedure exists/does not exist
- 2 Procedure included/not included in work passage
- 3 Written procedure used/not used

(go to section Verbal Support Information)

Aspect of the Document**K-11 Correctness and Completeness**

- 1 Individual step included/not included in written procedure
- 2 Steps in procedure proper/improper
- 3 Step order proper/improper
- 4 Content and format in procedure steps proper/improper
- 5 Description/drawing of area/component/part in procedure included/not included
- 6 Description/drawing of area/component/part adequate/not adequate
- 7 Units/values specified/not clearly specified
- 8 Indexing of procedures and procedural steps meaningful/not meaningful

K-12 Usability

- 1 Procedure contains adequate/inadequate information
- 2 Adherence/Non-Adherence to writer's guide
- 3 Minimizes/does not minimize inclusion of multiple tasks/procedures in work package when possible
- 4 Administrative control of work packages sufficient/insufficient
- 5 Specifies/does not specify if more than one mechanic needed
- 6 Specifies/does not specify need/method of communication needed

K-13 Supporting Data

- 1 Warning/caution/note included/not included in written procedures
- 2 Materials list in procedure appropriate/inappropriate
- 3 Tools list in procedure appropriate/inappropriate
- 4 Calibration equipment listed in procedure appropriate/inappropriate
- 5 Software list in procedure appropriate/inappropriate
- 6 Functional test considered/does not consider
- 7 Procedure specifies/does not specify covering/closing openings into vulnerable system(s) during maintenance

K-14 Verification and Inspection

- 1 Verification/no verification
- 2 Written checkoffs has provision/no provisions (provisions for signoff/checkoff in procedure)
- 3 Specification/no specification in procedure (Maintenance Manual/Admin/Other) for shiftly daily/procedural checks (e.g. walkaround inspections)

K-15 Warnings/Cautions and Notes

- 1 Warnings/cautions/notes in procedure appropriate/inappropriate
- 2 Content/format of warnings/cautions/notes appropriate/inappropriate
- 3 Consequences clearly presented/not clearly presented in warnings/cautions/notes
- 4 Information in warnings/cautions/notes adequate/complete or inadequate/incomplete
- 5 Related steps/information (for warnings/cautions/notes) in written procedure proper/improper
- 6 Considers/does not consider specifying minimum use of pliers/cutters for safety wiring (i.e. only for snipping loose ends after wiring)

Appendix H

Written Contributing Factors**Level Two, Section Two, Part B****K-16 Airplane/Part Design****1 Parts are easy to access/install on the airplane**

- Accessibility adequate accessibility/visibility
- Designed for proper/easy fit
- Are designed to allow access/use of required tools

2 Parts/systems are designed to make installations more error proof

- Avoid (when possible/practical), multiple, or similar appearing, areas/components/parts
- Clear legible labeling or other identifying features
- Designed for proper orientation
- Designed to prevent improper orientation of component/part
- Designed to prevent improper connections
- Designed to physically prevent improper configurations
- Designed not to be overly fragile to (or designed with fragile parts protected) Area designed with fragile parts protected
- Visual and/or aural alarms for indications requiring attention
- Computer alarms/warnings/messages for relevant out of sequence performance of steps performed on/by computer
- Inclusion of self test software features for software installations/etc.
- Design allowing covering/closing of opening into vulnerable systems during maintenance
- Designed with appropriate securing holes for safety wire (positioned to facilitate proper direction)
- No edges/surfaces to damage installed safety wire
- Designed for no contact of safety wiring with fragile parts/components. No contact of safety wire with fragile parts/components

3 Parts/systems designed with ease of maintenance considered

- Adherence to human factors principles
- Equipment design allowing proper adherence to procedure
- Try to avoid the need for related or ancillary task
- Placarded (however, consider information overload)
- Equipment/system designed for proper communication between multiple mechanics
- Area designed for proper communication between multiple mechanics

4 Indications and controls are designed to facilitate ease of maintenance

- Proper related indications/information available from equipment
- Proper scales/displays on equipment if needed
- Controls adequate/intuitive for setting values/units

5 Parts consumables are readily available

- parts/consumables readily obtainable

6 The airplane is designed to properly interface with tools/calibration equipment

- Designed to properly interface with tools/calibration equipment

K-17 Tools/Equipment**1 Required tools are available**

- Required tools available

2 Tools are designed properly

- Tool design allows proper adherence to procedure
- Properly designed tool if special tool required/specified
- Designed to properly interface with equipment
- Proper design of tools to facilitate inspection/ensuring/checking/verification
- Tools/test equipment designed to facilitate functional check/test

3 Tools are designed with ergonomic factors considered

- Proper scales/displays on tools/calibration equipment if needed
- Control/tool manipulation ergonomic and intuitive for setting values/units
- Tools designed to avoid need for large/excessive physical forces on the mechanic
- Designed to be compatible with part/task
- Pliers/cutters designed to minimize damage to work

4 Tools are designed for use in areas maintained

- Tools designed for use in area maintained
- Devices/coverings for openings into vulnerable systems during maintenance

5 Tools cannot easily be accidentally left on the component or airplane after maintenance

- Designed to avoid forgetting to remove/take tool when finished

K-18 Personnel**1 Maintenance personnel are skilled and knowledgeable**

- Training
- Experience
- Task Knowledge
- Airline Process Knowledge
- Airplane System Knowledge
- Proficiency

2 Maintenance personnel are in good psychological state

- Motivation
- Morale

3 Maintenance personnel have proper physical attributes to perform the task

- Physical attributes

K-19 Environment**1 Adequate lighting is available**

- Lighting

2 Environmental factors are ideal

- Temperature
- Humidity
- Wet
- Ice/Snow
- Wind

3 The physical environment in the maintenance area is safe and conducive to maintenance

- Space
- Noise
- Vibration
- Housekeeping
- Elevated
- Confined
- Ventilation

- Clothing
- Hazards
- Dirty/Foreign materials on Equip.

K-20 Organizational

- 1 Management is informed, supportive, and proactive in maintenance activity**
 - Management
- 2 Maintenance activity is administered in an efficient manner**
 - Administrative
- 3 Company or union policies do not inhibit proper maintenance**
 - Company Policy
 - Unions
- 4 Cultural customs, beliefs or activities do not inhibit maintenance**
 - Cultural

K-21 Work Group

- 1 Oversight/supervision is appropriate**
 - Level of oversight/supervision
 - Supervisor expectations of staff
- 2 Task/work planning/prioritization/delegation is appropriate**
 - Task planning/organization
 - Work prioritization
 - Work delegation /assignment
- 3 Communication between peers is adequate**
 - Communication between people
 - Communication between shifts
- 4 Communication between supervision and maintenance techs is adequate**
 - Communication between crew and lead
 - Communication between lead and management

5 Communications between departments is adequate

- Communication between departments

6 Peer pressure does not negatively affect maintenance

- Peer pressure

K-22 Task Related**1 Workload does not outweigh available staff and time**

- Workload
- Staffing
- Time

2 The task is easy without special coordination or support requirements

- Cognitive complexity
- Dynamic/step-by-step
- Special tools required

3 Proper feedback and verifications are available for the task

- Feedback
- Verifications

4 Familiarity will not negatively affect performance of the task

- Repetitive/monotonous
- New or changes task
- Different from similar tasks

5 Planning/prioritization is adequate

- Planning/prioritization

6 Tasks are not interrupted

- Task interruption

7 Level of stress or fatigue does not negatively affect performance. Task, task order, or placement in shift is not overly stressful or fatiguing

- Stress

- Fatigue

8 Technical support is available and sufficient

- Technical support

Appendix I

Verbal Support Information**Level Two, Section Three, Part A****K-23 Error involves verbal communication**

- 1 Between Depts: Specify which _____
- 2 Between Crew Members
- 3 Between Shifts
- 4 Between Crew and Lead
- 5 Between Lead and Mgmt
- 6 Between Airlines and Other _____
- 7 Other

K-24 Error does not involve verbal communication

(END)

Aspects of the Communication**K-25 Problem Solving and Decision Making Processes**

- 1 Recognize problems
- 2 State goals and subgoals
- 3 Plan and strategize
- 4 Gather information
- 5 Alert and predict
- 6 Explain
- 7 Situational awareness

K-26 Interpersonal Relationships

- 1 Personality Positive/Negative
- 2 Personal problems outside of the workplace
- 3 Strain/no strain between co-workers

K-27 Behavior Patterns

- 1 Integrates/does not integrate activities in a ordered, timely fashion
- 2 Actions completed/not completed at appropriate times

K-28 Attention to Task/Monitoring

- 1 Compete/Incomplete task
- 2 Interrupted/not interrupted task

K-29 Communication as a Management Tool

- 1 Prioritizing/not prioritizing tasks
- 2 Assigning/not assigning tasks (as in coordination of task)
- 3 Evaluating/Monitoring/lack of evaluation crew experience or skill with task

4 Leadership Style

Appendix J

Verbal Contributing Factors**Level Two, Section Three, Part B****K-30 Airplane/Part Design****1 Parts are easy to access/install on the airplane**

- Accessibility adequate accessibility/visibility
- Designed for proper/easy fit
- Are designed to allow access/use of required tools

2 Parts/systems are designed to make installations more error proof

- Avoid (when possible/practical), multiple, or similar appearing, areas/components/parts
- Clear legible labeling or other identifying features
- Designed for proper orientation
- Designed to prevent improper orientation of component/part
- Designed to prevent improper connections
- Designed to physically prevent improper configurations
- Designed not to be overly fragile to (or designed with fragile parts protected) Area designed with fragile parts protected
- Visual and/or aural alarms for indications requiring attention
- Computer alarms/warnings/messages for relevant out of sequence performance of steps performed on/by computer
- Inclusion of self test software features for software installations/etc.
- Design allowing covering/closing of opening into vulnerable systems during maintenance
- Designed with appropriate securing holes for safety wire (positioned to facilitate proper direction)
- No edges/surfaces to damage installed safety wire
- Designed for no contact of safety wiring with fragile parts/components. No contact of safety wire with fragile parts/components

3 Parts/systems designed with ease of maintenance considered

- Adherence to human factors principles
- Equipment design allowing proper adherence to procedure
- Try to avoid the need for related or ancillary task
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- Equipment/system designed for proper communication between multiple mechanics
- Area designed for proper communication between multiple mechanics

4 Indications and controls are designed to facilitate ease of maintenance

- Proper related indications/information available from equipment
- Proper scales/displays on equipment if needed
- Controls adequate/intuitive for setting values/units

5 Parts consumables are readily available

- parts/consumables readily obtainable

6 The airplane is designed to properly interface with tools/calibration equipment

- Designed to properly interface with tools/calibration equipment

K-31 Tools/Equipment**1 Required tools are available**

- Required tools available

2 Tools are designed properly

- Tool design allows proper adherence to procedure
- Properly designed tool if special tool required/specified
- Designed to properly interface with equipment
- Proper design of tools to facilitate inspection/ensuring/checking/verification
- Tools/test equipment designed to facilitate functional check/test

3 Tools are designed with ergonomic factors considered

- Proper scales/displays on tools/calibration equipment if needed
- Control/tool manipulation ergonomic and intuitive for setting values/units
- Tools designed to avoid need for large/excessive physical forces on the mechanic
- Designed to be compatible with part/task
- Pliers/cutters designed to minimize damage to wire

4 Tools are designed for use in areas maintained

- Tools designed for use in area maintained
- Devices/coverings for openings into vulnerable systems during maintenance

5 Tools cannot easily be accidentally left on the component or airplane after maintenance

- Designed to avoid forgetting to remove/take tool when finished

K-32 Personnel

1 Maintenance personnel are skilled and knowledgeable

- Training
- Experience
- Task Knowledge
- Airline Process Knowledge
- Airplane System Knowledge
- Proficiency

2 Maintenance personnel are in good psychological state

- Motivation
- Morale

3 Maintenance personnel have proper physical attributes to perform the task

- Physical attributes

K-33 Environment

1 Adequate lighting is available

- Lighting

2 Environmental factors are ideal

- Temperature
- Humidity
- Wet
- Ice/Snow
- Wind

3 The physical environment in the maintenance area is safe and conducive to maintenance

- Space
- Noise
- Vibration
- Housekeeping
- Elevated

- Confined
- Ventilation
- Clothing
- Hazards
- Dirty/Foreign materials on Equip.

K-34 Organizational

- 1 Management is informed, supportive, and proactive in maintenance activity**
 - Management
- 2 Maintenance activity is administered in an efficient manner**
 - Administrative
- 3 Company or union policies do not inhibit proper maintenance**
 - Company Policy
 - Unions
- 4 Cultural customs, beliefs or activities do not inhibit maintenance**
 - Cultural

K-35 Work Group

- 1 Oversight/supervision is appropriate**
 - Level of oversight/supervision
 - Supervisor expectations of staff
- 2 Task/work planning/prioritization/delegation is appropriate**
 - Task planning/organization
 - Work prioritization
 - Work delegation /assignment
- 3 Communication between peers is adequate**
 - Communication between people
 - Communication between shifts
- 4 Communication between supervision and maintenance techs is adequate**

- Communication between crew and lead
- Communication between lead and management

5 Communications between departments is adequate

- Communication between departments

6 Peer pressure does not negatively affect maintenance

- Peer pressure

K-36 Task Related

1 Workload does not outweigh available staff and time

- Workload
- Staffing
- Time

2 The task is easy without special coordination or support requirements

- Cognitive complexity
- Dynamic/step-by-step
- Special tools required

3 Proper feedback and verifications are available for the task

- Feedback
- Verifications

4 Familiarity will not negatively affect performance of the task

- Repetitive/monotonous
- New or changes task
- Different from similar tasks

5 Planning/prioritization is adequate

- Planning/prioritization

6 Tasks are not interrupted

- Task interruption

7 Level of stress or fatigue does not negatively affect performance. Task, task order, or placement in shift is not overly stressful or fatiguing

- Stress
- Fatigue

8 Technical support is available and sufficient

- Technical support

Appendix K

Signed Approval Form

San José State
UNIVERSITY

**Office of the Academic
Vice President**

**Associate Vice President
Graduate Studies and Research**

One Washington Square
San José, CA 95192-0025
Voice: 408-924-2480
Fax: 408-924-2477
E-mail: gstudies@wahco.sjsu.edu
<http://www.sjsu.edu>

TO: Kristen Nord
1457 Buena Luna Court
San Jose, CA 95128

FROM: Serena W. Stanford *Serena W. Stanford*
AVP, Graduate Studies & Research

DATE: February 19, 1998

The Human Subjects-Institutional Review Board has approved
your request to use human subjects in the study entitled:

**"Procedural Error Analysis in Aircraft
Maintenance Operations"**

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The Board's approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Serena Stanford, Ph.D., immediately. Injury includes but is not limited to bodily harm, psychological trauma and release of potentially damaging personal information.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at
(408) 924-2480.

IMAGE EVALUATION TEST TARGET (QA-3)

APPLIED IMAGE, Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989

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