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UK - HFCAG

United Kingdom Human Factors Combined Action Group

PEOPLE, PRACTICES AND PROCEDURES IN AVIATION ENGINEERING AND MAINTENANCE

A PRACTICAL GUIDE TO HUMAN FACTORS IN THE WORKPLACE

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Introduction

The term ‘Human Factors’, when used within aviation engineering and maintenance, seems to have a number of different definitions. Human factors is not a new subject, it is not a black art and can be dealt with by a practical and common sense approach.

Some people would say that human factors is about minimising human error and maximising human performance, others that it is “maintenance resource management” while there are others still who would say it is really about ergonomics and environmental conditions in the workplace. In truth all these definitions are valid.

To quote from the United States Department of Transport and Federal Aviation Administration joint document, ‘Human Factors in Aviation Maintenance and Inspection - Strategic Program Plan’:

“‘Human Factors’ refers to the study of human capabilities and limitations in the workplace. Human factors include, but are not limited to, such attributes as human physiology, psychology, work place design, environmental conditions, human-machine interface, and more. Human factors researchers study system performance. That is, they study the interaction of humans, the equipment they use, the written and verbal procedures and rules they follow and the environment and conditions of any system.”

So how do we, the UK-HFCAG, define Human Factors? Well as a simple definition we consider it to be the people, practices and procedures contained within the engineering and maintenance function; in other words anything that can impact upon the ‘quality’ the person achieves in his or her engineering and maintenance role. People must have their psychological, physiological, ergonomic and environmental needs considered. Practices must be safe, efficient and constructed in such a way that errors are minimised and those that are not avoided are caught well before they become incidents. Procedures must be reviewed, relevant, achievable, appropriate, fair and just.

On the following pages we have put together a five point plan for all aviation engineering and maintenance facilities but especially for those who have yet to embark on a human factors programme. While it is not to be regarded as a definitive programme which will cover all human factor areas within all companies it does give a common starting point and benchmark for all of us to use.

As a group which represents a wide and varied slice of the practitioners in the aviation engineering and maintenance industry we are more than willing to provide help or advice wherever we can. If we can help you please do not hesitate to contact us.

Step 1

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***Obtain top management commitment to improving Human Factors awareness and performance within the engineering and maintenance function*.**

This commitment must come from the highest level of the company i.e., the Chairman, Chief Executive or Managing Director and would be supported by the Operating Board and the senior management structure. The statement of commitment could take the form of a simple letter briefly defining the term 'human factors' and giving a general commitment towards increasing the company's awareness or performance with regard to human factors issues. Or it could be a detailed human factors plan with specific commitments and timescales.

The commitment must be communicated and demonstrated to all employees within the organisation - as all departments will have some impact on engineering and maintenance human factor issues - and would be reinforced by departmental communications such as team briefings, meetings, internal memos, etc.

'Selling' the area of human factors to the top management structure is an important issue here. You must ensure that you can provide an understandable definition of human factors and provide links to your own human factors problems. Just quoting the saying, "If you think safety is expensive you want to try an accident!" is sometimes not enough. There are a number of well researched documents and software packages which can provide some excellent information to help in any 'sales' process. One of these is the NTSB Maintenance Accident Info Database which is a computer based program produced by Galaxy Scientific for the Federal Aviation Administration's Office of Aviation Medicine. Another useful tool is the document 'The Human Factors Guide for Aviation Maintenance' which is available on the Internet at *http://www.hfskyway.com.* Contacting other companies in order to determine the effectiveness of their human factors programmes or projects can also be quite useful.

It will also be useful at this point to develop a framework document suggesting where in the organisation the human factors co-ordination responsibilities will lie. This is not in respect to a human factors co-ordinator (as detailed in Step 4) but instead a member of the senior management team who will oversee and champion the Human Factors Programme.

To complement the guidelines listed above the UK-HFCAG is also willing to provide, in conjunction with the CAA, a short presentation on the substantial safety and commercial benefits of increasing human factors performance. This presentation is aimed at senior management and directors and is available through David Hall, Deputy Regional Manager, Civil Aviation Authority (see 'UK-HFCAG Contact Details' further on in this document).

Step 2

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Conduct a review of the current culture, procedures, systems and work practices within the engineering and maintenance function.

As far as the culture is concerned the first question to consider is whether the workforce feel able to report incidents of human error without incurring disciplinary sanctions and penalties. In other words is it a 'just culture' where reported human error is tolerated - in the interests of safety - but reckless behaviour is not, or are people reluctant to admit to any mistake for fear of retribution? A sample Engineering and Maintenance Mishap Policy covering these areas is included in Appendix A and further information on "Human Factors Investigation and the Just Culture" is available from David Marx (see 'Further Information' in Appendix G). Some companies have successfully adopted an 'amnesty' programme where employees are encouraged to come forward with details of past incidents, without fear of disciplinary sanction, which then paves the way for a 'just' culture in the future (see 'Sample Amnesty Statement' in Appendix E).

Staff surveys are a useful tool to determine what kind of culture currently exists and a suggested format for a staff opinion survey can be found in Appendix B. 'Round Table' discussions (with managers, technicians and support staff) where people are encouraged to be open and honest about the real culture can also be very beneficial.

With regard to procedures, systems and work practices these can be reviewed by consultation with the workforce either through an amnesty programme (as detailed above) or through a 'workplace' audit conducted jointly by management and the workforce (this latter method is strongly recommended as it will encourage the workforce to 'buy into' the human factors process from the start) or by using computer based tools like the Ergonomic Audit Programme - designed by the State University of New York at Buffalo and the Galaxy Scientific Corporation (see "Further Information" in Appendix G).

Some of the many areas to consider during a workplace audit are:

<u>Documentation</u>

- Is the workcard clear and legible and are typographic clues (such as bold, italic or coloured typefaces) used to segregate important information?

- Is the information presented in an easily understood manner or are there too many acronyms or abbreviations used?

- Is there a definite and logical ordering or sequencing of tasks on the workcard?

- Is the work card or process sheet actually used?

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- Who is required to sign the workcard and does he or she know what their signature implies?

Communication

- Is there an overlap of personnel in order to communicate prior and outstanding work at a shift change?

- Are all staff able to communicate easily with their colleagues on work related issues?

- Are all engineering and maintenance staff able to communicate easily with their supervisor/manager?

Environment

- Is there adequate lighting available?

- Are there extremes of temperature?

- Is there excessive noise within the workplace and if there is do all personnel use personal protective equipment?

- Are all relevant tools available?

- Are safety procedures in place, understood and implemented rigorously?

- Is the responsibility for maintaining the environment clearly defined?

N.B. The examples detailed above are purely for guidance and do not represent the full contents of a workplace audit

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Step 3

Once the review has been completed the report findings should be communicated to all personnel. Human factors general awareness briefings should then be provided to reinforce the need for any change.

The details of the audit report should be communicated to all personnel. This will then provide valuable recognition and support from the workforce during any necessary change process. Any areas of change that cannot be immediately addressed (due to commercial or operational reasons) should be discussed with the workforce at this point.

To reinforce this recognition and support all engineering and maintenance personnel - including all support personnel and sub contracting staff (and ideally all personnel within the company) - should attend short human factors briefings which will highlight the principles behind human factors and the importance, both in a commercial and safety sense, of improving the company's current performance.

These briefings would give:

- A definition of the term 'Human Factors'.
- An overview of the aircraft incidents where a human factors error has been a contributory element.
- The current and proposed legislation with regard to human factors.
- The common types of human factors problems (taken from the audit report) that exist currently in the workplace.

(see 'Sample Management Briefing Agenda' in Appendix D')

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Step 4

Implement a change programme and conduct Maintenance Resource Management training.

The audit report will have given details of any changes that need to be made and from this information a change programme should now be created. Some changes, such as changing the typeface on a workcard, are relatively easy to accomplish. However other changes, such as changing the corporate culture, are far more difficult and will require a considerable amount of background information before embarking on a change programme.

In general for any changes to be effective they must follow a SMART format. That is they should be **S**pecific - **M**easurable - **A**ttainable - **R**ealistic - and **T**imescale driven.

A typical change programme might take the following format:

Appointment of a Human Factors Co-ordinator. This is not necessarily a Human Factors Manager but instead a short term project manager who will guide the change process and help to allocate resources where necessary. There is a temptation when appointing a co-ordinator to look no further than the Quality Assurance Department. However rather than considering only background or current job role it may be beneficial instead to look for someone who has had previous experience of project work or human resources. In order to gain workforce support it may also be advantageous to consult with the workforce over the final selection.

Consideration of resource levels is also an important point here. Data will need to be inputted and analysed from both the initial review and any ongoing investigations. However it may be possible to integrate this function with other existing systems such as Air Safety Reporting or Continuous Improvement Programmes. Once the findings have been released the HF Co-ordinator will review solutions and strategies to any problems that are highlighted.

Development of a 'Change Plan'. This is very much a key area; the plan will include details of the changes to be made, the people responsible for implementing the changes and the specific timescales involved. Dependant on the changes that need to be made there may be a need to acquire a considerable amount of background information before developing and finalising the plan.

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Communication of and Commitment to the Change Plan. The details of the plan should be communicated to all engineering and maintenance personnel to gain essential workforce support. In addition there should also be some demonstrable commitment to the plan, and human factors in general, from the senior management of the company

Implementation of the proposed changes. Once all the above elements are in place the programme can be implemented. However the process will need to be reviewed and assessed at various stages to ensure that the timescales are valid and resources are adequate.

In addition during the change process a 'Maintenance Resource Management' (MRM) training programme should also be initiated for all engineering and maintenance personnel (a suggested course content is contained in appendix C). Before commencing the MRM programme the following guidelines should be considered carefully.

- The course should comprise a mix of people and job roles to help the trainees gain an overall picture of HF problems and their impact across the company.
- The course should ideally be presented by company personnel or, if this is not possible, by individuals with airline or engineering and maintenance organisation experience.
- The CEO, a Director, General Manager or other very senior person within the company should visit each course to emphasise the company's commitment to the HF programme.
- Real company examples of the topics, concepts and theories contained in the course should be provided to, or elicited from, the trainees to help them transfer the information they obtain from the course back into the workplace.
- A 'just' culture is as important in the classroom as it is in the workplace. Trainees should feel able to voice their opinions without fear of reprisal.

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Step 5

Develop an evaluation and monitoring programme.

In order to ensure that human factors performance is increased and sustained it is important that an evaluation and monitoring programme is put into place. Regular audits should be an ongoing part of this programme which should also examine the effectiveness of the MRM training and whether, as a result of the changes implemented, any further changes are necessary.

There may well be a number of direct and tangible performance indicators that show that human factors performance has been increased; such as a distinct drop in human factors incidents! However it is far more likely that a successful programme will actually produce an initial increase in reported incidents as confidence in a 'just' environment itself increases. There are other indicators which may be less direct than the number of reported incidents. Indicators like increased staff awareness of human factors issues and increased staff morale through the introduction of a 'just' culture. All performance improvements are important but it is also important to ensure that through continual evaluation and monitoring these improvements are fully sustained.

The evaluation and monitoring programme must be linked to the change programme and specifically the change plan. In its simplest form, the evaluation and monitoring programme will look at the company's adherence to the change plan timescales and recommend alterations where necessary. However once the change plan has been fully implemented it is important to find out how effective the actual change process has been. One way to do this is by re-running the staff survey to determine the extent of the workforce's increased awareness in human factors issues. The MRM training can also be evaluated - by using post course critiques - to determine both its effectiveness and the necessity for human factors related recurrent or continuation training. Error management systems play an important role in an evaluation and monitoring programme.

Good performance in human factors issues can not be sustained merely by introducing a human factors programme. As the performance of people is the lifeblood of any organisation it follows that the commitment that any organisation makes to the principles of human factors is one that must last for life.

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What is the UK-HFCAG?

The United Kingdom Human Factors Combined Action Group (UK-HFCAG) has been created to co-ordinate UK activity on the subject of Human Factors in Engineering and Maintenance within the Aviation Industry.

The group will concentrate on providing outputs to both Industry and Regulators by pooling and focusing industry expertise and experience. The group currently comprises representatives of the following bodies:

Air Accidents Investigation Branch

Association of Licensed Aircraft Engineers

British Helicopter Advisory Board

Confidential Human Factors Incident Reporting Programme

Independent Maintenance Group

International Air Carriers Association

International Federation of Airworthiness

Royal Aeronautical Society

United Kingdom Flight Safety Committee

United Kingdom Operators Technical Group

In addition, members of the Civil Aviation Authority also sit with the group to offer guidance and advice.

The UK-HFCAG recommend strategies and solutions to Human Factors issues in Engineering and Maintenance and focuses resources on providing guidelines and best practice for use within the industry. In addition, the group also acts as the focal point for regulatory contact with the CAA and JAA.

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Appendix A

UK-HFCAG
Sample Engineering and Maintenance Mishap Policy

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United Kingdom Human Factors Combined Action Group

SAMPLE ENGINEERING AND MAINTENANCE MISHAP POLICY

<u>Introduction</u>

All aviation engineering and maintenance facilities must maintain both an excellent safety record and ensure that their operation is as profitable and as efficient as it can be. It is recognised however that human error will occur and that this error can have a substantial impact upon both an organisation's safety record and their financial performance.

In order to minimise, if not eliminate, this impact within the workplace an Engineering and Maintenance Mishap Policy is recommended. This is a 'stand alone' type of policy which complements, but does not replace, the company's existing disciplinary policy and procedures. The Engineering and Maintenance Mishap Policy (a sample policy is included below) is designed to promote communication with regard to engineering and maintenance mishaps and to encourage members of staff to report engineering and maintenance errors well before they turn into incidents.

Part of the following sample policy makes provision for those people who report an error or event, and actively participate in the subsequent investigation, to be able to benefit from a procedure which will not result in a disciplinary sanction unless the person involved was engaged in a reckless act. Once an error has been reported it is the choice of the employee concerned as to whether they wish to have the error investigated and reviewed under the Engineering and Maintenance Mishap Policy or under the company's standard disciplinary policy and procedures. The idea being to promote a situation where the workforce is able to report incidents of human error without the fear of incurring disciplinary sanctions and penalties. In other words it enables a 'just culture' where reported human error is tolerated - in the interests of safety - but reckless behaviour is not.

<u>Sample Policy</u>

The sample policy is in two distinct parts: A) Error Reporting and Event Investigation; and B) Mishap Review.

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Part A

Error Reporting

It is important that all errors are reported, especially those which jeopardise aircraft airworthiness or cause unacceptable economic harm to the Company, so that effective remedial action can be taken.

All levels of staff must be encouraged to report all errors to their supervisor or line manager immediately after they occur. Once the error has been reported the employee concerned must clearly state how they wish the error to be investigated and reviewed. If they decide to use the Engineering and Maintenance Mishap Policy this must be confirmed in writing.

Once a decision has been made to use the Engineering and Maintenance Mishap Policy the supervisor (or member of management) will then collect all available data relating to the error, i.e. details of the staff concerned, the time and date of the error, the airframe worked on, the type of error made and any other pertinent details and immediately forward these to the Engineering Manager.

Event Investigation

Once the Engineering Manager has received the preliminary error report containing the initial gathered facts he/she should, with the co-operation of all staff, conduct a detailed event investigation. The Engineering Manager may conduct this investigation personally or responsibility may be delegated to another member of engineering management/supervision. The investigation should concentrate on how and why the error occurred and what steps can be taken to prevent future errors.

The event investigation should cover:

1. The exact nature of the error and the process and practices being carried out at the time.

2. The written procedures in place covering the engineering and maintenance practice that was being undertaken when the error occurred.

3. Any variations to the written procedures that are performed regularly by the workforce and have become a ‘norm’.

4. Previous training undertaken by the member of staff.

5. The environmental conditions within the workplace (e.g., heating, lighting, etc.) at the time the error occurred.

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6. Any other extenuating circumstances (which should include a review of management processes and functions to determine if a lack of management or supervision contributed to the error).

N.B. The event investigation detailed above is provided to give a basic framework for investigation and is not designed to replace specific human factors analysis tools such as the Maintenance Error Decision Aid (MEDA) developed by Boeing. For information on MEDA see Appendix F and Appendix G.

Once these areas have been investigated a full, written report should be prepared and will be used to learn from any errors and put into place measures to avoid any recurrence. This report will be copied to the Mishap Review Board *(some organisations, for reasons of expediency, may wish the Mishap Review Board to only consider errors which affect airworthiness or cause unacceptable economic harm. If this is the case, those employees whose errors do not fall into this area should have no action, either non-disciplinary or disciplinary, taken against them)* .

Part B

Mishap Review

The object of the Maintenance Mishap Policy is to support the creation of a reporting culture where members of staff know that human error is tolerated in the interests of safety. Members of staff must be encouraged to report all errors but must be secure in the view that if they do report an error they will be treated in a fair and reasonable manner. The underlying principle is that the Maintenance Mishap Policy offers protection to members of staff who have reported an error but are subsequently found not to have behaved recklessly. During the mishap review process should it be found that the member of staff engaged in reckless behaviour then the Mishap Review Board should determine the level of discipline to be applied using the company's existing disciplinary policy. However, should the behaviour of the member of staff be judged as less than reckless then the Mishap Review Board will make recommendations to engineering management as to what type of action (such as re-training, procedure review, design change) is needed. It should be remembered that some employees find re-training adds little or no value to what they already know and therefore it may be ineffective in preventing future errors. The Mishap Review Board should carefully consider any necessary system changes before looking at the area of training.

The Mishap Review Board should be comprised of three members of senior management. One each from Quality Assurance, Human Resources and Engineering Management. The individual members of the board, selected by the Technical Director, should not include anyone who may be involved in any possible appeal process. It is desirable to include a member of the 'hands on' workforce or a trade union representative, always remembering that the board should be comprised of an odd number of people in order to ensure that a 'majority rule' decision can be arrived at.

Once the event investigation report has been received the Mishap Review Board should examine it in detail and carry out any additional investigations that may be

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required. During this process the Mishap Review Board may be required to interview the staff. This should occur no later than ten days after the mishap in order to preserve the freshness of evidence and any witness' recall of the circumstances.

As previously stated the threshold for disciplinary action is recklessness. Recklessness involves an objective determination that the subject member(s) of staff consciously disregarded the fact that their conduct would significantly and unjustifiably increase the risk that the mishap consequences would occur. The risk must be of such a nature and degree that, considering the circumstances known to the member(s) of staff, its disregard involves a gross deviation from the standard of care that a reasonable member of staff would observe in his or her situation.

The steps in determining recklessness are as follows:

1. Identify the undesirable consequences that did result or could have resulted from the behaviour displayed.

2. Identify the risk that these consequences would occur.

3. Determine if the risk was substantial.

4. Determine if the risk was unjustifiable.

5. Determine if the member of staff consciously disregarded the substantial and unjustifiable risk.

If any of the steps above cannot be identified or determined then recklessness cannot be proved on a balance of probabilities.

At this point in the mishap review process if, following the five steps above, it has been determined that the member of staff concerned was not guilty of recklessness the Mishap Review Board should determine what, if any, remedial non-disciplinary action is to be recommended to the staff and supervisor/manager and what other systemic changes are required to avoid a recurrence. Finally all staff involved should be informed in writing of the outcome.

If recklessness cannot be fully ruled out at this point then a disciplinary hearing should be convened. This hearing should follow exactly the same format as contained in the Company's existing disciplinary procedure but should be conducted by the Mishap Review Board. Prior to the hearing the member of staff concerned must be allowed to view the event investigation report.

As with any other disciplinary process the member of staff concerned should be made aware of all the facts to hand and given the opportunity to fully explain their actions. Once the Mishap Review Board has been satisfied that all available

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information has been presented then the hearing should be adjourned so that a decision can be reached.

During the adjournment the Mishap Review Board should consider the facts as a group and make a number of key decisions. This first decision should be whether the member of staff behaved recklessly. If this has been determined then the next step should be to decide the appropriate level of disciplinary action by following the Company's existing Disciplinary Procedure. Should the review board not be unanimous in their decisions then a group decision should be made on the basis of majority rule.

Once a decision has been made then the member of staff should be informed in writing of the outcome and if necessary should be given the right of appeal as per the Company's existing disciplinary procedure. A full report should be made by the Mishap Review Board for inclusion in the member of staff's personnel file.

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Appendix B

UK-HFCAG
Sample Staff Opinion Survey

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Sample Staff Opinion Survey

This survey has been designed to find out your views on working with your company. Although the survey has been designed to help your company look at its practices and procedures with regard to ‘Human Factors’ your responses to all the questions - whether Human Factors related or not - are very important.

Any information that you give will be treated in total confidence (in fact the following questionnaire will not ask for either your name or your job role). Please take your time when filling out this questionnaire; think carefully and answer honestly so that your company gets a true picture of how it is performing.

Your survey administrator will advise you of the completion deadline and who to return the questionnaire to once completed.

The survey results will be communicated to you as part of the Company’s ongoing Human Factors Programme.

Staff Opinion Survey

Listed below are a number of statements regarding your working environment. There are five possible responses to each statement:

1. *Strongly Agree*
2. *Agree to Some Extent*
3. *Neither Agree or Disagree*
4. *Disagree to Some Extent*
5. *Strongly Disagree*

When giving your response to each statement please circle the number that represents the response closest to your own opinion (for example if you 'Strongly Agree' with the statement circle the number '1', if you 'Strongly Disagree' circle the number '5').

(a)	I understand the meaning of the term 'Human Factors'.	1	2	3	4	5
(b)	'Human Factors' is important to my company.	1	2	3	4	5
(c)	My working environment helps me be efficient and effective.	1	2	3	4	5
(d)	My company follows efficient and effective work practices.	1	2	3	4	5
(e)	My company has a good safety record.	1	2	3	4	5
(f)	My company supports safety initiatives.	1	2	3	4	5
(g)	I feel able to discuss work related problems with my colleagues.	1	2	3	4	5
(h)	I feel able to discuss all problems with my supervisor.	1	2	3	4	5
(I)	The management understands the problems that I face in my job.	1	2	3	4	5
(j)	I have confidence and trust in the way that my company is managed.	1	2	3	4	5
(k)	My company is fair and just in its approach to discipline.	1	2	3	4	5
(l)	I feel able to report all errors that I make.	1	2	3	4	5
(m)	In the interests of safety I feel able to report all errors that my colleagues make.	1	2	3	4	5

(n)	Schedules seldom allow time to do the job according to the maintenance manual/procedures.	1	2	3	4	5
(o)	I have found better ways of doing my job than those in the maintenance manual/procedures	1	2	3	4	5
(p)	It is necessary to bend some rules and procedures to achieve a target.	1	2	3	4	5
(q)	The conditions that I work under stop me from working strictly to the maintenance manual/procedures.	1	2	3	4	5
(r)	I find that short cuts are acceptable when they involve little or no risk.	1	2	3	4	5
(s)	The management sometimes puts people under pressure to not follow the maintenance manual/procedures.	1	2	3	4	5
(t)	My co-workers sometimes put people under pressure to not follow the maintenance manual/procedures.	1	2	3	4	5
(u)	Some company procedures are very difficult to understand.	1	2	3	4	5
(v)	Supervisors and managers seldom discipline or correct people who do not follow the maintenance manual/ procedures unless there is an incident..	1	2	3	4	5

Notes to the Survey Administrator

The UK-HFCAG Staff Opinion Survey has been developed as a basic and easy to administer tool which will give a ‘flavour’ of the current Human Factors culture within your company. As with most surveys the results will only indicate the probable culture that exists, not the actual one. There are no ‘trick questions’ and no attempt has been made to isolate invalid or vexatious responses.

Statements (a) to (m) give an indication of the general level of awareness of Human Factors and also give a fairly general ‘snapshot’ of the current culture existing within the engineering/maintenance function.

Statements (n) to (v) will give a more detailed indication of recognised Human Factors problem areas.

When compiling the results of the survey it may be helpful to initially break the responses down into three main areas (rather than the five listed) for ease of viewing. These areas would be:

- Agree
- Don’t Know
- Disagree

If the responses to statements (a) to (m) show a marked swing towards ‘Disagree’ and/or the responses to statements (n) to (v) show a marked swing towards ‘Agree’ it is recommended that a more in-depth survey is conducted before any changes are put into place.

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MRM COURSE GUIDELINES

- **MRM Course - Basic Considerations**

Include a variety of means to present the material such as OHP transparencies, a laptop and projector, photos, videos, and individual/group exercises. Be sure that whatever means you use, it is entirely relevant, the messages are clear, and that the chosen method does not take longer, or is less easily understood and retained by the students than an alternative method.

Ensure that your handout material or training manuals look as professional as budgets will allow. Even older generation PCs, printers and photocopiers can produce satisfactory results, provided that the originals are good.

It is more cost effective to design your course to suit all disciplines who can affect maintenance safety, rather than to design courses for individual groups. However, in doing this you will need to ensure that you include practical examples of how the topics can relate specifically to their individual workplaces. In addition to Hangar and Line Maintenance personnel, the programme should include people from planning, technical support, technical records, airworthiness, quality audit, technical training etc. Smaller sized organisations may be able to combine everyone at the outset, including operational, commercial and administrative staff.

Assign seat positions beforehand to ensure that the participants are likely to be sitting next to someone from a different department, and of a different grade.

Include arrangements for your CEO, Maintenance Director, General Managers or VPs Maintenance, to visit as many of the courses as possible to demonstrate their support for the programme. They may even take the opportunity to relate their own past errors! A 20 minute chat, or simply mixing with the students during a working lunch, can send powerful messages, and add support to the efforts of the course facilitators.

Think of ways to brand your programme by calling it something other than Human Factors. This term, although widely used, does have its disadvantages. It is often confused with Human Resources and can sometimes be regarded by some maintenance staff as a function of the quality department. Whatever name you choose, try to ensure that it has an underlying safety and performance message, and can readily be remembered.

Tell the regulators about your programme. Invite them to a briefing to describe it. Better still, invite them to attend your course and provide you with their observations.

You may feel that your training programme is not perfect, and will need considerable development time before being ready to deliver. By having it 80% right and making improvements, as the result of feedback from the students as well as by keeping abreast of HF research and development outputs, as the programme progresses your content will always be relevant. Waiting for 100% perfection will not improve accident and incident rates.

- **Key areas on which to concentrate**.

Base your training on:-

- ✈ Existing relevant industry material such as Transport Canada's Dirty Dozen and Magnificent Seven.
- ✈ Your organisation's reporting and investigation processes.
- ✈ What your maintenance incident trend analysis process is telling you.
- ✈ Practical and relevant solutions and interventions that your organisation has devised and how you ensure that they are implemented and audited.
- ✈ Your organisation's disciplinary policy and process.
- ✈ Staff feedback mechanisms.
- ✈ Any particular areas for safety concerns within your organisation such as Shift Handover or Line Maintenance resource planning.
- ✈ Additional reports that indicate problems of a particular type, or affecting a particular work area.

Use data supplied by the regulators which highlight industry-wide problems, for example:-

- ✈ UK CAA analysis of Mandatory Occurrence Reports (MOR's).
- ✈ UK CAA Airworthiness Notice 47.
- ✈ JAR 145 Review Team report.
- ✈ JAR 66 Requirements.
- ✈ AAIB accident reports.

This data can add valuable weight to your message.

Review the content of the Crew Resource Management (CRM) or Integrated Crew Training (ICT) training your flight and cabin crews are receiving. Attend their courses if possible. You could gain some useful background knowledge and some of the training material could be amended to suit your programme.

- **Structuring your training programme.**

Use in-house examples from your Mandatory Occurrence Reports and other reporting systems. However, unless you already have a good method for determining the circumstances leading up to and during such events, and the factors which contributed to them, the reports will be of limited value.

Put an incident review process in place such as Boeing's Maintenance Error Decision Aid (MEDA) or other derivative. In the meantime, use other operator's reports which are relevant to your aircraft fleet.

Use information available from your Regulators, such as the CAA Safety Regulation Group, to obtain data specific to your organisation. Use reports which can illustrate problems that exist in your organisation, hence the need for the HF programme. Develop training versions of such reports for students to evaluate during your courses, and get them to determine the factors which contributed to the incidents and subsequent prevention measures.

It is vital to ensure that practical examples are used to reinforce the subject under discussion. Such examples may be already known by the course facilitator, particularly if he is an experienced maintenance engineer. Other examples can be discovered by having discreet conversations with individuals in their workplace, or eliciting examples from the students. Information from the Staff Opinion Survey (a sample survey can be found in Appendix B) can also be useful.

Use plenty of individual and group exercises and case studies to maximise student participation. A fairly comprehensive syllabus is outlined further on in this appendix, and would typically take 14 hours or two intensive days to deliver.

If you can afford the luxury of providing a buffet lunch in the training room, or somewhere in the vicinity, you will have better control over the time taken for a lunch break, and avoid the late return of the student who decided to 'check in' at the workplace. It might also serve as a convenient time for a visit from your senior management which will encourage further debate. It is beneficial to provide, at a minimum, bottled water and/or tea and coffee. It all helps to ease the way in developing an improved human factors culture.

Consider how you intend to maintain continued awareness. You may decide to run shortened refresher versions of your courses on a regular basis. An alternative and more interesting approach would be to arrange short conferences (1/2 to 1 day in duration) which would be attended by engineers, pilots, cabin crew and ramp workers. Short refresher presentations which are relevant to each of the groups could be used to start the proceedings and these could be followed by group case studies developed from the experiences of your organisation and involving a mix of the groups.

- **Developing standard training programmes.**

Training programmes should be developed to suit the needs of your individual organisation, taking account of your corporate maturity, culture, previous knowledge and training, and other safety or quality related initiatives. There are, however, some basic fundamentals and topics which should be common to all programmes, and it is in this area that a common standard for these essential elements may be arrived at through working with other organisations, including the regulators.

Smaller organisations, who are unable to devote the necessary resources to implementing a Human Factors training programme, could combine their efforts with other similarly placed organisations to provide an approach which generally satisfies the requirements of the ‘partnership’.

SUGGESTED MRM COURSE CONTENT

1. <u>INTRODUCTION</u>

- General housekeeping.
- Fire safety & evacuation.
- Student introductions.
- Course objectives.
- Course overview.

2. <u>INCIDENT STATISTICS</u>

- Causes of general accidents & incidents.
- Main causes of maintenance errors.
- Details of Company accidents and incidents.
- 'Dirty Dozen' causes.
- CAA, JAA & industry activities.

3. <u>HUMAN FACTORS</u>

- Theory & concept model.
- Company Human Factors Programme overview.
- Human characteristics.
- Human behaviour.
- Human psychology & health.
- Performance shaping factors.
- Technician characteristics.

4. <u>COMMUNICATION</u>

- Memory & information processing.
- Communication methods.
- Assertiveness.
- Situational awareness.
- Active listening.
- Approved data.
- Presentation skills.

5. <u>TEAMWORK</u>

- Team dynamics.
- Effective teams.
- Situational leadership.
- Effective meetings.

6. <u>PRESSURE</u>

- Definitions of pressure & stress.
- Instigation levels & performance.
- Identifying stressors.
- Performing under pressure.

7. <u>SHIFTWORKING</u>

- Working hours.
- Shift patterns.
- Circadian rhythms.
- Fatigue.
- Shift handover.

SUGGESTED MRM COURSE CONTENT

8. MANAGING ERROR

- Latent & active failures.
- Safety nets & defences.
- Preventative methods.
- Task analysis.

9. REPORTING ERRORS

- Reporting process.
- Disciplinary policy & procedure.
- Incident review & analysis.
- Feedback methods.
- CHIRP.

10. AUDIT TEAMS

- Reactive & proactive error identification.
- Team composition.
- Processes
- In-house examples.

11. MONITORING PROCESS

- Purpose.
- Who does it ?
- Process & procedure.

12. COURSE REVIEW

- In-house incidents - common factors and action status.
- Review of course objectives.
- Future plans.

N.B. *This course material is based on the content of courses currently being run by industry training organisations. Please contact your industry group representative for further details.*

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INDIVIDUAL AND TEAM EXERCISES

The exercises detailed below have been provided to complement the MRM course content.

- COMMUNICATION

Individual

At the start of the course, group the trainees in pairs and ask them to interview their 'partner' to obtain some key information such as: name; job role; length of service; previous career; hobbies or interests; course expectations. No notes are to be used. The trainees must then introduce their 'partner' from memory.

Team

Split the group into teams of four or five individuals and ask them to identify the difficulties faced during the course introductions. Ask the teams to then identify the barriers that are faced when using AMMs, Worksheets and Job Cards and how these barriers can be overcome.

- BEHAVIOURAL STYLES AND TEAM ROLES

Individual

Using a questionnaire (such as the Myers-Briggs) establish the preferred behavioural style of each of the trainees. Identify what action can be taken to modify those behaviours regarded as negative to help improve group co-operation.

Team

In this exercise, using groups of four or five, have each individual determine their own team role (using the Belbin models) and then as a group consider the mix of team roles to determine group effectiveness.

* INCIDENT CAUSES

Team only

Teams are provided with ‘sanitised’ versions of Company incidents and are required to identify the contributing factors. The team results are then compared with the findings of the actual incident report. The teams are then asked to recommend actions to prevent a recurrence and again their results are compared with the actual report recommendations.

* SHIFTWORK

Team only

Teams are asked to identify the essential elements required for an effective handover between individuals, teams and shifts. The results are then compared with the HSE recommendations (see “Guidelines in Producing an Effective shift and Task Handover System” by Bob Miles of the HSE).

Appendix D

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Sample Management Briefing Agenda

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SAMPLE MANAGEMENT BRIEFING AGENDA

HUMAN FACTORS AND [*YOUR COMPANY*]

Briefing for Managers and Supervisors

Session 1- [allow approximately 3 hours]

1.	Introduction	***Accountable Manager***
2.	The Influence of Human Factors on the Safety of Aircraft Engineering & Maintenance	***Director/Head of Engineering***
3.	[*Your Company's*] experience (including use of 'Every Day' Video)	***Quality Assurance Manager***
4.	Current Company Initiatives in Engineering	***Various***

- Company Commitment
- Current Plans in Engineering Services
- Current Plans in Maintenance/Line
- Exorcising the Blame Culture
- Practical Steps

5.	Group Discussion around 'set piece' example	***All***

Note: Information to support the above items is available through the UK HFCAG.

Appendix E

UK-HFCAG
Sample Amnesty Statement

SAMPLE AMNESTY STATEMENT

STAFF NOTICE

Following our launch of our new Human Factors initiative and the Staff Briefings to Management and Senior Staff, we would like to encourage all staff to come forward with any information that they have to further improve the quality of the product and the service to our customer(s).

Information requested is that relating to the following examples:

- Custom and Practice – methods used not reflected by publications
- Areas of concern about aircraft which may have almost caused incidents in the past
- Areas where additional checks should be put in place
- Training issues
- Management issues

We are willing to undertake that, for all items reported to us, no retrospective action will take place regarding any incidents or practices reported and inputs to us may be made confidentially, if preferred.

The Ground Occurrence Report *[your company's alternative here]* can be used to report items and is available from *[your preferred source – should be available freely and locally].* Alternatively talk to one of the QA personnel.

The single aim of this exercise is to ensure that we can take account of all the experience locked up in the company, and to improve our product. Please help us !

Accountable Manager

Note: Material to support the above is available through the UK HFCAG.

Appendix F

Maintenance Error Decision Aid
(MEDA)

User's Guide and Results Forms

The information contained in this appendix has been reproduced with the kind permission of the Boeing Commercial Airplane Group.

Introduction

There are three objectives of the User's Guide:

1. To give the user an overview of the MEDA philosophy and process
2. To provide information on how to complete the Results Form

3. To give the user examples of contributing factors to look for during the investigations.

This guide assumes that the user has been through the MEDA investigator workshop and understands the following:

- The definition of an event
- The definition of a maintenance error
- How MEDA provides a structured framework for documenting contributing factors to errors and for recommending error prevention strategies.

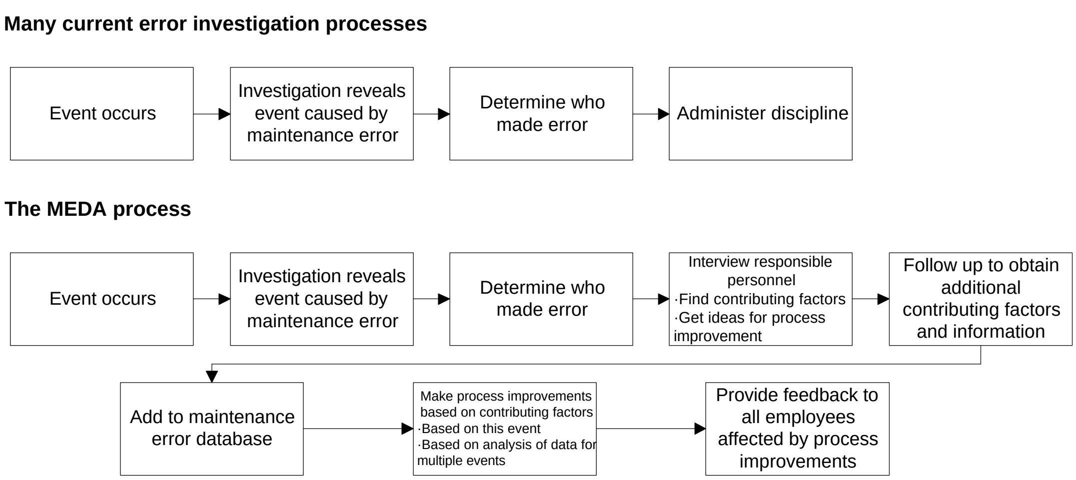
MEDA Philosophy

The fundamental philosophy behind MEDA is:

- Maintenance errors are not made on purpose
- Most maintenance errors result from a series of contributing factors
- Many of these contributing factors are part of an airline process, and, therefore, can be managed.

MEDA Process

MEDA is a process that helps airline maintenance organizations reduce errors by giving them a tool to identify factors that contribute to the errors. The following is a comparison of how the MEDA process is different from many current error investigation processes:



Instructions

Use the MEDA Results Form to collect data associated with a maintenance error. Each section of the form, as shown in Figure 1, captures specific data. The end product will contain information about what happened (the incident), why (contributing factors), system barriers that failed to prevent the error and recommendations for prevention strategies to prevent the error from occurring again. What follows are detailed instructions on how to fill in each section.

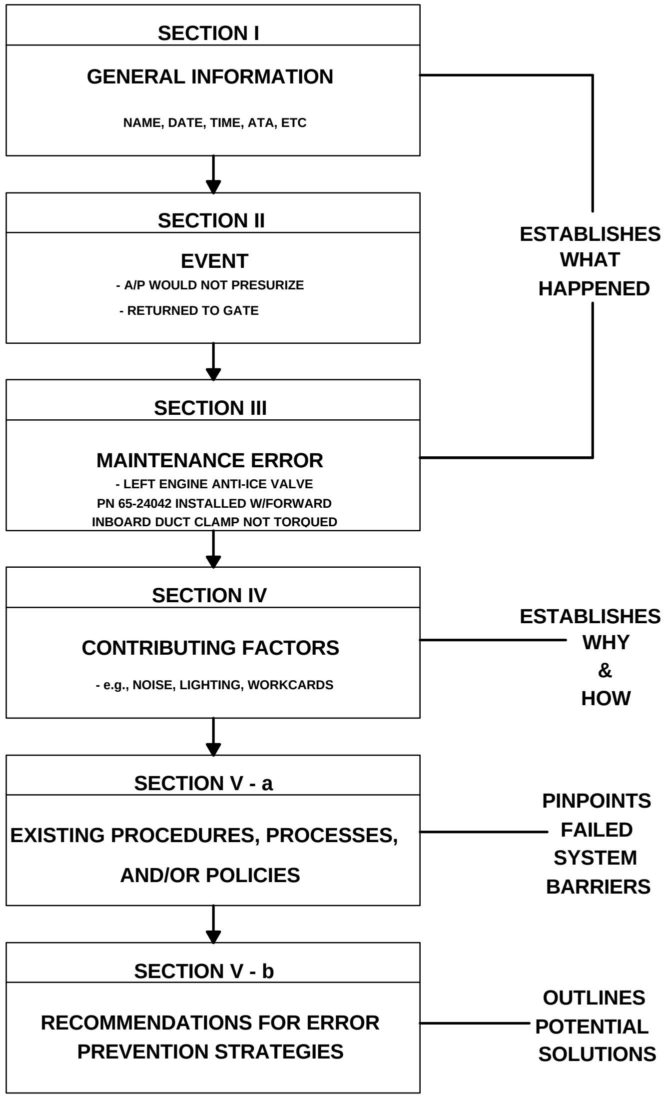


Figure 1 - MEDA Results Form Flow Chart

Section I - GENERAL

REFERENCE # : Two letter airline designator plus three sequential numbers (e.g., BA001, BA002, etc.)

AIRLINE : Two or three letter airline designator

STATION OF ERROR : Station where the error occurred NOT where it is being reported (if different)

AIRCRAFT TYPE : Manufacturer and model (e.g., B747-400, DC10-30, L1011-100, A320-200)

ENGINE TYPE : Manufacturer and model (e.g., PW4000, RB211-524, CF6-80A, etc.)

REG. # : Aircraft registration number

FLEET NUMBER : Letter or number designator

ATA # : ATA chapter (e.g., 30-10) most closely related to the error under investigation

AIRCRAFT ZONE : e.g., 210, 130, etc.

REF # OF PREVIOUS RELATED EVENT (IF APPLICABLE) : If this investigation is a repeat of a similar event, use this field to reference to the previous investigation's data

INTERVIEWER'S NAME / INTERVIEWER'S TELEPHONE # : This information is required in case the MEDA focal in your organization needs clarification or more detailed data

DATE OF INVESTIGATION : Date the investigation starts

DATE OF EVENT : Date the event occurred

TIME OF EVENT : Time of the event, if known

SHIFT OF ERROR : Shift during which the error occurred, if known

TYPE OF MAINTENANCE : Indicate whether the error occurred during line or base maintenance, and what type of check or maintenance was being performed (e.g., turnaround, A-Check, overhaul, etc.)

DATE CHANGES IMPLEMENTED : Date that recommended and approved prevention strategies were implemented and documented

Section II - EVENT

An event is an unexpected, unintended, or undesirable occurrence that interrupts normal operating procedures and may cause an incident or accident.

Step 1
Select as many of the event identifiers that apply:

Please select the event

- ( ) *Flight Delay ___days___hrs.___min.*
- ( ) *Flight Cancellation*
- ( ) *Gate Return*
- ( ) *In-Flight Shut Down*
- (✓) *Air Turn-back*
- ( ) *Diversion*
- ( ) *Aircraft Damage*
- ( ) *Injury*
- ( ) *Rework*
- ( ) *Other*

Step 2

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

Example:
After takeoff, the aircraft would not pressurize in the automatic mode. Manual control was noted as functional.

Section III - MAINTENANCE ERROR

A maintenance error is an action or inaction within the maintenance organization that leads to an aircraft problem.

Step 1

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

Select error and identify its contributing factors and error prevention strategies in Sections IV and V, respectively.

NOTE: Sometimes several errors combine to cause an incident. Investigation results are less confusing when Sections IV and V describe contributing factors and error prevention strategies for a single error at a time. Therefore, it is important that only ONE error be identified in this section. If two or more errors combined to cause the incident, use Sections III, IV and V on separate forms and staple them to the back of the first.

Step 2

Describe the specific maintenance error (e.g., auto pressure controller installed with wrong orientation)

Enter a brief written description of the maintenance error.

Example:
The auto pressure controller installed with the sense lines backwards.

Section IV - CONTRIBUTING FACTORS CHECKLIST

This checklist will help the analyst identify the contributing factors that contributed to the error. If several errors combined to cause the event, it is important to remember that you are identifying only those factors contributing to **one error at a time**. Use Sections III, IV and V on separate forms for multiple errors.

Step 1

Select all the applicable contributing factors for the error identified in Section III. See the Contributing Factors Checklist Examples section for additional information on each factor.

Step 2

If a contributing factor on the list was not involved, mark N/A. The purpose of this step is to ensure that each contributing factor is considered during the interview.

Step 3

For each factor identified, give a written description of how it contributed to the error.

Section V - ERROR PREVENTION STRATEGIES

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

This section highlights organizational barriers that were in place but failed to prevent the error from occurring.

Select and describe as many items as are related to the error identified in Section III.

List recommendations for error prevention strategies

List all proposed changes or actions that are recommended to prevent the error from occurring again. This may include changes based on analysis of the contributing factors for this error and also process or system improvements based on the analysis of data across several errors.

Contributing Factors Checklist Examples

The following pages contain additional data about each contributing factor from Section IV of the MEDA Results Form. Each lettered section heading corresponds to a lettered block on the Results Form, and each numbered item beneath that heading corresponds to a numbered item on the Results Form. Use this supplemental material during your error analysis to assist you in filling out the Results Form.

A. Information

Information refers to the written or computerized source data that a maintenance technician needs to carry out a task or job. It includes workcards, maintenance manual procedures, service bulletins or engineering orders, maintenance tips, illustrated parts catalogs and other manufacturer supplied or internal resources.

To determine that information was a contributing factor to the maintenance error, either the information itself must be problematical (e.g., hard to understand, not complete, conflicting), or the information should have been used but was not (e.g., it was not available, it was ignored). If it is expected that the maintenance technician has this information memorized, then refer to the Technical Knowledge/Skills section.

Examples to look for:

1. Not understandable

Unfamiliar words or acronyms

Unusual or non-standard format

Poor or insufficient illustrations

Not enough detail or missing steps

Poorly written procedures

2. Unavailable/inaccessible

Procedure does not exist

Not located in correct or usual place

Not located near worksite

3. Incorrect

Missing pages or revisions

Does not match aircraft configuration

Transferred from source document incorrectly

Steps out of sequence

Not the most current revision

Procedure does not work

4. Too much/conflicting information

Similar procedures in different resources do not agree (e.g. MM versus task card)
Too many references to other documents
Configurations shown in different resources do not agree

5. Update process is too long/complicated
Requested revisions have not been incorporated yet
Configurations changed by Service Bulletins or Engineering Orders have not been updated in applicable maintenance procedures
Document change requests are not submitted, lost, or incorrectly filled out

6. Incorrectly modified manufacturer's MM/SB
Intent of manufacturer's procedure is not met
Non-standard practices or steps are added
Format does not match rest of procedure or other procedures

7. Information not used
Procedure available but ignored
Technician too familiar with procedure

8. Other
Operator cannot use digital information

B. Equipment/Tools

Equipment and tools are the tools and materials necessary for performance of a maintenance task. Equipment and tools refer to things such as non-destructive test equipment, work stands, calibrated torque wrenches, screwdrivers, test boxes, and special tools called out in maintenance procedures.

Unsafe equipment and tools may cause a maintenance technician to become distracted from the task due to concern for personal safety. If equipment or tools are not available or are inaccessible, the maintenance technician may use other equipment or tools that are not fully suited for the job. Other factors that can contribute to error include mis-calibrated instruments, use of unreliable equipment, or equipment or tools with no instructions for use.

Examples to look for:

1. Unsafe

Platform moves and is unstable

Brakes or safety devices inoperative

Non-skid material worn or missing

A lock-out mechanism is missing or faulty

Placards (warnings or cautions) are missing or faded

Sharp edges are exposed or personal protective devices are missing

Power sources are not labeled or protected

2. Unreliable

Intermittent or fluctuating readings on dials or indicators

Damaged or worn out

Expired use limits

History of defects

3. Poor layout of controls or displays

Easy to read wrong display or use wrong control

Awkward locations, hard to reach

Too small to read or control

Directional control of knobs or dials is not clear

4. Mis-calibrated

Tool out of calibration from the start of use
Wrong specifications used during calibration procedure

5. Inappropriate for the task
Standard hand tools used for leverage
Not capable of handling weights, forces, or pressures required for the task
Connections or grips not the right size

6. Unavailable
Is not owned or in stock
Not available for procurement

7. Cannot be used in intended environment
Not enough space to operate tool
Requires level surface where one is not available

8. No instructions
Instructional placards missing or faded
Directional markings missing
Tool usage instructions not available

9. Too complicated
Tool usage requires too many simultaneous movements and/or readings
Fault isolation or testing is too complex

10. Incorrectly labeled
Hand marked labeling or operating instructions are incorrect
Tool has incorrect scale readings
Illegible labels

11. Not used

Equipment/tool/part is available but not used

Not all parts installed during multiple installation

12. Other

System protection devices on tool/equipment not available

C. Aircraft Design/Configuration/Parts

An aircraft should be designed/configured so that parts and systems are accessible for maintenance. The maintenance technician should be able to reach a part, should be able to remove it from a reach and strength standpoint, and should be able to easily replace the part in the correct orientation. When reviewing accessibility as a contributor to maintenance error, it must be seen as a real contributor to the error and not just as an inconvenience to the maintenance technician.

Configuration variability between models and aircraft can contribute to error when there are small differences between the configurations that require maintenance tasks to be carried out differently or require slightly different parts.

Parts refer to aircraft parts that are to be replaced. Incorrectly labeled parts can contribute to improper installation or repair. Parts that are unavailable can contribute to error by the maintenance technician who uses a substitute part.

Good part design also incorporates feedback that helps the maintenance technician know that something has been performed correctly. For example, an electrical connector that has a ratchet effect provides feedback to the maintenance technician when the installation is correct. If this ratchet effect is included in some connectors and not others, this could contribute to error. If a maintenance technician goes from a ratchet connector to a non-ratchet connector, the technician may overtighten the second connector looking for the ratchet.

Examples to look for:

1. Complex

Fault isolation on the system or component is difficult

Installation of components is confusing, long, or error prone

Multiple similar connections exist on the system or component (electrical, hydraulic, pneumatic, etc.)

Installation tests for the component are extensive and confusing

Different sized fasteners can be installed in multiple locations

2. Inaccessible

Components or area to be maintained is surrounded by structure

No access doors exist in the maintenance area

Area lacks footing space or hand-holds

Small or odd-shaped area

3. Aircraft configuration variability

Similar parts on different models are installed differently

Aircraft modifications have changed installation or other maintenance procedures between aircraft

4. Parts unavailable

Part not owned or in stock

Not available for procurement

5. Parts incorrectly labeled

Hand marked labeling incorrect

Wrong part number on part

6. Easy to install incorrectly

Can be easily installed with wrong orientation

No orientation indicators (e.g., arrow, colors)

Connections identical in size, color or length

7. Other

Components are too heavy for easy removal/installation

Lack of feedback provided by component or system

Direction of flow indicators do not exist

D. Job/Task

A maintenance technician's job/task can logically be separated into a series of tasks. If the interviewer feels the task was a contributing factor, he should analyze the combination or sequence of tasks. The interviewer, when examining the task sequencing, should also determine whether written information was being used, what technical skills and knowledge were expected of the maintenance technician, and what communication took place.

Examples to look for:

1. Repetitive/monotonous

Similar steps are performed over and over (opening and closing circuit breakers during a long test)

The same task performed many times in multiple locations (removing seats)

2. Complex/confusing

Multiple other tasks are required during this task

Multiple steps required at the same time by different maintenance technicians

Long procedure with step sequences critical

System interacts with other systems during testing or fault isolation

Multiple electrical checks are required

Task requires exceptional mental or physical effort

3. New task or task change

New maintenance requirement or component

Revision to a procedure

Engineering modification to existing fleet

New aircraft model

4. *Different from other similar tasks*

Same procedure on different models is slightly different

Recent change to aircraft configuration has slightly changed task

Same job at different worksites is performed slightly different

5. Other

The workgroup performs the task differently than specified in the source data (or written information)

E. Technical Knowledge/Skills

Technical skills (sometimes also referred to as abilities) refer to tasks or subtasks that maintenance technicians are expected to perform without having to refer to other information. Technical skills include such things as being able to lock wire, use a torque wrench, and remove common parts from an aircraft. For (lack of) technical skills to be a contributing factor to error, the technician must not have skill that was generally expected of him/her.

Technical knowledge refers to the understanding of a body of information that is applied directly to performing a task. Technical knowledge, in order to be a contributing factor to error, is knowledge that is supposed to be known (memorized) by the maintenance technician. Three broad categories of knowledge are required of a technician: airline process knowledge, aircraft systems knowledge, and maintenance task knowledge. These are discussed in more detail below.

Airline process knowledge refers to knowledge of the processes and practices of the airline or repair station in which the maintenance technician works. Examples include shift handover procedures, parts tagging requirements, and sign off requirements. While this knowledge is generally acquired through general maintenance operating procedures and on-the-job discussion with peers, it may also be acquired from other sources such as employee bulletins and special training.

Aircraft system knowledge refers to knowledge of the physical aircraft systems and equipment. Examples include location and function of hydraulic pumps and rework options for corroded or fatigued parts. While this knowledge is generally acquired from the aircraft design characteristics, training, maintenance manuals, and on-the-job discussion with peers, it may also be acquired from other sources such as trade journals and maintenance tips.

Maintenance task knowledge refers to the specific knowledge required to perform a unique task. Examples include the procedure for bleeding a hydraulic system and limits for wear of a tire. While this knowledge is generally acquired through maintenance instructions or on-the-job discussions with peers, it may also be acquired from aircraft placards, design characteristics, or even other maintenance technicians when working as a team.

Examples to look for:

1. Inadequate skills

History of frequently made similar errors

Poorly installed or serviced items when procedures were available and straightforward

History of poor performance after extensive training in tasks, airline processes, and aircraft systems

Trouble with memory items or poor decision making

2. Inadequate task knowledge

Slow task completion

Technician change of maintenance responsibilities

Task performed by maintenance technician for the first time

Task performed in wrong sequence

3. Inadequate task planning

Frequent work interruptions to get tools or parts

Failure to perform preparation tasks first

Too many tasks scheduled for limited time period

Task necessary for safety not performed first

4. Inadequate airline process knowledge

Failure to acquire parts on time

Technician new to airline or to type of work (from line to hangar, etc.)

Airline processes not documented or stressed in training

5. *Inadequate aircraft system knowledge*

Technician changes aircraft types or major systems

Fault isolation takes too much time or is incomplete

6. Other

Technician performance/skills not accurately tracked/measured

F. Individual Factors

Factors affecting individual performance vary from person to person and include factors brought to the job by individuals (e.g., body size/strength, health, and personal events) and those caused by outside factors (e.g., peer pressure, time constraints, and fatigue caused by the job itself).

Physical health includes the acuity of human senses as well as physical conditions and physical illnesses. Human senses, especially vision, hearing, and touch, play an important role in maintenance. Technicians are frequently required to perform tasks that are at or near the limits of their sensory capabilities. For example, some tasks require good vision and/or touch, such as visual inspection for cracks or finger inspection for burrs. Good hearing is also required in order to hear instructions or feedback before and during a maintenance task.

Physical conditions, such as headaches and chronic pain, also have been shown to relate to errors. Alcohol/drug use, as well as side effects of various prescription and over-the-counter medicines, can negatively affect the senses. Physical illness, such as having a cold or the flu, can also negatively affect the senses and the ability to concentrate. Illnesses can also lead to less energy, which can affect fatigue.

Fatigue has been defined by the U.S. Federal Aviation Administration (FAA) as a depletion of body energy reserves, leading to below-par performance. Fatigue may be emotional or physical in origin. Acute fatigue may be caused by emotional stress, depletion of physical energy, lack of sleep, lack of food, poor physical health, or over excitement. Fatigue may also be caused by the work situation itself. The time of the day, the length one has been working, and complex mental tasks or very physical tasks can cause fatigue.

Time constraints or time "pressure" are common to the maintenance technician. The need to finish a maintenance task so an aircraft can be released from the gate or to finish a heavy maintenance task so an aircraft can be put back into service often cause technicians to feel pressure to get their tasks done. Studies have linked both too little time and too much time with increased error. There is a well known speed/accuracy trade-off, in that the faster one tries to finish a task the more likely an error is to happen. This trade-off also holds for speed and safety. However, when things are done too slowly, boredom can set in and also increase the chance of errors.

Peer pressure can also influence a maintenance technician's performance. For example, there may be peer pressure not to use maintenance manuals because it is seen as a sign of lack of technical knowledge. Peer pressure may also influence a technician's safety-related behavior.

Complacency is over-contentment with a situation that may lead to a failure to recognize cues that indicate a potential error.

Body size and strength are two obvious factors that affect a maintenance technician's ability to perform a task. If someone is too small to reach a plug or if someone is unable to let down an LRU from an upper rack, this can contribute to error.

Examples to look for:

1. Physical health

Sensory acuity (e.g. vision loss, hearing loss, touch)

Failure to wear corrective lenses

Failure to use hearing aids or ear plugs

Restricted field of vision due to protective eye equipment

Pre-existing disease

Personal injury

Chronic pain limiting range of movement

Nutritional factors (missed meals, poor diet)

Adverse affects of medication

Drug or alcohol use

Complaints of frequent muscle/soft tissue injury

Chronic joint pain in hands/arms/knees

2. Fatigue

Lack of sleep

Emotional stress (e.g. tension, anxiety, depression)

Judgment errors

Inadequate vigilance, attention span, alertness

Inability to concentrate

Slow reaction time

Significant increase in work hours or change in conditions

Excessive length of work day

Excessive time spent on one task

Chronic overloading

Task saturation (e.g., inspecting rows of rivets)

3. Time constraints
Constant fast-paced environment

Multiple tasks to be performed by one person in a limited time

Increase in workload without an increase in staff

Too much emphasis on schedule without proper planning

Perceived pressure to finish a task more quickly than needed in order to release the aircraft from the gate

4. Peer pressure
Unwillingness to use written information because it is seen as a lack of technical skills/knowledge

Lack of individual confidence

Not questioning other's processes

Not following safe operating procedures because others don't follow them

5. Complacency
Hazardous attitudes (invulnerability, arrogance, over-confidence)
Task repetition leads to loss of mental sharpness or efficiency

6. Body size/strength
Abnormal reach, unusual fit, or unusual strength required for the task

Inability to access confined spaces

7. Personal event
Death of a family member

Marital difficulties

Change in health of a family member

Change in work responsibilities/assignment

Change in living conditions

8. Workplace distractions/interruptions during task performance
Confusion or disorientation about where one is in a task

Missed steps in a multi-step task

Not completing a task

Working environment is too dynamic

9. Other
Vacations, Absenteeism, Medical leave

Risk-taking behavior

G. Environment/Facilities

The working environment/facilities can contribute to error. For example, temperature extremes (either too hot or too cold), high noise levels, inadequate lighting (reflection/glare, etc.), unusual vibrations, and dirty work surfaces could all potentially lead to maintenance errors. Concerns about health and safety issues could also contribute to maintenance technician errors.

Examples to look for:

1. High noise levels

High noise impacts the communication necessary to perform a task

Extended exposure to noise reduces ability to concentrate and makes one tired

Noise covers up system feedback during a test

2. Hot

Work area is too hot so the task is carried out quickly

Extremely high temperatures cause fatigue

Long exposure to direct sunlight

Exterior components or structure too hot for maintenance technicians to physically handle or work on

3. Cold

Work area is too cold so the task is carried out quickly

Long exposure to low temperature decreases sense of touch and smell

4. Humidity

High humidity creates moisture on aircraft, part and tool surfaces

Humidity contributes to fatigue

5. Rain

Causes obscured visibility

Causes slippery or unsafe conditions

6. Snow

Causes obscured visibility

Causes slippery or unsafe conditions

Protective gear makes grasping, movement difficult

7. Lighting

Insufficient for reading instructions, placards, etc.

Insufficient for visual inspections

Insufficient for general maintenance activity

Excessive - creates glare, reflection, or eye spotting

8. Wind

Interferes with ability to hear and communicate

Moves stands and other equipment (creates instability)

Blows debris into eyes, ears, nose or throat

Makes using written material difficult

9. Vibrations

Use of power tools fatigues hands and arms

Makes standing on surfaces difficult

Makes instrument reading difficult

10. Cleanliness

Loss of footing/grip due to dirt, grease or fluids on parts/surfaces

Clutter reduces available/usable work space

Inhibits ability to perform visual inspection tasks

11. Hazardous/toxic substances

Reduces sensory acuity (e.g. smell, vision)

Exposure causes headaches, nausea, dizziness

Exposure causes burning, itching, general pain

Personal protective equipment limits motion or reach

Exposure causes general or sudden fatigue

Exposure causes general concern about long term effect on health

12. Power sources

Not labeled with caution or warning

Guarding devices missing or damaged

Power left on inappropriately

Circuit protection devices not utilized or damaged

Cords chafed, split, or frayed

13. Inadequate ventilation

Strong odor present

Burning or itching eyes

Shortness of breath

Sudden fatigue

14. Other

Area(s) not organized efficiently (difficult to find parts, work cards, etc.)

Area too crowded with maintenance technicians and/or other personnel

H. Organizational Factors

The organizational culture can have a great impact on maintenance error. Factors such as internal communication with support organizations, trust level between management and maintenance technicians, management goals and technician awareness and buy-in of those goals, union activities, and attitudes, morale, etc., all affect productivity and quality of work. The amount of ownership the technician has of his/her work environment and the ability to change/improve processes and systems is of key importance to technician morale and self esteem, which in turn, affects the quality of task performance.

Examples to look for:

1. Quality of support from technical organizations

Inconsistent quality of support information

Late or missing support information

Poor or unrealistic maintenance plans

Lack of feedback on change requests

Reluctance to make technical decisions

Frequent changes in company procedures and maintenance programs

2. Company policies

Unfair or inconsistent application of company policies

Standard policies do not exist or are not emphasized

Standard error prevention strategies don't exist or are not applied

Inflexibility in considering special circumstances

Lack of ability to change or update policies

3. Company work processes

Standard operating procedures (SOPs) incorrect

General maintenance manuals outdated

Local/organizational “norms” negatively influence the task

Inadequate inspection allowed

4. Union action

Contract negotiations create distractions

Historical management/labor relations are not good

Positive or negative communication from union leadership

Strike, work slowdown, or other labor action creates a disruption

5. Corporate change/restructuring

Layoffs are occurring

Early retirement programs drain experience

Reorganizations, consolidations and transfers cause more people to be in new jobs

Demotions and pay cuts

Frequent management changes

6. Other

Company is acquired by another company

Work previously accomplished in-house is contracted out

Overall inadequate staffing levels

I. Leadership/Supervision

Even though supervisors normally do not perform the tasks, they can still contribute to maintenance error by poor planning, prioritizing, and organizing of job tasks. Delegation of tasks is a very important supervisory skill and if not done properly, can result in poor work quality. Also, there is a direct link between the management/supervisory attitudes and expectations of the maintenance technician and the quality of the work that is performed.

Supervisors and higher-level management must also provide leadership. That is, they should have a vision of where the maintenance function should be headed and how it will get there. In addition, leadership is exhibited by management "walking the talk", that is, showing the same type of behavior expected of others.

Examples to look for:

1. Inadequate planning/organization of tasks

Excessive downtime between tasks

Not enough time between tasks

Paperwork is disorganized

Tasks are not in a logical sequence

2. Inadequate prioritization of work

Technicians not told which tasks to carry out first

Important or safety related tasks are scheduled last

Fault isolation is not performed with the most likely causes checked first

3. Inadequate delegation/assignment of tasks

Assigning the wrong person to carry out a task

Inconsistency or lack of processes for delegating tasks

Giving the same task to the same person consistently

Wide variance in workload among maintenance technicians or departments

4. Unrealistic attitude/expectations

Frequent dissatisfaction, anger, and arguments between a supervisor and a technician about how to do a task or how quickly a task should be finished

Pressure on maintenance technicians to finish tasks sooner than possible or reasonable

Berating individuals, especially in front of others

Zero tolerance for errors

No overall performance expectations of maintenance staff based on management vision

5. Amount of supervision

"Look over the shoulder" management style

Frequent questioning of decisions made

Failure to involve employees in decision-making

6. Other

Meetings do not have purpose or agendas

Supervisor does not have confidence in group's abilities

Management doesn't "walk the talk" and thereby sets poor work standards for maintenance staff

J. Communication

Communication refers to breakdown in communication that prevents the maintenance technician from getting the correct information in a timely manner regarding a maintenance task. The types of communication include both written and verbal.

Examples to look for:

1. Between departments

Written communication incomplete or vague

Information not routed to the correct groups

Department responsibilities not clearly defined or communicated

Personality conflicts create barriers to communication between departments

Information not provided at all or not in time to use

2. Between mechanics

Failure to communicate important information

Misinterpretation of words, intent or tone of voice

Language barriers

Use of slang or unfamiliar terms

Use of unfamiliar acronyms

Failure to question actions when necessary

Failure to offer ideas or process improvement proposals

Personality differences

3. Between shifts

Work turnover not accomplished or done poorly or quickly

Inadequate record of work accomplished

Processes not documented for all shifts to use

Job boards or check-off lists not kept up to date

4. Between maintenance crew and lead

Lead fails to communicate important information to crew

Poor verbal turnover or job assignment at the beginning of a shift

Unclear roles and responsibilities

Lead does not provide feedback to crew on performance

Crew fails to report problems and opportunities for improvement to lead person

Communication tools (written, phones, radios, etc.) not used

5. Between lead and management

Little or no communication exists

Goals and plans not discussed regularly

No feedback from management to lead on performance

Lead does not report problems and opportunities for improvement to management

Management fails to communicate important information to lead

6. Between flight crew and maintenance

Late notification of defect

ACARS/data downlink not used

MEL/DDG interpretation problem

Logbook write-up vague or unclear

7. Other

Computer or network malfunctions lead to loss of information

E-mail not used or ignored

Types of Error Prevention Strategies

There are four broad categories for error prevention strategies. These are as follows:

Error Reduction/Error Elimination

The most often used, and most readily available, error prevention strategies are those that directly reduce or eliminate the contributing factors to the error. Examples include increasing lighting to improve inspection reliability and using Simplified English procedures to reduce the potential for mis-interpretation. These error prevention strategies try to improve task reliability by eliminating any adverse conditions that have increased the risk of maintenance error.

Often, the individual error investigation does not yield contributing factors with strong linkages to the error under investigation. Sometimes the effect of certain contributing factors is not fully understood until a number of events are investigated with the same contributing factor(s) related to them. The difficulty for the front-line manager performing an investigation is the pressure to take action resulting from a single event investigation. The dilemma, however, is how to decide on a prevention strategy when you do not have any strong identifiable contributing factors leading to the error. What if the error had safety implications? Somehow, the error must be addressed. Two additional types of error management strategies are available to address error.

Error Capturing

Error capturing refers to tasks that are performed specifically to catch an error made during a maintenance task. Examples include a post task inspection, an operational or functional test, or a verification step added to the end of a long procedure. Error capturing is different than error reduction in that it does not directly serve to reduce the "human error". For example, adding a leak check does little to reduce the probability of a mis-installed chip detector. It does, however, reduce the probability that an aircraft will be dispatched with a mis-installed chip detector. This is why most regulatory authorities require a subsequent inspection of any maintenance task that could endanger safe operation of the aircraft if performed improperly.

While error capturing is an important part of error management, new views point to a general over-confidence in the error capturing strategy to manage maintenance error. In theory, adding a post-task inspection will require two human errors to occur in order for a maintenance-induced discrepancy to make it onto a revenue flight. In recent years, however, there has been a growing view that the additional inspection to ensure the integrity of an installation will adversely impact the reliability of the basic task. That is, humans consciously or subconsciously relax when it is known that a subsequent task has been scheduled to "capture" any errors made during the primary task. It is not unusual to hear an airline manager say that the addition of an inspection did little to reduce the in-service experience of the error. For example, several major carriers are pulling inspections out of scheduled line-maintenance tasks, in the hopes of improving quality.

Error Tolerance

Error tolerance refers to the ability of a system to remain functional even after a maintenance error. The classic illustration of this is the 1983 Eastern Airlines loss of all three engines due to O rings not installed on the chip detectors. As a strategy to prevent the loss of multiple engines, most regulatory authorities granting ETOPS (extended twin operations) approval prohibit the application of the same maintenance task on both engines prior to the same flight. The theory is that even if a human error is made, it will be limited to only one engine. This was not the case in the Eastern loss of all three engines. One type of human error, the same incorrect application of a task applied to all three engines, nearly caused an aircraft to be lost.

Another example of building error tolerance into the maintenance operation is the scheduled maintenance program for damage tolerant structures (allowing multiple opportunities for catching a fatigue crack before it reaches critical length).

Error tolerance, as a prevention strategy, is often limited to areas outside the control of the first line investigator. However, it is important for the first line supervisor or interviewer to be aware of this type of prevention strategy, and consider it when it may be the best way to effectively deal with the error.

Audit Programs

Audit programs refer to an approach that actually chooses not to directly address the error. In other words, by not directly trying to reduce/eliminate the error, or increase the tolerance for the error, the organization chooses to do something else. What this can include is a high-level search of the organization, to see if something can be done that will serve as a prevention strategy. Examples of these types of strategies are independent audit programs and special investigation training. Airlines typically implement audit projects or programs as a quick fix in response to errors. Yet, these programs are rarely effective over the long-term in reducing error because the short-term awareness that results from them wears off, and the organization is not able to achieve any long-term change

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 <u>information</u> 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 <u>equipment/tool</u> 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 <u>aircraft design/configuration/parts</u> 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 <u>job/task</u> 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 <u>technical knowledge/skills</u> factor(s) contributed to the error.

N/A __

F. Individual Factors

__ 1. Physical health (including hearing and sight)
__ 2. Fatigue
__ 3. Time constraints
__ 4. Peer pressure
__ 5. Complacency
__ 6. Body size/strength
__ 7. Personal event (e.g., family problem, car accident)
__ 8. Workplace distractions/interruptions during task performance
__ 9. 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
__ 2. Hot
__ 3. Cold
__ 4. Humidity
__ 5. Rain
__ 6. Snow
__ 7. Lighting
__ 8. Wind
__ 9. Vibrations
__ 10. Cleanliness
__ 11. Hazardous/toxic substances
__ 12. Power sources
__ 13. Inadequate ventilation
__ 14. Other (explain below)

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

N/A __

H. Organizational Factors

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

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

N/A __

I. Leadership/Supervision

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

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

N/A __

J. Communication

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

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

N/A __

K. Other Contributing Factors (explain below)

Describe specifically how this other factor contributed to the error.

Section V – Error Prevention Strategies

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

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

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

Required Maintenance Documentation

( ) Maintenance manuals (specify)____________________

( ) Logbooks (specify)____________________

( ) Work cards (specify)____________________

( ) Engineering documents (specify)____________________

( ) Other (specify)____________________

Supporting Documentation

( ) Service Bulletins (specify)____________________

( ) Training materials (specify)____________________

( ) All-operator letters (specify)____________________

( ) Inter-company bulletins (specify)____________________

( ) Other (specify)____________________

( ) **Other**
(specify)____________________

B. List recommendations for error prevention strategies.

Appendix G

Further Information

Further Information

Human Factors Issues in Aircraft Maintenance and Inspection 98
FAA CD ROM and Galaxy web site

ICAO Circular, Human Factors Digest No. 1,
Ref Circular 216-AN/131

ICAO Circular, Human Factors Digest No. 3,
Ref Circular 227-AN/136

ICAO Circular, Human Factors Digest No. 12,
Ref Circular 253-AN/151

Improving Compliance with Safety Procedures, Health & Safety Executive
ISBN 0-7176-0970-7

Effective Shift Handover-A literature Review, Health & Safety Executive
Report - OTO 96 003

Managing the Risks of Organisational Accidents, James Reason
ISBN 1-84014-105-0

Human Error, James Reason
ISBN 0-521-31419-4

Handbook of Human Performance (Volume 1, Physical Environment), A P Smith & D M Jones
ISBN 0-12.650351-6

Handbook of Human Performance (Volume 2, Health & Performance), A P Smith & D M Jones *ISBN 0-12-650352-4*

Handbook of Human Performance (Volume 3, State & Trait), A P Smith & D M Jones
ISBN 0-12-650353-2

AAIB Report, BAC 1-11, G-BJRT
Accident Report 1/92

AAIB Report, A320, G-KMAM
Accident report 2/95

AAIB Report, B737, G-OBMM
Accident Report 3/96

Further Information

Where the Safety Rubber Meets the Shop Floor, FAA, Office of Aviation Medicine
DOT/FAA/AM-97/8

Aviation Psychology in Practice (Chap 5, Human Error in Aircraft Maintenance)
ISBN 0 291 398 081

Human Factors in Engineering and Design 1993, M Sanders & E McCormick
ISBN 0 070 549 01X

Websites

Galaxy Scientific Corporation
http://www.galaxyscientific.com

Federal Aviation Administration
http://www.faa.gov

Transport Canada
http://www.tc.gc.ca

Maintenance and Ramp Safety Society
http://groundeffects.org

David Marx Consulting
http://www.davidmarx.com

International Federation of Airworthiness
http://www.ifairworthy.org

FAA Human Factors in Aviation Maintenance and Inspection
http://www.hfskyway.com

Maintenance Error Decision Aid (MEDA)
http://www.boeing.com/commercial/aeromagazine/aero_03/textonly/m01txt.html
http://www.hfskyway.com/hfami/mtng10/allen.htm

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