CAP716 Issue 2 (Appendices)
Aviation Maintenance Human Factors
(EASA / JAR145 Approved Organisations)

Guidance material on the UK CAA interpretation of Part-145 human factors and safety management requirements

Note: There may be very minor differences between this document and the published version.

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Explanatory note

This document is aimed primarily at organisations approved in accordance with Annex 2 (Part-145) of the Commission Regulation (EC) No. 2042-2003 "Continuing airworthiness of aircraft - previously JAR145. It is aimed at organisations approved by UK CAA Aircraft Maintenance Standards Department (AMSD), to help them meet the error management and human factors requirements within EASA Part-145 (originally introduced as NPA12 to JAR 145, and subsequently as amendment 5 to JAR145). It contains guidance material which, if applied appropriately within maintenance organisations, should help reduce the risks associated with human error and human factors, and improve safety.

References throughout the document will primarily be to "Part-145", which is the requirement, "AMC-145", which is the acceptable means of compliance, and "GM-145", which is guidance material. References will also be made to Part-66, Part-147 and Part-21, which are the parts of the EASA Implementing Rule (IR) equivalent to JAR66, JAR147 and JAR21. Occasional references are made to JARs for historical purposes, or where JARs are still current (eg. JAR-OPS). There are no fundamental differences between the JAR and EASA requirements, as far as the human factors elements are concerned.

This is a living document and will be revised at intervals to take into account changes in regulations, feedback from industry, and recognised best practices. This document was originally issued as the CAA Maintenance Human Factors Handbook, and subsequently published, in support of NPA12 to JAR145, as CAP 716 issue 1. It has now been up-issued to Issue 2, incorporating additional and revised guidance material based on industry experience obtained since JAR 145 amendment 5 was implemented on 1st January 2003. It is envisaged that the document will eventually be up-issued to Issue 3, once further best practice emerges with long term experience of working with the new human factors requirements.

Updates to this and other documents will be notified via the CAA website. You may register to receive automatic notifications of any updates by accessing www.caa.co.uk/publications and selecting "human factors". The document is free to download from the website, or printed copies may be purchased.

If you have any comments concerning this document, or any proposals for Issue 3, please pass them back to the CAA Aircraft Maintenance Standards Department, the address of which can be found on the website, or direct to the editor at osdhf@srg.caa.co.uk.

Contents

Appendix A JAA Maintenance Human Factors Working Group Report

The text in Appendix A is a direct copy of the JAA Maintenance Human Factors Working Group (MHFWG) report, 8 May 2001, as published on the JAA website.

1. General

1.1 Introduction & Terms of Reference

According to recent publications, reports, etc, on aviation safety, between 70 and 80 per cent of aircraft accidents are due to human factors. In a significant part of them, a maintenance error is one of the main causes or at least a contributing factor. Furthermore, recent statistics show a relative of increase of accidents where Maintenance is a primary factor. Many of these accidents could have been avoided if basic human factors concepts had been observed.

Although accidents have reduced over the years to about 1 per 5 million departures in Western Europe, it has remained at this level with no signs of declining. With the foreseeable increase of air traffic in the coming years, the number of fatal accidents per year will undoubtedly increase, giving the public the wrong impression that the skies are becoming less safe. In order to stabilise the number of fatal accidents per year, the main aviation safety authorities around the world (FAA, Transport Canada, JAA) have undertaken a series of initiatives, including the taking into consideration of Human Factors in Operations, Certification and Maintenance.

As far as Maintenance is concerned, while the FAA has decided to focus on research, publication of guidance material and the promotion of Human Factors Programmes without changing the regulatory framework, the JAA and Transport Canada decided to enhance their maintenance regulations by imbedding human factors concepts in them.

Accordingly the JAA Committee decided, in December 1998, to set up a JAA Maintenance Human Factors Working Group with the view of improving the JAR 145 requirements in the light of recent developments in Maintenance Human Factors research. In order to ensure a consistent approach with Human Factors development in Certification and Operation, the Maintenance Human Factors Working Group had to work in close co-operation with the JAA Human Factors Steering Group

1.2 Working Group Members

The Working Group included a balanced membership of “Authority” representatives (5) and “Industry” representatives (5). It had its first meeting in January 1999.
The working Group member ship as of 1 January 2001 was:

J.M Cluzeau	*Central JAA*
E. Demosthenous	*Aircraft Engineer International (AEI)*
D. Hall	*CAA-UK*
J. Kerkhoff	*EAIA/Transavia.*
F. Merritt	*CAA-UK*
D. Adriaenssens	*ERA / Delta Air Transport*
K. Zwart	*Nationale Luchtvaart Autoriteit (NLA) Netherlands.*
M. Costantini	*ENAC Italy / Central JAA*

T. Foltis *AEA / LHT*
G. Galéa *AEA / Air France*

1.3 Working method

The agreed working method was the following:

At a first stage, the working group would review and analyse information, data, incident/accidents reports, publications, research material, etc… in order to identify Maintenance Human Factors Issues and classify them by order of importance. It was decided to give a level of criticality (from 1 to 3) to each human factor topic, 1 being the more critical level.

The working Group would then work on the more critical issues, being understood that less critical issues could be incorporated in the rule at a later stage. The prevailing idea was to avoid overweighing the Notice of Proposed Amendment (NPA) on Human Factors with too many issues, the risk being that the NPA process could be delayed by too many comments on secondary issues.

The working group was then required to establish a detailed work plan, to show which issue would be addressed and how it should be addressed (by a JAR change, and AMC/IEM or guidance material). It should be noted that only level 1 (critical) organisational issues were included in the work plan, but all level 1, 2 and 3 training issues were included, as it was agreed that training on maintenance human factors should be comprehensive and include all, minor and major issues. However, while "shortage of engineers" was identified as a level 1 organisational issue, it was not included in the work plan, because the working group considered that solving this particular issue was beyond the capability of the regulator.

At a second stage the working group had to draft an NPA based upon the detailed work programme.

The recent ICAO Annex 6 changes on Maintenance Human Factors were also taken into consideration. The Working Group considered its draft proposal is in compliance with ICAO Annex 6 paragraph 8.7.5.4 on Human Factors training. However the Working Group did not identify any issue directly related to Maintenance Programmes, therefore its proposal intentionally does not address ICAO Annex 6 paragraph 8.3 on Maintenance Programmes.

The drafting phase has been completed on January 2001, then submitted to the Maintenance Sectorial Team, who discussed it during their March 2001 meeting.

2. Human Factors issues

2.1 Definitions

The working group identified two categories of issues: those that can be addressed through an organisation rule change ("organisational issues") and those that can be addressed through a dedicated Human Factors training ("training issues"). Obviously some issues belong to both groups For instance the performance of "Duplicate Inspections" is typically an organisational issue, while the "Limitation of Human Performance" is a training issue, but the development of a good "Safety Culture" pertains to both groups.

2.2 List and priorities

Attachment 1 to this report includes the list of prioritised Maintenance Human Factors Issues. For every Human Factors issue, it specifies the justification for its criticality and what action is recommended. This table is subdivided in two parts:

- ♦ Part 1 includes Human Factors issues to be addressed through a dedicated training programme for maintenance personnel ("training issues").
- ♦ Part 2 includes Human factors issues for which it is envisaged to change / improve a JAA rule ("organisational issues"). Obviously some Human Factors issues belong to both parts.

2.3 Justifications

Attachment 2 to this report includes expanded justification for the criticality of the Human Factors issue. In particular, it refers to known incidents and accidents.

3. Details on Human Factors Issues

The Working Group scope of work was not limited to JAR 145; it also included in principle JAR-OPS Subpart M, JAR 66 and JAR 147. The detailed review of Maintenance Human Factors issues did not indicate that any change was needed for these regulations. In fact, all the proposed changes concentrate on JAR 145: this is not the result of a postulate but is an outcome of the analysis explained above. JAR 66 contains a requirement for certifying staff to demonstrate a basic knowledge level in Human Factors by examination (ref. JAR 66 Appendix 1 Module 9). Paragraph 3.2.4 of this report will explain how this interact with the Working Group's proposal to require Human Factors training

As mentioned above, the Working Group identified 2 categories of changes to JAR 145:

- Changes affecting the JAR 145 approved maintenance organisation itself –qualified as "organisational issues"-, such as a new paragraph on "maintenance planning" and an improved paragraph on "maintenance data".
- Changes affecting maintenance personnel, more specifically the introduction of a Human Factors training requirement –qualified as "training issues".

More specifically, the Working Group proposes to address the following Human Factors Issues:

3.1 Organisational issues:

3.1.1. Design / Maintenance Interface

Inaccuracies, ambiguities, etc in maintenance data may lead to maintenance errors. Indirectly, they may also encourage or give good reasons to maintenance personnel to deviate from these instructions.

The Working Group proposes that a new JAR and AMC require that inaccurate, ambiguous, incomplete maintenance procedures practices, information or maintenance instructions contained in the maintenance data used by personnel be notified to the TC holder.

It is acknowledged that the standard itself of TC holder's instructions is not a maintenance regulatory issue, but a certification regulatory issue, therefore JAR 145 cannot address this. However the Working Group has ensured that the JAA Human Factors Steering Group is considering this issue with Certification.

3.1.2 Safety culture

While it is recognised that it is impractical to write a requirement demanding a safety culture, one can write requirements and guidance material that set out the *elements* that would enable one to flourish.

The Working Group proposes that a new JAR 145 paragraph require the maintenance organisation respectively to establish and publish the organisation's safety policy. This paragraph would identify the accountable manager as the person responsible for establishing and promoting this safety policy, and Section 2 of JAR 145 would further expand on the content of a safety policy

3.1.3. Internal Occurrence Reporting

Another key element for the development of a safety culture is a "Internal Occurrence Reporting System" which consists of a closed loop occurrence & safety hazard reporting, recording & investigation system. A similar system has been proposed through NPA 145-10. The JAA Maintenance Human Factors working group considered minor changes were needed to make the NPA 145-10 proposal an acceptable basis for an Internal Occurrence Reporting System. Comments on NPA 145-10 were submitted to the Maintenance Division on behalf of the working group.

Furthermore the Working Group considers that in order to ensure that effective Occurrence Reporting Systems will be put in place, additional guidance would be needed by the Industry.

The Working Group has prepared more detailed information on the subject. This information is included in this report as Attachment 3.

3.1.4 Procedural Non-compliance

Failure to comply with good maintenance procedures can hardly be covered by regulation. It is a matter of education, safety culture and discipline. However, failure to comply with poor procedures, can be minimised by focusing the requirement on a system that ensures procedures are accurate, appropriate and reflect best practice

The Working Group proposes that JAR 145 be amended to require that human factors principles be taken into account when establishing and writing procedures, and that new AMC material recommend, among other things, the involvement of the end users in writing the procedures, the verification and validation of the procedures, and an effective mechanism for reporting errors and ambiguities and changing / updating the procedures.

The Working Group has prepared more detailed information on the subject. This information is included as Attachment 4 to this report.

3.1.5 Shift and task handover

This is a routine process that repeatedly appears in accident and incident reports.

The Working Group recommends that a new JAR 145 paragraph specifically require a shift and task handover procedure acceptable to the NAA and that additional AMC material provide material that would describe best practice based on current knowledge and scientific research.

3.1.6 Fatigue of personnel

The effect of fatigue on maintenance errors is a well established fact.

The Working Group proposes that a new JAR 145 paragraph require the organisation's production planning procedures to take into account the limitations of human performance, focusing on the fatigue aspect.

The Working Group believes that taking into account the impact of fatigue in production planning is not an issue that can be regulated in a prescriptive manner. Consideration should be given to allowing each JAR 145 approved maintenance organisation to find creative solutions adapted to their own organisational structure. More detailed information has also been prepared on this issue. This information is included as Attachment 5 to this report.

Finally the Working Group understands that the JAA will not be addressing fatigue through duty time limitations, as this is considered as a social issue, not to be covered by a JAA rule. The EU working time directive will cover this in the longer term.

3.1.7 Error capturing

Error capturing forms an important element of the safety net in the approved maintenance organisation. Duplicate inspections may be a means of capturing maintenance errors, but not necessarily the only means.

The Working Group proposes that new AMC material recommend that duplicate inspections be considered as a possible means of error capturing. The AMC should provide additional guidance as to the circumstances where this might be warranted.

3.1.8 Preparation of work (tasks, equipment and spares)

Current JAR 145 does not require a procedure on planning of work. However, the absence of effective planning/preparation may contribute towards increased work pressure, which itself may lead to deviation from procedures. Deviation from procedures is known as a contributing factor in many aircraft incidents and accidents.

The Working Group proposes that new JAR and AMC material clarify the objective of good planning/preparation and include further guidance on elements to consider when establishing the planning/preparation procedure.

3.1.9. Responsibility for "Signing off" tasks.

Recent research proved that many maintenance tasks are signed off while not seen or checked by authorised personnel, potentially leading to incomplete maintenance.

The Working Group proposes that new AMC material elaborate on the meaning of sign-off and the need to self-check or inspect the task before signing off.

3.2 Training issues

3.2 1 General

The Working Group considers that the development of human factors related skills, knowledge and attitudes in the maintenance organisation should be achieved through the training of all concerned maintenance personnel on the subject.

The Working Group proposes to add new JAR and AMC paragraphs on Human factors training. These paragraphs would identify the maintenance staff concerned and would address the need for both initial and continuation training.

3.2.2. Personnel to be trained

The Working Group proposes that all personnel whose error or poor decision could affect safety or compliance with JAR 145. More specifically, the Working Group identified personnel in the following functions:

- Post-holders, managers, supervisors
- Certifying staff, technicians, and mechanics
- Planners, engineers,

- Quality control/assurance staff
- Specialised services staff
- Human factors staff/ Human factors trainers
- Store department staff, Purchasing dept. staff
- Ground equipment operators
- Contract staff in the above categories

3.2.3 Initial training

The Working Group developed a syllabus on Maintenance Human Factors training to be included in an Appendix to JAR 145

Contrarily to JAR 66 Appendix 1, this syllabus does not include knowledge level requirements (see Attachment 6). The intent is at a first stage to give the maintenance organisation the flexibility to adapt the training syllabus to the size and work scope of the organisation.

The Working Group also developed more detailed information on Human Factors training. The intent of this material is to provide additional support to those organisations that will develop training courses. This guidance material identifies training objectives in term of skill, knowledge and attitude, and includes examples and references on subjects to be taught. This draft guidance material is included in Attachment 7.

3.2.4 Continuation training

The Working Group considers that the implementation of Maintenance Human Factors principles in an organisation can only be successful if concerned personnel are regularly fed back and retrained on the issue. The experience shows that an initial human factor training without continuation training proves inefficient after a few years. The Working Group therefore proposes that continuation training on Human Factors be performed every 2 years and include a feedback element on Human Factors issues identified in the organisation.

3.2.5 Training Syllabus of JAR 66 Module 9

JAR 66 already includes a requirement to demonstrate knowledge of Human Factors elements, which included in Module 9 of the syllabus. This applies to certifying staff only and is not a requirement for training: it is only tested by means of examination.

However the Working Group's experience is that an appreciation of human factors can only be obtained by training, ideally within the context of the organisation within which the people work. Furthermore an examination only cannot really assess certain aspects such like "skill" and above all "attitude", which are 2 training objectives identified in the draft guidance material (see attachment 7): training is the way forward.

The Working Group understands that it is not the intention of either JAR 66 or JAR 145 to have unnecessary overlap in terms of human factors training, therefore it explored various possibilities to ensure the consistency between JAR 145 Human Factors training and JAR 66 Human Factors examination.

In the information material (see attachment 7), the Working Group proposes the solution of cross credits –under specific conditions- between JAR 145 training and JAR 66 examination on Human Factors.

Another possibility would be, if the Working Group proposed rule changes are adopted, to take Human Factors out of JAR 66, because the Working Group proposal would in practice supersede the JAR 66 requirement (the WG proposal includes all functions of maintenance personnel and is deemed to address the issue at a higher level)

4. Conclusion

Based upon the above recommendations, the JAA Maintenance Human Factors Working Group submitted a draft proposal for a JAR 145 NPA (Notice of Propose Amendment) to the JAA Maintenance Director. The Working Group expects that this report will help understanding its approach toward Maintenance Human Factors and will provide good support information for the discussions within the JAA Maintenance Sectorial Team and during the NPA public comment period, as well as in the application of good human factors principles when the NPA is adopted.

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Attachment 1 JAA MHFWG - List of proposed improvements to JAA Maintenance regulations
Maintenance Human Factors Issues
Note : Maintenance Human Factors Issues are sorted by criticality, “1” being the more critical and “3” the less critical

Part 1 Training issues

<table>
<tr><th></th><th>Issue</th><th>Critic-ality</th><th>Justification</th><th>Action</th></tr>
<tr><td>1.</td><td>Behaviour
-error provoking
-non compliance with procedures / violations</td><td>1</td><td>A lot of maintenance errors and unsafe conditions are due to behavioural aspects
According to the Adams research (draft report), 1/3 of maintenance tasks are not performed i.a.w. the maintenance manual
Maintenance personnel non complying with procedures is reported as contributing factor in many accidents/incidents</td><td rowspan="5">HF training should address:
✓ the behavioural aspect
✓ the causes and effect of not complying with procedures
✓ communication
✓ the causes and effect of fatigue
✓ recurrent Human Factors Training
✓ the interest of error reporting system & non punitive culture
✓ the effect of interruptions
✓ the effects of poor planning
✓ design of maintenance documentation
✓ the causes and effect of excessive pressure
✓ the awareness that (temporary) unfitness must be considered when performing maintenance tasks
✓ the awareness that repetitive tasks may increase chance of errors due to upcoming complacency
✓ the awareness that problems may arise from different cultures

Identify categories of personnel concerned by HF training and develop related training syllabus.
Duration, frequency, objectives of each training should be defined</td></tr>
<tr><td>2.</td><td>Communication</td><td>1</td><td>Poor communication has been reported as a contributing factor in many incidents/accidents</td></tr>
<tr><td>3.</td><td>Fatigue</td><td>1</td><td>• Long hours worked increases vulnerability to error.
• Several maintenance incidents had a contributing factor fatigue due to excessive hours of work (refer to reports by CHIRP in ‘Feedback’ issues 46, 47, 50)</td></tr>
<tr><td>4.</td><td>Human Factors Training</td><td>1</td><td>Although several organisations have introduced HF training, it seems that sometimes it is not very successful. Its success depends on several factors.</td></tr>
<tr><td>5.</td><td>Safety culture</td><td>1</td><td>To reduce maintenance errors is essential to determine why errors occur and what can be done to improve the reliability of the maintenance system. This is the aim of an Error reporting and analysis system</td></tr>
</table>

	Issue	Critic-ality	Justification	Action
6.	Interruptions whilst performing tasks	1	AAIB reports cite interruptions as a contributing factor in three near fatal accidents	Requirements for instructors should be specified.
7.	Poor planning of tasks, equipment and spares	1	Many reports show that poor planning lead to deviations from procedures and was a contributing factor to incidents	
8.	Technical documen-tation : • access • quality	2	The quality of and access to the (many) documents used in maintenance organisation (Work cards, Maintenance Manual, etc.) has a direct impact on maintenance errors	
9.	Pressure	2	Excessive pressure does lead to maintenance errors	
10.	Personal performance: • eyesight • hearing • physical condition	3	can lead to incomplete work and / or poor quality due to lack of personal perception /awareness	
11.	Repetitive tasks (complacency)	3	repetitive tasks may lead to complacency / distraction and thus cause errors	
12.	culture issues	3	intercultural problems may lead to lack of communication between personnel of different origin	

Part 2 Organisational Issues

	Issue	Critic-ality	Justification	Action
1.	Design : • manufacturer's documentation • maintainability • no Maintenance Manual validation	1	• Manuals not followed or difficult to follow because of poor quality • Cross connections and other design deficiencies have been major contributing factors in past accidents and incidents • Note: B777 did have its manuals validated and over 1000 changes were needed	Maintenance organisations should ensure that design issues are relayed to the manufacturers, in the hope that they will feed back into the design of new aircraft / components/documentation etc.. Side action : co-ordinate with Human Factors Steering Group actions for design/certification
2.	Fatigue	1	• Long hours worked increases vulnerability to error. • Several maintenance incidents had a contributing factor fatigue due to excessive hours of work (refer to reports by CHIRP in 'Feedback' issues 46, 47, 50	-Adequate staffing number and qualification. -Take into consideration circadian rhythms when designing and planning work. (pending availability of additional studies and organisational models) -Consideration be given to duty time limitation (pending JAA MC action)
3.	Safety culture	1	To reduce maintenance errors is essential to determine why errors occur and what can be done to improve the reliability of the maintenance system. This is the aim of an Error reporting and analysis system	Develop guidance material for Error reporting/analysis system. The regulation should address the need for a Human error reporting/analysis system. AMC material should spell out the elements of such a system and promote the interest of non punitive culture.
4.	Inspection	1	History has shown double inspection helps capture maintenance errors	Develop a requirement for double inspection. Identify items subjected to double inspection
5.	Non compliance with procedures	1	Maintenance personnel non complying with procedures is reported as contributing factor in many accidents/incidents	Develop guidance on how to develop "good" procedures. Such guidance should address the validation of procedures and the necessary user's feed back

	Issue	Critic-ality	Justification	Action
6.	Poor planning of tasks, equipment and spares	1	Many reports show that poor planning lead to deviations from procedures and was a contributing factor to incidents	AMC material to cover pre-task planning.
7.	Shift / Task handover (note the training aspect is covered under "communication")	1	Shift/task handover is known as an important issue as it could lead to incomplete maintenance if not properly performed. Criticality is 1 because bad shift handover is known to have been a major contributing factor in an aircraft accident	The regulation should address the need for shift/task handover procedures. AMC material should spell out the preferred elements of a shift/task handover procedure.
8.	Signing off tasks not seen/ checked	1	Incidents	Procedures to only sign off tasks which has been witnessed or checked.
9.	Shortage of engineers	1	UK Royal Aeronautical Society paper; "The challenge for the future", highlights the problem of current and future shortage of aircraft maintenance engineering staff, stating that there exists: "a significant shortage of appropriately skilled labour due to a contraction of the supply of skilled personnel from the armed services, manufacturing sectors, and the traditional airline apprenticeship schemes". The UK Government Transport Sub-Committee of the Environment, Transport and Regional Affairs Committee (ETRAC), have stated: "we are extremely concerned about the shortage of maintenance engineers,	None

	Issue	Critic-ality	Justification	Action
			both in the Commercial and general Aviation sectors". In 1998, the President of Embrey Riddell University, in the USA, stated: "The worldwide shortage of skilled and trained aviation maintenance technicians has reached a critical stage. Predictions indicated that this shortage will continue to worsen as the active fleet is growing while the number of individuals preparing for an aviation maintenance career declines"	
10	Technical documen-tation : • access • quality	2	The quality of and access to the (many) documents used in maintenance organisation (Work cards, Maintenance Manual, etc.) has a direct impact on maintenance errors	Develop general guidance for the design of good (from a HF perspective) documents; ensure proper access to documentation
11	Pressure	2	Excessive pressure does lead to maintenance errors	• Note : The Working Group members' opinion diverge on the possibility to address this issue through an organisational requirement
12	tools & equipment : • design • accessibility • availability	2	poor design, accessibility and availability of tools and equipment may lead to poor work performance because personnel must fight adverse situation rather than concentrate on job performance	• Develop guidance material on validation of internal tooling, accessibility and availability of tools and equipment. • Report to TC Holder tooling that does not work properly • Emphasise tools & equipment monitoring by quality system
13	Workplace :	2	Inadequate working conditions may lead to poor work performance because personnel must fight	• Develop guidance material on how working conditions should be designed

	Issue	Critic-ality	Justification	Action
	• lighting • temperature / climate • noise		adverse working condition rather than concentrate on job performance.	• Emphasise working conditions monitoring by quality system.
14	Computerisation	3	introduction of a computerised system which was not 'ready' - leading to problems	• Properly test and evaluate computerised systems before going live • Provide training for use

Attachment 2 -JAA MHFWG -Justifications for proposed improvements to JAA Maintenance regulations. Maintenance Human Factors Issues

Part 1 Training issues and their justification

Issue	**Justification**
Behaviour -error provoking -non compliance with procedures / violations	• A lot of maintenance errors and unsafe conditions are due to behavioural aspects • According to the Adams research (draft report), 1/3 of maintenance tasks are not performed i.a.w. the maintenance manual • Maintenance personnel non complying with procedures is reported as contributing factor in many accidents/incidents • *BAC1-11 windscreen accident - inadequate care, poor trade practices, etc.* • *A320 - failure to comply with procedures; deviations from MM* • *B737-400 incident - short-term and long-term deviations from procedures* • *B737-400 - inadequate reference to MM, and failure to comply with MM in order to save time* • *A320 incident AAIB report stated "the engineers who carried out the flap change demonstrated a willingness to work around difficulties without reference to the design authority, including situations where compliance with the MM could not be achieved".* • *Many incidents from the Netherlands citing human performance/ errors (but not enough detail as to causes)*
Communication	• Poor communication has been reported as a contributing factor in many incidents/accidents • *B737-400 oil pressure loss incident - the line engineer had intended to complete the task himself therefore did not make a written statement or annotation on a work sheet to show where he had got to in the inspection, and the verbal handover was not adequate* • *A320 incident - handovers were verbal only, and ineffective* • *Incidents from Germany, eg. failure to communicate that a system has been de-activated/ re-activated; incidents where engineers have been asked to clear the area for functional checks (eg. landing gear operation) but have not heard, and equipment remains in the way; inadequate detail in ground finding sheets (eg. concerning the precise location of corrosion); etc.* • *Several Dutch incidents, eg. 3289,*

Issue	Justification
Fatigue	• Long hours worked increases vulnerability to error. • Several maintenance incidents had a contributing factor fatigue due to excessive hours of work • *Engineer fatigue was included as a problem in the UK Transport Select Committee Enquiry, 1998.* • *CHIRP reports in 'Feedback' issues 47 p11, 48 p4, 49 p10, 50 p15.* • *B737-400 loss of oil pressure incident. The AAIB report stated that the task "occurred around the time that the Night Base Maintenance Controller's capabilities were likely to be at their lowest".* • *In the BAC1-11 windscreen loss incident, the AAIB report stated that "errors were made more likely by the sleep deprivation and circadian effects associated with the end of a first night shift"* • *In the A320 incident, the AAIB report stated that "the shift handovers took place, for the nightshift engineer, at a time when he could be expected to be tired and with circadian rhythms desynchronised"* • *Flight Safety Foundation paper "managing sleep for night shifts requires personal strategies", March 1999* • *Paper by Alan Simmons, AAIB, stating that when circadian lows are combined with time on shift >8 hours, "research shows the ability of individuals to perform simple cognitive tasks correctly …drops from 10/10 to 1/10"* • *The UK CAA AWN47 states "Tiredness and fatigue can adversely affect performance. Excessive hours of duty and shift working, particularly with multiple shift periods or additional overtime, can lead to problems. …Individuals should be fully aware of the dangers of impaired performance due to these factors and of their personal responsibilities."* • *Valujet accident.* • *There is an Australian study looking into the problem of fatigue in aircraft maintenance engineers - (further details not yet available)* • *FAA research*
Ineffective Human Factors Training	• Although several organisations have introduced HF training, it seems that sometimes it is not very successful. Its success depends on several factors.

Issue	Justification
Safety culture *- no just culture* *- inadequate incident reporting or analysis* *- inadequate maintenance error management* *- lack of support from senior management* *- failing to learn from previous instances*	• To reduce maintenance errors is essential to determine why errors occur and what can be done to improve the reliability of the maintenance system. This is the aim of an Error reporting and analysis system • *All the major experts on human factors and maintenance engineering (Jim Reason, David Marx, etc.) stress the need for a good safety culture as a prerequisite to addressing many of the HF problems* • *Statement from IATA Director "non-punitive reporting o air incidents is an essential element of our safety improvement programme"* • *B737-400 incident - 5 previous similar occurrences before anything was done, and 3 more (+ this one) since then, suggesting that the remedial action was ineffective* • *A320 incident - at least 3 other occurrences where spoilers had been left in maintenance mode - lessons not learned* • *A MEDA investigation carried out by a UK operator showed that an incident where an idle stop plate had been incorrectly installed (resulting in inability to select either thrust reverser on landing), had important contributory factors (MM poorly designed). These would probably not otherwise have been identified and rectified, without a MEDA investigation* • *A320 incident AAIB report "the errors made were a result of a belief on the part of the engineers that the practices employed were justified" - poor safety culture; cutting corners appeared to be condoned by the company*
Interruptions whilst performing tasks	• AAIB reports cite interruptions as a contributing factor in three near fatal accidents • *B737-400 - many interruptions. The AAIB report stated that the borescope inspection task "was clearly of the type which would benefit from being done in isolation and without interruptions"*
Poor planning of tasks, equipment, spares *and resources*	• Many reports show that poor planning lead to deviations from procedures and was a contributing factor to incidents • *A320 - planning was not particularly thorough* • *B737-400 - Minimal pre-planned paperwork* • *B737-400 oil pressure loss incident - frequent staff shortages, including absence of 4 out of 5 supervisors that night. AAIB report stated "If the airline had had an effective system in place to monitor functionally related available manpower vs workload, a shortfall of Line Maintenance engineers and Base Maintenance supervision on the night would have been predicted* • *Examples from Germany, eg: putting out a D-check job caard set for an IL-layover; non-provisioning of a standard parts set for a layover; wrong paint; shipping parts to wrong overhaul agency, etc*

Issue	Justification
Technical documentation : • access • quality	• The quality of and access to the (many) documents used in maintenance organisation (Work cards, Maintenance Manual, etc.) has a direct impact on maintenance errors
Pressure - *actual* *-perceived*	• Excessive pressure could lead to maintenance errors • *BAC1-11 - perceived time pressure* • *The A320 incident AAIB report stated that "The 07:00 hrs estimated time to service originally established was entirely unrealistic, placing unnecessary additional pressure on the engineers to expedite the task"* • *The UK CAA ELD Newslink Issue 2 (July 99)* • *CHIRP Feedback issue 45, 46 p3.*
Personal performance: • eyesight • hearing • physical condition	• can lead to incomplete work and / or poor quality due to lack of personal perception /awareness • *The UK CAA AWN47 provides guidance concerning eyesight, hearing and fitness, highlighting some of the adverse affects on performance which can occur if these are inadequate."* • *BAC1-11 - failure to use reading glasses*
Repetitive tasks *eg. visual inspection*	• repetitive tasks may lead to complacency / distraction and thus cause errors • *Aloha accident - visual inspection*
culture issues	• intercultural problems may lead to lack of communication between personnel of different origin

Part 2 Additional Organisational Issues not already covered above:

Issue	Justification
Design : • manufacturer's documentation • maintainability • no Maintenance Manual validation	• Manuals not followed or difficult to follow because of poor quality • Cross connections and other design deficiencies have been major contributing factors in past accidents and incidents • *MSc thesis (Dohertey S) - many examples of cross connection problems/ incidents* • *Note: B777 did have its manuals validated and over 1000 changes were needed* • *AirFrance validated an A320 MM and over 2000 changes were needed* • *the A320 incident AAIB report stated that "industry must ensure that it has in place effective, rapid support, including usable systems for consultation with the design authority"* *Dutch incident - 5995*
Inspection	• History has shown double inspection helps capture maintenance errors • *BAC1-11 windscreen accident - no duplicate inspection required* • *The A320 incident AAIB report stated that "the duplicate inspecting engineer sought the requirements for the duplicates and functions from the dayshift engineer rather than consult the MM; this appears to be accepted practice but compromises the independence of the duplicate inspection"* • *Examples from Germany, eg. to check that static port covers have been removed after painting; tightening of nuts of a limited height and in a confined space now requires two people - one to check that an appropriate tool is being used, etc*
Shift / Task handover (note the training aspect is covered under "communication")	• Shift/task handover is known as an important issue as it could lead to incomplete maintenance if not properly performed. Criticality is 1 because bad shift handover is known to have been a major contributing factor in an aircraft accident • *A320- shift handover was verbal; paperwork was not complete; misunderstanding arose* • *B737-400 oil pressure loss incident - the line engineer had intended to complete the task himself therefore did not make a written statement or annotation on a work sheet to show where he had got to in the inspection, and the verbal handover was not adequate* • *A320 incident - handovers were verbal only, and ineffective* • *Incidents from Germany, eg. failure to communicate that a system has been de-activated/ re-activated*

Issue	Justification
Signing off tasks not seen/ checked	• Incidents • *737-400 oil pressure loss incident, Feb 95* • *Examples from Germany: greasing of landing gears; checking of proper adjustment of engine control cables by installation of rig pins. etc*
Shortage of engineers	• UK Royal Aeronautical Society paper; "The challenge for the future", highlights the problem of current and future shortage of aircraft maintenance engineering staff, stating that there exists:"a significant shortage of appropriately skilled labour due to a contraction of the supply of skilled personnel from the armed services, manufacturing sectors, and the traditional airline apprenticeship schemes". • The UK Government Transport Sub-Committee of the Environment, Transport and Regional Affairs Committee (ETRAC), have stated: "we are extremely concerned about the shortage of maintenance engineers, both in the Commercial and general Aviation sectors". • In 1998, the President of Embrey Riddell University, in the USA, stated: "The worldwide shortage of skilled and trained aviation maintenance technicians has reached a critical stage. Predictions indicated that this shortage will continue to worsen as the active fleet is growing while the number of individuals preparing for an aviation maintenance career declines" • *Anecdotal evidence from industry* • *Incidents where there are reports of licensed engineers having to work long hours due to staff shortages* • *BAC1-11 windscreen incident - short staffed* • *A320 locked spoilers incident- LAE requested extra help but none was available* • *B737-400 oil pressure loss incident - staff shortages*
tools & equipment & *documentation*: • design • accessibility • availability	• poor design, accessibility and availability of tools and equipment may lead to poor work performance because personnel must fight adverse situation rather than concentrate on job performance • *A320 - tooling supplied was deficient or incorrect; no collars for locking spoiler* • *Examples from Germany: non-availability of the correct AMM, CMM, IPC; no documentation for dome jobs*

Issue	Justification
Workplace : • lighting • temperature / climate • noise	• Inadequate working conditions may lead to poor work performance because personnel must fight adverse working condition rather than concentrate on job performance. • *B737-400 poor lighting conditions* • *Germany - non-detection of cracks because of poor lighting; repair of components in a dusty area leading to malfunctions after a short time of operation; a listening check of the flight controls cannot be completed due to riveting noise*
Computerisation	• introduction of a computerised system which was not 'ready' - leading to problems • *Germany - computer system for entry and rectification of findings out of service for hours or days*

Attachment 3 - Establishment of an Occurrence Management Scheme

1. Introduction

NPA 145-10 introduces a requirement for an internal occurrence reporting scheme. This document provides guidance material concerning how such a scheme may be set up and run effectively.

2. Key elements for the establishment of an occurrence management scheme.

Note: guidance is provided for an Occurrence Management Scheme (OMS), of which occurrence *reporting* is just one element.

2.1 Prevailing industry best practice has shown that an OMS should contain the following elements:

- Clearly identified aims and objectives
- Demonstrable corporate commitment with responsibilities for the OMS clearly defined
- Corporate encouragement of uninhibited reporting and participation by individuals
- Disciplinary policies and boundaries identified and published
- An occurrence investigation process
- The events that will trigger error investigations identified and published
- Investigators selected and trained
- OMS education for staff, and training where necessary
- Appropriate action based on investigation findings
- Feedback of results to workforce
- Analysis of the collective data showing contributing factor trends and frequencies

2.2 The aim of the scheme is to identify the factors contributing to incidents, and to make the *system* resistant to similar errors. Whilst not essential to the success of an OMS, it is recommended that for large organisations a computerised database be used for storage and analysis of occurrence data. This would help enable the full potential of such a system to be utilised in managing errors.

2.3 An occurrence management system should enable and encourage free and frank reporting of any (potentially) safety related occurrence. This will be facilitated by the establishment of a just culture. An organisation should ensure that personnel are not inappropriately punished for reporting or co-operating with occurrence investigations. Further information is given in para 3.1

2.4 A mechanism for reporting such occurrences should be available. Further information is given in para 3.2

2.5 A mechanism for recording such occurrences should be available. Further information is given in para 3.3

2.6 Significant occurrences should be investigated in order to determine causal and contributory factors, ie. why the incident occurred. Further information concerning which incidents should be investigated, and how, is given in para 3.4.

2.7 The occurrence management process should facilitate analysis of data in order to be able to identify patterns of causal and contributory factors, and trends over time. Further information is given in para 3.5.

2.8 The process should be closed-loop, ensuring that actions are taken to address safety hazards, both in the case of individual incidents and also in more global terms. Further information is given in para 3.6.

2.9 Feedback to reportees, both on an individual and more general basis, is important to ensure their continued support for the scheme. Further guidance is given in para 3.7.

2.10 The process should enable data sharing, whilst ensuring confidentiality of sensitive information. Further information is given in para 3.8.

3. Detailed Guidance

3.1 Just culture code of practice

3.1.1. Organisations are encouraged to adopt the following code of practice to establish a just culture and encourage occurrence reporting:

3.1.2. Where a reported occurrence indicates an unpremeditated or inadvertent lapse by an employee, as described below, an organisation would be expected to act reasonably, agreeing that free and full reporting is the primary aim in order to establish *why* the event happened by studying the contributory factors that led to the incident, and that every effort should be made to avoid action that may inhibit reporting.

3.1.3. It is recognised that whilst the majority of actions should not incur remedial or punitive action, there will be some situations where such action is necessary. A rule of thumb is to use the 'substitution test' whereby if, under similar circumstances, another individual who was similarly trained and experienced would probably have made the same error, then punitive action is generally inappropriate. Each organisation should establish a code of practice, and publish this to employees.

3.1.4. An unpremeditated or inadvertent lapse should not incur any punitive action, but a breach of professionalism may do so. As a guideline, individuals should not attract punitive action unless:

a) The act was intended to cause deliberate harm or damage.
b) The person concerned does not have a constructive attitude towards complying with safe operating procedures.
c) The person concerned knowingly violated procedures that were readily available, workable, intelligible and correct.
d) The person concerned has been involved previously in similar lapses.
e) The person concerned has attempted to hide their lapse or part in a mishap.
f) The act was the result of a substantial disregard for safety.
   "Substantial disregard", for this purpose, means:
   -In the case of a certification authorisation holder (e.g. licensed engineer or Certifying Staff) the act or failure to act was a substantial deviation from the degree of care, judgement and responsibility reasonably expected of such a person.
   -In the case of a person holding no maintenance certification responsibility, the act or failure to act was a substantial deviation for the degree of care and diligence expected of a reasonable person in those circumstances.

3.1.5. The degree of culpability would vary depending on any mitigating circumstances that are identified as a result of the occurrence investigation. It follows that any action taken by the organisation would also be on a sliding scale varying from corrective measures such as re-training through to dismissal of the individual.

3.1.6 Organisations should publish their disciplinary policy, making it known to all employees.

3.2 Processes for reporting occurrences

3.2.1 The reporting mechanism should be made as easy as possible for reportees, requesting as much key information as is necessary whilst not placing an undue burden upon reportees to give too much detail. Avoid requesting unnecessary information. Avoid unnecessary duplication of forms. The reporting mechanism should be as flexible as possible to encourage employees to report (eg. via free-text letter, structured paper forms, via computer, via e-mail, via phone, face-to-face, etc), whilst taking into account the requirements of those who may need to investigate the incident or analyse the data. Inevitably a compromise will be necessary.

3.2.2. It is likely that the reporting mechanism will already be prescribed, partially or wholly, by the existing mandatory reporting requirements or by an existing company reporting scheme.

3.2.3 Reporting should be confidential but not anonymous, since it may be necessary to contact the reportee to obtain more information about the occurrence.

3.2.4 Further guidance as to appropriate mechanisms for reporting, and how to ensure confidentiality, may be obtained from various sources, including organisations which have successful schemes in place and from the Global Aviation Information Network (GAIN) programme (www.gainweb.org)

3.3 Processes for recording occurrences

3.3.1 There are numerous processes and tools in existence to assist with the recording of occurrence data. These generally involve some form of classification scheme or taxonomy, such that the information may be recorded in a structured fashion. These range from processes which record just basic data, such as date, time, location, etc., leaving the remaining data in free text form, to processes where there are many specific categories and keywords, with all the data being classified according to a rigid structure.

3.3.2 Existing schemes for general occurrence data recording include: ICAO's ADREP, ECCAIRS, UK CAA's MORS, USA's ASRS, UK's CHIRP, etc. Existing schemes for recording of maintenance-related occurrences include: MEDA, the ADAMS classification scheme, etc.

3.3.3 When choosing a process, organisations should take into account many factors such as:

a) is one general process, suitable for recording all occurrences, required?
b) what level of detail of recording is necessary?
c) is compatibility with any other scheme (eg. NAA) necessary?
d) analysis needs - what you want to get out may dictate how you code the data in the first place
e) links with other company processes, eg. health and safety monitoring, Quality Assurance, etc.

f) existing products/ tools, and their cost.

3.3.4 The prime criterion for the selection of an occurrence recording process should always be to enable an organisation to better understand safety hazards in order to be able to better control the risks.

3.4 Investigation of occurrences

3.4.1 The reporting scheme should encourage reportees to try to identify causes and contributory factors, but further investigation will be necessary in some cases. Ideally, all those occurrences for which the cause or contributory factors are not known, should be investigated. However, this may be too resource intensive, so an organisation may wish to set certain criteria, usually related to the significance of the incident, to determine which occurrences are investigated.

3.4.2 Investigation processes can vary considerably in depth and nature. Organisations are encouraged to adopt the MEDA investigation process as a model, since this is the most widely used process in the maintenance industry currently. Further information can be obtained from the "Human Factors and Aircraft Maintenance Handbook[1]".

3.5 Data analysis

3.5.1 Analysis of occurrence data is encouraged in order to better identify patterns of causal or contributory factors, and to determine trends over time. An electronic database can assist greatly in this process.

3.5.2 Various analysis tools are available. Further information can be obtained from the "Human Factors and Aircraft Maintenance Handbook".

3.6 Managing identified hazards

3.6.1 Once hazards are identified (including both actual and potential hazards), a risk assessment should be made of the causes and contributory factors, and a decision made as to whether action is required. Action may be in the form of a change (eg. to a procedure, issue of a notice, personnel action, etc) or merely monitoring the situation to determine that the risk is controlled. Changes should address both the root causes of hazards and the detection and trapping of problems before they can jeopardize flight safety. Actions which are inappropriate to the cause of the problem (eg. 'blame and train') may result in the ORS losing credibility among staff. The occurrence management process should be closed-loop in order to ensure that actions are identified and carried out.

3.6.2 An ORS should record actions taken in respect of previous occurrences, so that managers may look at the effectiveness (or otherwise) of the remedial action(s) in the event of a repetition of an occurrence. Alternative action may be appropriate if the remedial action has previously been ineffective.

3.7 Feedback

[1] Te Human Factors and Aircraft Maintenance Handbook was produced by the CAA in July 2000, and was the precursor to CAP 716. The handbook is no longer available.

3.7.1 Feedback should be given to the workforce and to original reportees concerning actions, to encourage continued future reporting. A magazine can be an effective way of providing feedback to the workforce in general, although care needs to be taken not to breach confidentiality and to disidentify occurrences. The most effective feedback is that which shows that something has been changed for the better as the result of an occurrence report or investigation.

3.8 Sharing of results

3.8.1 Information should be effectively promulgated to those individuals and organisations who may need to act upon the results, including own employees, contracted staff, sub-contracted organisations, operators, suppliers, manufacturers and regulators.

3.8.2 ACJ 20X8 addresses data exchange between maintenance organisations and manufacturers & operators.

3.8.3 Organisations are encouraged to share their occurrence analysis results with other maintenance organisations.. However, it is appreciated that some information in an occurrence database may be considered sensitive to the organisation affected, and may need to be dis-identified before being shared with other organisations.

3.8.4 Information sharing may be accomplished on an informal or formal basis, and can range from regular discussions between organisations concerning possible common problems, to electronic data exchange arrangements, whereby all the organisations who have agreed to exchange data can look at one another's databases (usually at a level where confidential details are disidentified). BA's Safety Information Exchange (SIE) is one such example.

3.8.5 Further information concerning data exchange can be found in the "Human Factors and Aircraft Maintenance Handbook", or obtained from Global Aviation Information Network (GAIN) (www.gainweb.org)

4. Applicability according to size of organisation

4.1 All the principles described in this Guidance Material are applicable to all JAR-145 approved organisations. However, it is recognised that the mechanisms to enable these principles to be put into practice may differ in terms of their appropriateness to different sized organisations. For example, it would be appropriate for a large organisation to have a computerised database, but this my not be necessary for a small organisation. The important point is to ensure that occurrences are reported, investigated, risks identified and action taken to control those risks; how this may best be accomplished may vary from organisation to organisation.

Attachment 4 - Human Factors Principles for the Design of Procedures

1 Introduction

1.1 Investigation of maintenance related incidents has shown that many procedures are poorly written or presented. Whilst it is important that the manufacturers' data is incorporated accurately within the procedures, this information can be presented well or poorly, depending upon the skill of the procedure writer and the extent to which the procedure is revised based on experience and practice.

2 The following guidelines may assist in the production and amendment of procedures:

2.1 Procedure design and changes should involve maintenance personnel who have a good working knowledge of the tasks.

2.2 All procedures, and changes to those procedures, should be validated before use where practicable

2.3 Ensure procedures are accurate, appropriate and usable, and reflect best practice

2.4 Take account the level of expertise and experience of the user; where appropriate provide an abbreviated version of the procedure for use by experienced technicians.

2.5 Take account of the environment in which they are to be used

2.6 Ensure that all key information is included without the procedure being unnecessarily complex

2.7 Where appropriate, explain the reason for the procedure.

2.8 The order of tasks and steps should reflect best practice, with the procedure clearly stating where the order of steps is critical, and where the order is optional.

2.9 If the order of steps is not already dictated, consider ordering the steps according to logic, or space (eg. working around the aircraft sequentially, as with a pilot's checklist), as opposed to alphabetical or ATA chapter order.

2.10 Group step into 'chunks' and plan for interruptions. Train staff to complete a 'chunk' of steps before allowing themselves to be interrupted, and design the procedure such that it can be marked when and where an interruption occurs

2.11 Ensure consistency in the design of procedures and use of terminology, abbreviations, references, etc.

2.12 Print should be clear, with a plain font being used (eg. Times New Roman, Arial) with a size of 12 point recommended (minimum 10 point) for text, and 14 point for headings.

2.13 Coloured paper is not recommended as it does not photocopy well. Black ink on white paper is recommended

2.14 Use of colour for primary coding should be avoided, since the colour is lost when photocopies are made. However, colour can be a useful aid to clarity, especially in diagrams and photos, if used redundantly or if not essential.

2.15 Where possible, try to ensure that a complete procedure, or chunk of information, is on one page. Where a procedure runs to more than one page, make this clear.

2.16 Use standard sized pages (A4 or A5 in Europe)

2.17 Include clear titles at the top of each page and section of the procedure. Where the procedure has been changed, highlight this change where appropriate (with a line or the letter 'R' at the side of the page), and note the revision date at the bottom of the page.

2.18 Cross referencing should be avoided where possible. This may require steps to be repeated in several places (note: the drawback of this is that any changes have to be made in several places also).

2.19 Logical flow should be clear, using a flow chart if necessary. If procedures include options and branches, care should be taken that the path through the procedure is clear, especially if the user is required to return to an earlier point in the procedure after having actioned a set of steps. This can be particularly important in troubleshooting.

2.20 Group associated steps on the page; separate non-associated steps on the page. Use blank lines or spaces appropriately.

2.21 Use emphasis (eg. italics, bold) consistently. Avoid over-use of uppercase for emphasis; lower case is easier to read. Avoid over-use of italics, reserving this for single words or short phrases only, or for notes. Boxing is useful to distinguish very important steps or chunks from less important steps or chunks

2.22 A diagram or photograph can be very useful and can communicate large amounts of information efficiently. However, care must be taken with their use, ensuring:

- it is correct (a diagram of a similar piece of equipment which is not exactly the same, can cause more confusion that help)
- it photocopies well (if photocopying is likely to take place)
- the fine detail can be read in the lighting conditions under which it will be used
- it is orientated appropriately
- it is labelled appropriately
- the diagram/photo is clearly linked with a procedure/step

2.23 Insert warnings and notes into the procedure wherever necessary, without unduly detracting from clarity, to ensure safe and accurate performance

2.24 Consider the use of warnings, cautions or notes to highlight important points and steps where errors are likely (information from the internal error management scheme should identify error-prone procedures and steps).

2.25 Distinguish between directive information, reference information, warnings, cautions, notes, procedures and methods

2.26 Use cautions and warnings directly above the text to which they refer, or, where this is inappropriate, clearly link the text and the warning or note. Use notes after the related text.

2.27 Cautions, warnings and notes must be on the same page as the text to which they refer.

2.28 Where practical, build in check boxes into the procedure to enable and encourage the user to check off steps as they are completed.

2.29 Clearly link the check box with the associated step, eg. using dotted lines.

2.30 Allow enough space if information needs to be entered

2.31 Stress the importance of clear handwriting if written information needs to be handed over to another person.

2.32 Ensure that printing and copy quality is good, and that there are enough printers, copiers, etc.

2.33 Provide training on the use of technology to access and print procedures and maintenance data.

Attachment 5 Minimising the Occurrence of Fatigue

1 Introduction

Approved Maintenance Organisations should take account the limitations of human performance when planning maintenance tasks.

Some specific guidance on how to minimise the fatigue of shift personnel is provided below:.

2. Shift personnel fatigue may be minimised by:

- Avoiding excessive working hours
- Allowing as much regular night sleep as possible;
- Minimising sleep loss;
- Giving the opportunity for extended rest when night sleep has been disrupted;
- Taking into account reduced physical and mental capacity at night;
- Taking into account individual circumstances;
- Providing organisational support services;
- Giving the opportunity for recovery.
- Rotating shifts toward the biological day, i.e., rotate to later rather than earlier shifts.
- Minimising night shifts through creative scheduling
- Providing longer rest periods following night shifts
- Within a week providing longer continuous rest periods when the week includes more than 2 night shifts

3. The impact of fatigue may be minimised by:

- Allocating more critical tasks during day shifts when staff are likely to be more alert
- Ensuring that appropriate checks are carried out after night shift work
- Breaking up lengthy repetitive tasks into smaller tasks, with breaks in between

Attachment 6 - Syllabus for Initial Maintenance Human Factors Training

General / Introduction to human factors
Need to address Human Factors
Statistics
Incidents

Safety Culture / Organisational factors
Human Error
Error models and theories
Types of errors in maintenance tasks
Violations
Implications of errors
Avoiding and managing errors
Human Reliability

Human Performance & Limitations
Vision
Hearing
Information-Processing
Attention and Perception
Situational awareness
Memory
Claustrophobia and physical access
Motivation
Fitness/Health
Stress
Workload management
Fatigue
Alcohol, medication, drugs
Physical work
Repetitive tasks / complacency

Environment
Peer pressure
Stressors
Time pressure and deadlines
Workload
Shift Work
Noise and fumes
Illumination
Climate and temperature
Motion and vibration
Complex systems
Hazards in the workplace
Lack of manpower
Distractions and interruptions

Procedures, Information, Tools and Practices
Visual Inspection
Work logging and recording
Procedure – practice / mismatch / Norms
Technical documentation – access and quality

Communication
Shift / Task Handover
Dissemination of information
Cultural differences

Teamwork
Responsibility
Management, supervision and leadership
Decision making

Professionalism and integrity
Keeping up to date; currency
Error provoking behaviour
Assertiveness

Organisation's HF Program
Reporting errors
Disciplinary policy
Error investigation
Action to address problems
Feedback

Attachment 7 Detailed Guidance on Human Factors Training

1. Introduction

1.1 The JAA Maintenance Human Factors Working Group proposed to include in JAR 145 a Human Factors training syllabus intended for all maintenance organisations. This syllabus was left intentionally very general in order to provide the necessary flexibility to the maintenance organisation to adapt it to its own size and scope of work. Furthermore it was considered that training on human factors being a new subject for the biggest part of the maintenance industry, experience should be first gained on the issue before making a prescriptive requirement. On the other end, it is acknowledged that additional guidance is certainly needed to develop an effective maintenance human factors training programme. This document includes such a guidance, but it is recommended to use it with the necessary flexibility during the first years of implementation of the requirement. This means that deviation from this guidance material should be accepted if appropriate justifications (size, scope of the organisation, etc..) are provided.

1.2 JAR 66 already includes a requirement for examination on Human Factors for applicant to a JAR 66 Aircraft Maintenance Licence (AML). It should be noted that while JAR 66 does not include any training requirement but only examination requirement on Maintenance Human Factors, those applicant to a JAR 66 AML trained by a JAR 147 approved training organisation would have undergo a training course on Maintenance Human Factors. This document includes a proposal on possible credits against JAR 145 Human Factors training that could be granted to JAR 66 AML holder. The Working Group proposes that examination credits against JAR 66 Appendix 1 Module 9 be granted to those applicant already trained on Maintenance Human Factors in accordance with this Guidance Material.

1.3 Finally this document provides additional guidance on which categories of maintenance personnel should undergo Human Factors training, training methods, training duration and requirements for trainers

2. Aim and objectives of Maintenance Human Factors training

2.1 The aim of Human Factors training is *to increase safety, quality and efficiency in aircraft maintenance operations by reducing human error and its impact in maintenance activities*. This is obtained through the integration of appropriate categories of maintenance personnel's technical knowledge and skills with basic human factors knowledge and skills and promotion of a positive attitude towards safety.

2.2 The objectives of Human Factors training are:

- To enhance maintenance personnel's' awareness of individual and organisational human factors issues, both positive and negative, that may affect airworthiness.
- To develop human factors skills (such as communication, effective teamwork, task management, situational awareness, writing of procedures) as appropriate to the job, in order to make a positive impact on the safety and efficiency of maintenance operations.
- To encourage a positive attitude towards safety, and to discourage unsafe behaviour and practices.

3. Categories of staff to be trained on Maintenance Human Factors.

3.1 Categories of staff to be trained on Maintenance Human Factors include all personnel of a JAR 145 approved maintenance organisation whose work has a direct or indirect affect on the safety of the aircraft or compliance with JAR 145; this means, but not exclusively, the following categories of personnel:

(a) Post-holders, managers, supervisors
(b) Certifying staff, technicians, and mechanics.
(c) Planners, engineers,
(d) Quality control/assurance staff
(e) Specialised services staff
(f) Human factors staff/ Human factors trainers
(g) Store department staff, Purchasing dept. staff
(h) Ground equipment operators
(i) Contract staff in the above categories

4. Duration of training

4.1 The duration of training will vary depending on the category of personnel involved, for example a typical training course duration would range from 1 day for managers and up to 2-3 days for certifying staff.

4.2 Although training courses may be tailored for certain categories of personnel, consideration should also be given to the benefits of having combination of personnel from different functional groups during training sessions.

5. Continuation training

Continuation training may take the form of a dedicated course or, alternatively, may be integrated into other training or company processes.

The aim of the continuation training is to:

(a) Refresh those topics of the Human Factors Training Syllabus that are most significant for the organisation;
(b) Further develop skills (communication, team work, task management, situational awareness, etc) as appropriate to the job;
(c) Make staff aware of human factors issues identified from internal or external analysis of incidents/ occurrences, including instances where staff failed to follow procedures and the reasons why particular procedures are not always followed, reinforcement of the need to follow procedures and the need to ensure that incomplete or incorrect procedures are identified to the company in order that they can be corrected. This does not preclude the possible need to carry out a quality audit of such procedures.

6. Requirements for trainers.

6.1 Human Factors training shall be conducted by at least one Human Factors trainer nominated by the Approved Maintenance Organisation, who may be assisted by experts in order to address specific areas. Trainers should meet the following requirements:

(a) Have attended an acceptable Human Factors training course that covers the JAR 145 initial training syllabus,

(b) Have received additional instruction in training and facilitation techniques,

(c) Have worked for at least 3 years for a maintenance organisation, in the case of continuation training.

6.2 Training could be provided by either a trainer employed by the organisation or by trainers outside the organisation, although training is likely to be most effective if it is tailored to the specific needs and problems of one's own organisation and the instructor is someone familiar with the needs and problems of that organisation.

7. Training methods

7.1 Consideration should be given to the use of different training methods and tools including classroom training, group discussions, accident/ incident analysis, case studies from one's own organisation, video, role-play exercises, teamwork exercises etc

8. Training credits

8.1 A requirement already exists within JAR 66 to demonstrate knowledge of the elements included within the Module 9 (human factors) syllabus. This is tested by means of examination.

8.1.1 The concern is that the emphasis within JAR 66 Module 9 will be upon those aspects of human factors which can be examined, rather than upon the organisational and safety culture aspects of human factors which are more important to safety in a maintenance organisation.

8.1.2 Accordingly it is considered that an appreciation of human factors can only be obtained by training, ideally within the context of the organisation within which the people work.

8.1.3 It is not the intention of either JAR 66 or JAR 145 to have unnecessary overlap in terms of human factors training, therefore 'credits' should offered whereby:

(a) personnel having been certified under a JAR66 license incorporating Module 9 (human factors) only after having received human factors training within a JAR147 organisation, are exempted from those modules common to the JAR66 module 9 syllabus and the JAR145 Human Factors training syllabus.

(b) personnel having been certified under a JAR66 license incorporating Module 9 (human factors) who have not received human factors training within a JAR147 organisation, are required to complete JAR 145 initial human factors training, without any exemptions.

(c) personnel having completed a JAR 145 human factors course meeting the criteria of this Guidance Material, are exempted from the JAR 66 Module 9 examination.

(d) personnel having completed a human factors course below the criteria of this Guidance Material, are not exempted from the JAR 66 Module 9 examination.

9. Training Syllabus for Human Factors

9.1 Introduction

9.1.1 Taking into consideration the general training objectives, the Training Syllabus table identifies the topics and subtopics to be addressed during the Human Factors training (Appendix T, column 2 & 3).

9.1.2 For each training topic specific objectives are defined (Appendix T, column 4). These objectives are specified in term of knowledge (to know), skills (how to do), attitude (how to be) according to the principle that effective Human Factors training, besides improving the knowledge of the trainees, should foster behavioural skill developments and attitude changes:

a) Knowledge objectives (K), knowledge and understanding of factual information that should be acquired during the training;
b) Skill objectives (S), development of skills which may be applied in the workplace, eg., problem solving, decision making, communication, team-work, stress coping strategies, workload management.
c) Attitude objectives (A), development, change or re-inforcement of a safety conscious attitude, eg., following procedures, using reference data rather than relying upon memory, checking work rather than assuming that it has been done properly, resisting pressure to cut corners when under time constraints, etc.

9.1.3 The last column (Appendix T, column 5) gives examples related to the objectives which organisations may wish to incorporate in their human factors training.

9.1.4 The Training syllabus refers to Initial Human Factors training .For continuation training, Topics and related Objectives can be selected taking into consideration the criteria given in the AMC.

9.1.5 The maintenance organisation may combine, divide, change the order of any subject of the syllabus to suit its own needs, so long as all subjects are covered to a level of detail appropriate to the organisation and its personnel.

9.1.6 Some of the topics may be covered in separate training (health and safety, management, supervisory skills, etc.) in which case duplication of training is not necessary.

9.1.7 Where possible, practical illustrations and examples should be used, especially accident and incident reports

9.1.8 Topics should be related to existing legislation, where relevant (JAA/NAA/EU)

9.1.9 Topics should be related to existing guidance/ advisory material, where relevant (eg. ICAO HF Digests and Training Manual, UKCAA AWN47)

9.1.10 Topics should be related to maintenance engineering where possible; too much unrelated theory should be avoided.

Attachment 7 cont'd. Detailed Guidance on Human Factors Training

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
1	General / Introduction to human factors		K: Achieve a basic understanding of the meaning of the term "human factors" K: Recognize the contribution of human factors to aviation accidents K: Understand the goal of human factors training	• See ICAO HF Digests, including ICAO circular 253 • Definition(s) of human factors • ICAO SHELL model • "Dirty dozen" as a concept. • Well-known accidents where maintenance human factors has been the cause • Company incidents where HF has been the cause
1.1		Need to address Human Factors	A: Appreciate the need to understand and address human factors	• The statistic that 80% of accidents are due to human error • US statistics which indicate that 50% of recent accidents have featured maintenance HF problems • Human factors within the control of the individual, and those which are not.
1.2		Statistics	K: Become reasonably familiar with some of the well-known incidents and studies of incident data, where human factors have contributed. Understand why these incidents occurred	• See ICAO Circular 253 • Boeing, Pratt & Whitney in-flight shut-down causes, Reason/Continental - 89-91, UKCAA 1992, etc.
1.3		Incidents		• See ICAO Circular 253 • Accidents and incidents where maintenance human factors has been the cause: • Aloha, 1988 • BAC1-11 windscreen, 1990 • A320 locked spoiler, 1993 • B737-400 oil loss, 1995 • B747 engine drop, Narita, 1994 • NTSB accident reports as referenced on the *hfskyway* website
2	Safety Culture / Organisational factors		K: Achieve a good understanding of the concept of "safety culture" K: Understand what is meant by the "organisational aspects" of human factors A: Appreciate the vital importance of a good safety culture,. K: Identify the elements of a good safety culture	• Definition of "culture" and "safety culture" • Reason, J: The elements of a good safety culture: • ·Commitment from senior level • ·A just culture • ·A good error reporting scheme • ·An effective Maintenance Error Management Scheme (MEMS) • ·Flexibility • ·Training investment • ·Willingness to learn and to change if necessary • ·Respect for the workforce

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
3	Human Error		K: Appreciate that human error cannot be totally eliminated; it must be controlled K: Understand the different types of errors, their implications, avoiding and managing error K: Recognize where the individual is most prone to error, A: Guard against error	• Definition of human error • Types of errors in maintenance engineering - Accidents and incidents to illustrate. • Causes of errors • How to reduce errors and mitigate their consequences
3.1		Error models and theories	K: Achieve a reasonable practical knowledge of the main error models and theories	• A reasonable practical knowledge of the main error models (SRK, GEMS, Reason's slips, lapses, mistakes & violations), and how this knowledge can help in a practical context (eg. investigation of incidents)
3.2		Types of errors in maintenance tasks	K: Understand the main error types (eg. slips, lapses, mistakes) and how these differ from violations	• Types of errors which have contributed to accidents and incidents in the past. Well-known analysis studies, eg. Boeing, Pratt & Whitney in-flight shut-down causes, Reason/Continental - 89-91, UKCAA 1992, etc. • Types of errors in maintenance engineering - Accidents and incidents to illustrate. • Causes of errors • MEDA categories
3.3		Violations	K: Understand the different types and causes of violations A: Avoid violating procedures and rules A: Strive towards eliminating situations which may provoke violations	• Types of violations (J Reason) • The different types of violations, eg. routine, situational, optimising. • Violation provoking situations, eg.poor procedures which do not reflect best practice, inadequate time to do the job, inadequate manpower, etc
3.4		Implications of errors	K: Achieve a good understanding of well-known incidents in terms of errors leading to the incidents A: Appeciate that it is not errors themselves which are the problem, but their consequences if undetected or uncorrected	• Accidents, incidents, learning opportunities; errors detected/ not detected • Accidents, incidents, learning opportunities; errors detected/ not detected • What *could* have happened...
3.5		Avoiding and managing errors	K: Understand the different ways of reducing errors and mitigating their consequences	• Error management = error containment + error reduction. • Error management techniques • Practical methods for error reduction

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
3.6		Human Reliability	K: Basic understanding of the main human reliability concepts, and how these relate to risk assessment Note: this may only be applicable to managers	• Concepts of human reliability • Human Reliability Techniques, eg. HAZOP, MORT, HTA, THERP, etc. · • Quantitative and qualitative techniques • Human reliability in the context of risk assessment
4	Human Performance & Limitations		K: Recognize the effect of physical limitations and environmental factors on human performance A: Appreciate that humans are fallible K. Achieve basic knowledge of when and where humans are vulnerable to error A: Recognize where self or others suffer, and ensure this does not jeopardize personal or aviation safety	• Many texts have been written on human performance & limitations for pilots - some of this material will also be relevant for maintenance personnel
4.1		Vision	K: Understand how vision, and visual limitations, affects your job A: Recognise the need to have adequate (corrected) vision for the task and circumstances	• Practical guidance on vision standards associated with jobs/ tasks (eg. avionics, driving on airports, close visual inspection, etc), and in certain conditions (eg. low light conditions)
4.2		Hearing	K: Be aware of the health and safety best practice regarding noise and hearing A: Appreciate that hearing is not necessarily understanding	• Practical guidance on the dangers of exposure to loud noise, and its effect on hearing, both temporary and permanent
4.3		Information-Processing	K: Obtain a basic familiarity with the key terms used to describe information processing (ie. perception, attention, memory)	• An overview of the information process – perception, attention, memory
4.4		Attention and Perception	K: Achieve a basic understanding of the meaning of attention and perception	• Models and theories of attention; single channel theory, cocktail party effect, etc. • Expectation - dangers of "seeing what you want to see" & "hearing what you want to hear" • Boredom and attention
4.5		Situational awareness	K: Understand the dimension of situational awareness S: Develop ways of improving situational awareness	• Concept of situational awareness in a maintenance engineering context. • Stages of situational awareness "Perception, understanding of the significance of what you see; determination of future implications."

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
4.6		Memory	K: Achieve a basic understanding of the different types of memory (sensory, short term, working, long-term) and how these may affect you at work. A: Appreciate that memory is fallible and should not be relied upon.	• The fallibility of human memory - sensory, short term, working, long-term. • Accidents and incidents where individuals have relied upon memory, rather than consulting written information.
4.7		Claustrophobia and physical access	A: Appreciate that claustrophobia, fear of heights, etc., may affect the performance of some individuals.	• Concepts of claustrophobia & fear of heights • Difficult physical access and awkward working positions - what can be done to help (eg. Boeing work, design for better access, etc.)
4.8		Motivation	K: Understand what motivates people and what de-motivates people, in a maintenance engineering context A: Appreciate the need to avoid misdirected motivation	• Main theories of motivation, eg. Maslow, Herzberg • Accidents/ incidents where someone has failed to apply correct procedures, but with good intentions • Misdirected motivation - the desire to cut corners in order to get things done
4.9		Fitness/Health	A: Develop willingness to admit when feeling unwell, and taking steps to ensure this does not affect safety	• How can illness, poor health, poor fitness adversely affect work performance and affect safety. • Practical guidance as to what an individual can do if feeling unwell, eg. ask to swap to a less demanding task, ask a colleague to check performance, take medication (but be aware of its effects), stay at home, etc
4.10		Stress	K: Recognize the basic concepts and symptoms of stress S: Develop different techniques and positive attitudes to cope with stress	• The difference between stress and stressors • Effects of stress on human performance; individual differences • Concepts of arousal; Yerkes-Dodson curve; one person's -ve stress is another person's +ve stress • Signs of stress • Reactions to stress - denial, dealing with minor tasks instead, deferring, etc
4.11		Workload management	K: Recognise the need to manage workload S: Develop methods to manage workload	• Accidents or incidents illustrating the consequences of poorly managed workload

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
4.12		Fatigue	K: Understand how fatigue can affect your performance, especially during shiftwork or when working long hours S: Develop ways of managing fatigue A: Develop a personal integrity not to work on safety critical tasks when unduly fatigued	• Concepts of sleep, fatigue and circadian rhythms • Effects on performance of sleep deprivation, interrupted sleep, inadequate REM sleep, poor placement of sleep, etc. • Equating fatigue to alcohol intake (see work by Drew Dawson) • Incidents where fatigue has been cited as a factor, eg. CHIRP reports
4.13		Alcohol, medication, drugs	A: Appreciate that alcohol, drugs and medication can affect your performance	• Guidance on the effects on performance, after taking alcohol, medication or illicit drugs (see UKCAA AWN47)
4.14		Physical work	K: Understand the effects of sustained physical work on overall performance, especially cognitive performance, in a maintenance engineering environment	
4.15		Repetitive tasks / complacency	K: Be aware of examples of incidents where repetitive tasks and complacency have been a factor S: Develop ways of avoiding complacency	• Types of repetitive tasks where complacency might be a factor; possible reasons; how to avoid it (eg. by having breaks, by increased probability of detecting a problem, by training, by selection, etc) • Accidents and incidents involving repetitive tasks (eg, visual inspection of rivets) • Techniques of developing to deal with complacency
5	Environment		K: Achieve a basic appreciation of how the physical and social environment can affect on human performance	• Introduction to how the physical and social environment can affect work performance, & personal and aviation safety. • Examples of accidents/ incidents where the environment was a factor (eg. Narita 747 engine drop)
5.1		Peer pressure	A: Appreciate the · importance of sticking to the rules, procedures and documents even if others aren't · importance of personal integrity · importance of avoiding placing peer pressure on others S: Develop assertive behaviour appropriate to the job	• Concepts of peer pressure and conformity; concept of norms Examples of accident/ incidents where a bad norm was a factor, e.g. (i)Unwillingness to use written information because it is seen as a lack of technical knowledge, (ii) Lack of individual confidence, (iii) Not following safe operation procedures because others don't follow them

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
5.2		Stressors	K: Achieve a basic understanding of the concepts of stress and stressors, as related to the work environment	• What types of environmental stressors are there • Causes of stress; work, domestic, environmental, etc
5.3		Time pressure and deadlines	K: Recognise the dangers of · cutting corners · applying inappropriate deadlines · self-imposed, supervisor and management time pressures S: develop assertive behaviour appropriate to the job	• Accidents/ incidents where time pressures have been a factor, eg. BAC1-11 windscreen accident in 1990. • Recognition that commercial pressure exists in some areas. Stress the importance of not letting this interfere with the job, or doing things properly.
5.4		Workload	K: Understand the basic contributors to workload S: Develop planning and organising skills.	• What constitutes workload; relationship between workload and stress; relationship between workload and arousal; overload and underload • Causes of high workload (eg. unrealistic deadlines, undermanning) and how these might be dealt with
5.5		Shift Work	K: Understand the basic concept of circadian rhythms as this relates to shiftwork. K: Be familiar with best practice regarding working hours and shift patterns S: Develop strategies to manage shiftwork.	• Circadian rhythms, sleep and shiftwork - relationships and effects on performance. • Circadian 'dips', and how to combat them • Shift patterns - pros and cons • Research concerning shiftwork and shift patterns • Good practices for shiftworkers - guidance concerning sleep, meals, etc. • EU Working Time Directive, and how it affects maintenance staff & shiftworkers
5.6		Noise and fumes	K: Be aware of the health and safety guidance concerning noise and fumes	• General effects of noise on performance (the issue is complex; do not go into too much detail) • Effect of noise on hearing - temporary or permanent damage • How to reduce noise (eg. noise insulation) and how protect hearing against noise (eg. ear muffs) • Effects of fumes on performance
5.7		Illumination	K: Be aware of the effects of lighting upon performance, especially visual performance	• Guidance as to what illuminations are appropriate for various tasks
5.8		Climate and temperature	K: Be aware of the effects of climate and temperature upon performance	• Effects of extremes in temperature and humidity upon performance; practical guidance as to what can be done to help, where such extremes are unavoidable

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
5.9		Motion and vibration	K: Be aware of the health and safety guidance concerning motion and vibration	• Examples where motion and vibration affect performance e.g. engine ground running, riveting, use of moving platforms.
5.10		Complex systems	A: Be aware of the implications of your actions upon other parts of the system	• Examples that steps in procedures which may not seem particularly important, may have implications elsewhere in the system of which you are not aware.
5.11		Hazards in the workplace	K: Be aware of the health and safety guidance concerning hazards in the workplace	• Overlap areas between Health and Safety principles and National legislation, and Human Factors. • The need to remain calm and collected in a difficult situation. Examples may include engine fires, surges during ground runs, personal injury or danger when operating aircraft systems.
5.12		Lack of manpower	K: Understand how take into consideration the available manpower when (i) scheduling/planning work. (ii) performing a task Note: this topic may not be applicable for all staff	• Accidents and incidents where lack of manpower was a contributing factor. • Importance of reviewing the manhour plan
5.13		Distractions and interruptions	S: Develop ways of managing distractions and interruptions	• Recognition that distractions and interruptions will always exist • Stress the importance of recording work as you do it, just in case you are interrupted. • Go a few steps backwards in a checklist after returning to a job

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
6	Procedures, Information, Tools and Practices		A: Appreciate the importance of having available the appropriate tools and procedures A: Appreciate the importance of following the procedures and using the appropriate tools. A: Appreciate the importance of checking work before signing it off A: Appreciate the need of reporting irregularities in procedures or documentation.	• Identify the dangers of people cutting corners if tools are not available, procedures are difficult to use, information difficult to access, etc • Stress that perceived short-term benefits are usually outweighed by actual long-term dis-benefits. • Formal practices vs 'custom and practice' - stress that the two should be the same • Accidents/ incidents where problems have occurred due to unavailability of information, poor procedures, lack of appropriate tools, etc. • Keeping maintenance information up to date: • Looking for updates, rather than assuming all changes have been incorporated into one source • Notifying the appropriate person/ department of any inaccuracies/ ambiguities in maintenance information • Sign-Offs: • The responsibilties for sign-offs • Accidents/ incidents where work was signed off without being properly checked • Principles of good planning; the importance of good communication and feedback between planners and 'front-line' maintenance staff.
6.1		Visual Inspection	K: Understand the factors that affect visual inspections. S: Develop skills to improve visual inspections.	• Definition; differences between visual inspection and NDI/NDT, and human factors implications - awareness • Vision requirements for NDI - overview • What is meant by type 1 errors and type 2 errors • Accidents and incidents caused by poor visual inspection - eg Aloha Airlines • Factors affecting visual inspection, eg. age, vision standard, lighting, torch beam, task repetitiveness & monotony, task breaks, probability of detecting a fault, attitude, training, visual search pattern, etc.
6.2		Work logging and recording	A: Appreciate the importance of correct logging and recording of work	• Good practices concerning work logging and recording, and job aids/ good task card design, which can help • Accidents/ incidents where poor logging was a cause - plenty to choose from

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
6.3		Procedure – practice / mismatch / Norms	A: Be aware that norms exist and that it can be dangerous to follow them. K: Be aware of instances where the procedures, practices or norms have been wrong.	• The concept of norms; differences between a norm and a habit. • Positive and negative norms • Formal practices & policies vs 'custom and practice' - stress that the two should be the same • The importance of providing the technician with usable procedures; the dangers of people cutting corners if procedures are difficult to use. • Accidents/ incidents where problems have occurred due to poor procedures, procedure/ practice mismatches or bad norm.
6.5		Technical documentation – access and quality	A: Appreciate the importance of having a good standard of technical documentation in terms of access and quality. .S: Learn how to write good procedures which reflect best practice (note: this may not be applicable to all staff) S: Learn how to validate procedures (note: this may not be applicable to all staff)	• Overview of good and bad examples of technical documentation • Use of standardized English where appropriate • Importance of commonality of terms and abbreviations, especially where technicians are working on different types of a/c, eg. Boeing and Airbus. • Formats of information (eg. paper, photocopies, microfiche, computerised, etc) and their pros and cons. • Accidents/ incidents involving poor access to technical documentation, eg. Narita 747 engine drop.
7	Communicatio n		K: Recognize the need for an effective communication at all levels and mediums. K: Understand the basic principles of communication. S: Develop skills for correct verbal and written communication appropriate to the job and context.	• Principles of good written communication; need for important information (eg. on shift handover) to be communicated both verbally and in writing. • OJT + classroom exercises, eg. domino exercise • Communication within and between teams
7.1		Shift / Task Handover	K: Detailed knowledge of some incidents where a poor handover has been a contributory factor A: Appreciation of the importance of good handovers S: Learn how to carry out a good handover	• Principles of good shift/task handover; verbal and written information exchange - built in redundancy; clear, thorough communication; need for shift overlap; etc. • OTJ + classroom exercises, eg. domino exercise • Accidents/ incidents involving shift handover deficiencies, eg. A320 locked spoiler incident, 1993.

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
7.2		Dissemination of information	A: Appreciate the importance of information being kept up-to-date, and being accessible by those who need it; important/urgent information getting to the people who need it	• Accidents/ incidents caused by poor information management
7.3		Cultural differences	A: Appreciate that cultural differences can affect communication.	• Cultural differences between countries; between companies; between types of maintenance (line & base); between shifts; between individuals, between pilots and maintenance personnel • Hofstede's work – differences between National cultures - but try to relate this to maintenance engineering.
8	Teamwork		K: Understand the general principles of teamwork. A: Accept the benefits of teamwork. S: Develop skills for effective teamwork . A: Believe that maintenance personnel, flight crew, cabin crew, operations personnel, planners etc should work together as effectively as possible.	• Concepts of Maintenance Resource management (MRM) • Where human factors and teamwork relate to maintenance • Effective work relationships • Motivation • Running meetings • Conflict management
8.1		Responsibility	A: Encourage a team concept, but without devolving or degrading individual responsibility	
8.2		Management, supervision and leadership	K: Understand the role of managers, supervisors and leaders in teamwork. S: Develop management skills for appropriate personnel.	• Difficulties associated with doing both a management/ supervisory job, and 'hands-on' engineering • Incidents involving supervisors, and reasons why, eg. B737-400 oil loss incident. • Delegation, prioritisation of tasks • Leadership styles – use of authority or assertiveness
8.3		Decision making	S: Develop decision making skills based on good situational awareness and consultation where appropriate	• Explain the different phases of the decision making process.

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
9	Professionalism and integrity		K: Understand what is expected from individuals in terms of professionalism, integrity, and personal responsibility. A: Understand one's own responsibility to keep aviation safety standards high, and put this into practice at all times	• The general characteristics of a professional and how these fit to the aircraft maintenance profession • The contribution of aviation maintenance personnel to aviation safety • Abiding by rules and procedures, refusing to succumb to pressure, etc • Responsibilities of individuals, (eg. signing off work, inspecting tasks, reporting non-conformities, etc.) • Examples where cooperation between different aviation trades has contributed to the avoidance of incidents/accidents
9.1		Keeping up to date; currency	A: Accept the personal responsibility to keep up to date with necessary knowledge and information	• All personnel should read the applicable information from the organization such as revisions, memos, etc.
9.2		Error provoking behaviour	K: Achieve a good understanding of what constitutes error provoking behaviour. A: Appreciate the importance of avoiding the type of behaviour which is likely to provoke errors	• Give examples of error provoking behaviours (eg. cutting corners, failing to consult information, relying upon memory, working when fatigued, etc.) and strategies to avoid them.
9.3		Assertiveness	A: Appreciate the importance of being assertive.	• Give examples of assertive behaviour , e.g. refusing to sign off a job if it has not been completed properly, despite pressure from more senior people to do so.
10	Organisation's HF Program		K: Achieve an depth understanding of the structure and aims of your company's HF programme. Note: if your organisation does not have all the elements of a HF programme, explain in general terms what these elements might be, ie: • Maintenance Error Management System • Links with Quality System • Links with Safety Management System • Disciplinary reporting and just culture • Top-level support • HF training for all staff • Action to address problems • Good safety culture	• Overview of the elements of your organisation's HF programme: • ·Commitment from senior level • ·Practical support from management • ·HF training for all staff • ·A just disciplinary policy • ·A good error reporting scheme • ·An effective Maintenance Error Management Scheme (MEMS), including (i)error investigation scheme (ii)analysis of problems; identification of improvements; acting upon recommendations (iii)feedback concerning problems and improvements (for guidance, see UKCAA AWN71) • ·Learning from accidents/ incidents/ previous occurrences; warning technicians of common errors/ problems so that they can guard against these; writing in warnings into the procedures

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
10.1		Reporting errors	A: Appreciate the importance of reporting incidents, errors, problems K: Understand what type of problems should be reported K: Understand the mechanisms of reporting	• Describe the reporting procedure.
10.2		Disciplinary policy	K: Understand the organisation's disciplinary policy, and the circumstances under which disciplinary action may be appropriate, and when not A: Appreciate that you will not be unfairly penalised for reporting, or assisting with investigations	• Give each employee a copy of the company's disciplinary policy. • Use case studies to illustrate the policy. • Encourage group discussions concerning the policy
10.3		Error investigation	K: Understand the mechanisms of incident investigation	• Explain what process your organisation uses, eg. MEDA • Consider using a worked example • Stress the importance of having trained investigators
10.4		Action to address problems	K: Understand the mechanisms of action to address errors	• Ensure staff are aware that reporting incidents will result in action
10.4		Feedback	K: Understand the mechanisms of feedback	• What feedback employees might expect from the MEMS. eg. company magazine, feedback to individuals involved in incidents, etc

Appendix B Definition of Human Factors

What is human factors?

Human Factors[2] as a term has to be clearly defined because when these words are used in the vernacular they are often applied to any factor related to humans. The human element is the most flexible, adaptable and valuable part of the aviation system, but it is also the most vulnerable to influences which can adversely affect its performance. Throughout the years, some three out of four accidents have resulted from less than optimum human performance. This has commonly been classified as human error.

The term "human error" can be misleading when referring to human factors in accident prevention, because although it may indicate WHERE in the system a breakdown occurs, it provides no guidance as to WHY it occurs. An error attributed to humans in the system may have been design-induced or stimulated by inadequate training, badly designed procedures or the poor concept or layout of manuals. Further, the term "human error" allows concealment of the underlying factors which must be brought to the fore if accidents are to be prevented. In fact, contemporary safety-thinking argues that human error should be the starting point rather than the stop-rule in accident investigation and prevention.

An understanding of the predictable human capabilities and limitations and the application of this understanding are the primary concerns of Human Factors. Human Factors has been progressively developed, refined and institutionalised for many decades, and is now backed by a vast store of knowledge which can be used by those concerned with enhancing the safety of the complex system which is today's civil aviation.

Some Definitions of Human Factors

Human Factors is concerned to optimise the relationship between people and their activities, by the systematic application of human sciences, integrated within the framework of systems engineering *Elwyn Edwards*
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 environmental conditions of any system. *FAA Human Factors Guide for Aviation Maintenance*

[2] ICAO Human Factors Training Manual, 1998. Doc 9683-AN/950

Human Factors and ergonomics and engineering psychology are roughly equivalent terms used for the field of science concerned with the optimisation of the relationship between people and the machines they operate through the systematic application of human sciences integrated within the framework of systems engineering. Human Factors has been more widely used in the USA, ergonomics has been more widely used outside of the USA, and engineering psychology has been more widely used in academia. *Jensen R. Opening address for the 9th International Symposium on Aviation Psychology, 1997.*
Human Factors focuses on human beings and their interaction with products, equipment, facilities, procedures, and environments used in work and every-day living. The emphasis is on human beings (as opposed to engineering, where the emphasis is more on strictly technical engineering considerations) and how the design of things influences people. Human Factors, then, seeks to change the things people use and the environments in which they use these things to better match the capabilities, limitations, and needs of people. *Human Factors in Engineering and Design, Sanders M.S. and McCormick J. McGraw-Hill*
Fitting the man to the job and the job to the man. *Chapanis*
Within the FAA, human factors entails a multidisciplinary effort to generate and compile information about human capabilities and limitations and apply that information to equipment, systems, facilities, procedures, jobs, environments, training, staffing, and personnel management for safe, comfortable, effective human performance. *FAA*
Human factors refer to environmental, organisational and job factors, and human and individual characteristics which influence behaviour at work in a way which can affect health and safety *HSE*[3]

ICAO definitions relating to human factors

Human Factors Principles: Principles which apply to aeronautical design, certification, training, operations and maintenance and which seek safe interface between the human and other system components by proper consideration to human performance. *Annex 6, part 1.*
Human performance: Human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations *Annex 6, part 1, Definitions.*

[3] HSG48

Human Factors is about people: it is about people in their working and living environments, and it is about their relationship with equipment, procedures and the environment. Just as importantly, it is about their relationships with other people. Human Factors involves the overall performance of human beings within the aviation system; it seeks to optimise people's performance through the systematic application of the human sciences, often integrated within the framework of system engineering. Its twin objectives can be seen as safety and efficiency. *ICAO HF Training Manual; Part 2, para 1.4.2.*
Human factors is essentially a multi-disciplinary field, including but not limited to: psychology, engineering, physiology, sociology and anthropometry. *ICAO HF Training Manual; Part 2, para 1.4.3.*
Human Factors has come to be concerned with diverse elements of the aviation system. These include human behaviour and performance; decision-making and other cognitive processes; the design of controls and displays; flight deck and cabin layout; communication and software aspects of computers; maps, charts and documentation; and the refinement of training. Each of these aspects demands skilled and effective human performance. *ICAO HF Training Manual; Part 2, para 1.4.4* .
Aviation Human factors is primarily oriented towards solving practical problems in the real world. As a concept, its relationship to the human sciences might well be likened to that of engineering to the physical sciences. And, just as technology links the physical sciences to various engineering applications, there are a growing number of integrated Human Factors techniques or methods; these varied and developing techniques can be applied to problems as diverse as accident investigation and the optimisation of pilot training. *ICAO HF Training Manual; Part 2, para 1.4.6.*

Models describing Human Factors

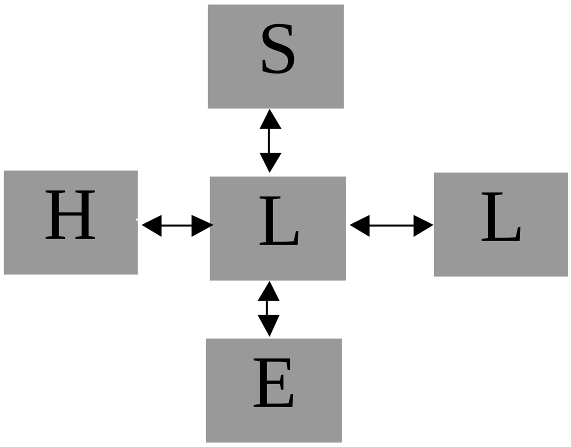
It can be helpful to use a model to aid in the understanding of human factors, or as a framework around which human factors issues can be structured. A model which is often used, particularly by ICAO[4], is the SHEL model (see Fig. 1), the name being derived from the initial letters of its components: Software (eg. maintenance procedures & documentation), Hardware (eg. design for maintenance), Environment (eg. lighting) and Liveware (ie. the person or people, including maintenance technicians & mechanics, supervisors, planners, managers, etc.).

The model shows the interfaces between the human (the 'L' in the centre box) and the other elements of the SHELL model[5], eg: interpretation of procedures, illegible manuals, poorly designed checklists, ineffective regulation, untested computer software ('S'), not enough tools, inappropriate equipment, poor aircraft design for maintainability ('H'), uncomfortable workplace, inadequate

[4] ICAO Circular 216; Fundamental Human Factors Concepts; Human Factors Digest No.1. 1989. ICAO
[5] Hawkins, F.H. Human Factors in Flight. Gower

hangar space, variable temperature, noise, poor morale, ('E'), relationships with other people, shortage of manpower, lack of supervision, lack of support from managers ('L'). However, the model also accepts that sometimes the 'L' in the centre box can stand alone, and there can be problems associated with a single individual which are not necessarily related to any of the L-S, L-H, L-E, L-L interfaces.

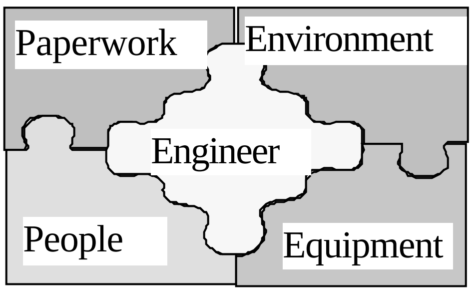
Fig A1. SHEL Model



Edwards, 1972,
modified by Hawkins, 1975

Many people use variants of the SHEL model, eg. British Airways' PEEP model (see Fig. 2), the emphasis being upon the interfaces and integration between the technician and the aspects which affect his performance.

Fig 2. BA's PEEP model: an integrated approach



PAPERWORK
-rules and procedures

ENVIRONMENT
-work area, light, heat

EQUIPMENT
-tools, buildings

PEOPLE
-colleagues, managers

One aspect cannot be changed without impacting on the other elements

The HSE use a variant of the SHELL model, which looks at the interrelationships between:

- The job (eg. task, workload, environment, displays and controls, procedures)
- The individual (eg. competence, skills, personality, attitudes, risk perception)
- The organisation (eg. culture, leadership, resources, work patterns, communication)

One approach to human factors is to look at the human being as a component within a system and to appreciate how potentially unreliable that component actually is! We cannot re-design the human being to be 100% reliable; we have to accept the fact that the human being is intrinsically unreliable. However, we can work around that unreliability by providing good training, procedures, tools, duplicate inspections, etc. We can also reduce the potential for error by improving aircraft design such that, for example, it is physically impossible to reconnect something the wrong way round. Human factors can provide guidance to enable technicians, supervisors, planners, managers, designers, regulators, etc., to apply good human factors practices and principles within their own spheres of influence.

Appendix C ICAO Standards for Human Factors in Maintenance.

In 1986 The ICAO Assembly adopted Resolution A26-9 on Flight Safety and Human Factors. As a follow-up to the Assembly Resolution, the Air Navigation Commission formulated the following objective for the task:

"To improve safety in aviation by making States more aware and responsive to the importance of human factors in civil aviation operations through the provision of practical human factors material and measures developed on the basis of experience in States, and by developing and recommending appropriate amendments to existing materials in Annexes and other documents with regard to the role of human factors in the present and future operational environments."

ICAO Annex standards apply to all ICAO signatory States, with the responsibility being upon the NAA or JAA to implement these requirements. The Annex standards and recommended practices (SARPS) relating to human factors and maintenance are listed in Tables 1, 2 and 3. The extent to which UKCAA and other NAAs, and JAA comply with the ICAO Annexe requirements should be judged by comparing current National and JAA regulations, with both the spirit and letter of the ICAO requirements and associated guidance material. Ultimately what is important is the degree to which industry practice complied with the spirit of the ICAO human factors SARPS.

Table 1. Annex 1 (Licensing) SARPS

4.2.1.2 The applicant shall have demonstrated a level of knowledge relevant to the privileges to be granted and appropriate to the responsibilities of an aircraft maintenance licence holder, in at least the following subjects: *e) Human performance relevant aircraft maintenance* *4.2.1.4 Training* *Recommendation - the applicant should have completed a course of training appropriate to the privileges to be granted.*

It is worth stating that ICAO examination in human factors is not specifically required to demonstrate compliance with Annex 1. What ICAO recommends is 'demonstration' of such knowledge.

Table 2. Annex 6 (Operations), part 1 SARPS

8.3.1.....The design and application of the operator's maintenance programme shall observe Human Factors principles. *8.7.5.4.....The training programme established by the maintenance organisation shall include training in knowledge and skills related to human performance, including co-ordination with other maintenance personnel and flight crew.*

Annex 6 Part 3 (Helicopters) contains a similar statement about the company's maintenance programme.

Table 3. ICAO guidance material on human factors

Guidance material on the application of Human Factors principles can be found in:

- ICAO. Human Factors Training Manual, Doc 9683-AN/950 (Edition 1 1998)(amendment 1, 30/9/03)
- ICAO. Human Factors Digest No. 1. Fundamental Human Factors Concepts (ICAO Circular 216-AN/131)
- ICAO. Human Factors Digest No. 6. Ergonomics. (Circular 238-AN/143) 1992
- ICAO. Human Factors Digest No. 12: Human Factors in Aircraft Maintenance and Inspection. (Circular 253-AN/151) 1995
- ICAO. Human Factors in Aviation Maintenance. Doc 9824-AN/450. (2003)
- ICAO. Human Guidelines for Safety Audits Manual. Doc 9806-AN/763. (2002)
- ICAO. Manual of Aircraft Accident and Incident Investigation Doc 9756-AN/965
- ICAO Annex 13. Aircraft Accident and Incident Investigation

Guidance material to design training programmes to develop knowledge and skills in human performance can be found in:

- ICAO. Human Factors Training Manual, Doc 9683-AN/950 (Edition 1 1998)(amendment 1, 30/9/03)
- ICAO. Human Factors Digest No. 1. Fundamental Human Factors Concepts (ICAO Circular 216-AN/131)
- ICAO. Human Factors Digest No. 2. Flight Crew Training: Cockpit Resource Management (CRM) and Line Oriented Flight Training (LOFT). (ICAO Circular 217)
- ICAO. Human Factors Digest No. 3. Training of Operational Personnel in Human Factors. 1991 (ICAO Circular 227)
- ICAO. Human Factors Digest No. 6. Ergonomics. (Circular 238-AN/143) 1992
- ICAO. Human Factors Digest No. 12: Human Factors in Aircraft Maintenance and Inspection. (Circular 253-AN/151) 1995
- ICAO. Human Factors in Aviation Maintenance. Doc 9824-AN/450. 2003

Note: The ICAO digests are now out of print, having been replaced by the ICAO Human Factors Training Manual which includes the main elements from the Digests. However, ICAO has kindly given permission to the CAA to republish the Digests under CAA cover, and some of the documents are available for free download from the CAA internet site.

During recent years, the ICAO focus has been upon the importance of the “organisational approach” and the emphasis upon the role of management in ensuring safety. When addressing the Plenary meeting of the Aviation Study Group on 16 February 2001, Dr Assad Kotaite, the President of the ICAO Council, stated:
“I suggest to you today that it is through the organisational perspective that we will break the current safety impasse in which we find ourselves. I strongly believe that the contribution of the aviation system’s management towards enhancing safety is paramount. Regulators and

airline management alike define the environment within which individuals conduct their tasks. They define the policies and procedures individuals must follow and respect. They allocate the critical resources which individuals need in order the system's safety and production goals. Lastly, when the system fails, they must thoroughly investigate these failures and take all needed remedial action to avoid repetition.
Simply put, managers play a fundamental role in defining and sustaining the safety culture of their organisation"

Appendix D Accidents, Incidents and Statistics

1. Accidents

There have been several high profile accidents and incidents which have involved maintenance human factors problems. The *hfskyway* website lists 24 NTSB accident reports of accidents where maintenance human factors problems have been the cause or a major contributory factor. In the UK, there have been three major incidents, details of which can be found on the AAIB web site (www.dft.gov.uk/aaib) Several of the major incidents and accidents where maintenance Human Factors have been a significant factor are summarised below:

NTSB/AAR-89/03. Aloha Airlines, B737-200, N73711, Hawaii, April 1988

The Aloha accident involved 18 feet of the upper cabin structure suddenly being ripped away, in flight, due to structural failure. The Boeing737 involved in this accident had been examined, as required by US regulations, by two of the engineering inspectors. One inspector had 22 years experience and the other, the chief inspector, had 33 years experience. Neither found any cracks in their inspection. Post-accident analysis determined there were over 240 cracks in the skin of this aircraft at the time of the inspection. The ensuing investigation identified many human-factors-related problems leading to the failed inspections.

NTSB/AAR-92/04. Britt Airways, (d/b/a Continental Express), EMB-120, N33701, Eagle Lake, September 1991

The EMB-120 suffered in-flight structural break up and crashed with no survivors. The accident occurred because the attaching screws on the top of the left side leading edge of the horizontal stabiliser had been removed during maintenance, leaving the leading edge/de-ice boot assembly secured to the horizontal stabiliser by only the bottom attachment screws.

The report of this accident is of particular interest to human factors because, although the wording of the accident report placed the blame upon the individual technician(s) who failed to refit the horizontal stabiliser de-ice boots correctly, there was a dissenting statement by John Lauber (then of the NTSB) which referred to corporate culture being partially to blame, in addition to the many contributory factors leading to the incorrect re-fitment.

2. Incidents

There are many incidents where maintenance human factors has been a cause or major contributory factor. Just a few examples have been included here. Good sources include the NTSB and AAIB websites, numerous national and company incident databases, and various publications.

NTSB/AAR-84/04. Eastern Airlines, L-1011, N334EA, Miami, May 1983

During maintenance, technicians failed to fit O-ring seals on the master chip detector assemblies. This led to loss of oil and engine failure. The aircraft landed safely with one engine. Technicians had been used to receiving the master chip detectors with O-ring seals already fitted and informal procedures were in use regarding fitment of the chip detectors. This problem has occurred before, but no appropriate action had been carried out to prevent a re-occurrence.

AAIB/AAR 1/92, British Airways BAC1-11, G-BJRT, Didcot, June 1990

In 1990, in the UK, a BAC1-11 was climbing through 17,300 feet on departure from Birmingham International Airport when the left windscreen, which had been replaced prior to flight, was blown out under the effects of cabin pressure when it overcame the retention of the securing bolts, 84 of which, out of a total of 90, were smaller than the specified diameter. The commander was sucked halfway out of the windscreen aperture and was restrained by cabin crew whilst the co-pilot flew the aircraft to a safe landing at Southampton Airport.

The Shift Maintenance Manager (SMM), short-handed on a night shift, had decided to carry out the windscreen replacement himself. He consulted the Maintenance Manual (MM) and concluded that it was a straightforward job. He decided to replace the old bolts and, taking one of the bolts with him (a7D), he looked for replacements. The storeman advised him that the job required 8Ds, but since there were not enough 8Ds, the SMM decided that 7Ds would do (since these had been in place previously). However, he used sight and touch to match the bolts and, erroneously, selected 8Cs instead, which were longer but thinner. He failed to notice that the countersink was lower than it should be, once the bolts were in position. He completed the job himself and signed it off, the procedures not requiring a pressure check or duplicated check.

There were several human factors issues contributing to this incident, including perceptual errors made by the SMM when identifying the replacement bolts, poor lighting in the stores area, failure to wear spectacles, circadian effects, working practices, and possible organisational and design factors. The full text of the investigation can be found in AAIB report 1/92 and in the AAIB website, and an in-depth discussion of the human factors aspects of this accident can be found in the book "Beyond Aviation Human Factors"[6], by Maurino et al.

AAIB/ AAR 2/95, Excalibur Airways, A320-212, G-KMAM, Gatwick, August 1993

Another incident in August 1993 involved an Airbus 320 which, during its first flight after a flap change, exhibited an undemanded roll to the right after takeoff. The aircraft returned to Gatwick and landed safely. The investigation discovered that during maintenance, in order to replace the right outboard flap, the spoilers had been placed in maintenance mode and moved using an incomplete procedure; specifically the collars and flags were not fitted. The purpose of the collars and the way in which the spoilers functioned was not fully understood by the technicians. This misunderstanding was due, in part, to familiarity of the technicians with other aircraft (mainly 757) and contributed to a lack of adequate briefing on the status of the spoilers during the shift handover. The locked spoiler was not detected during standard pilot functional checks.

[6] Reason, D., Maurino, D., Johnston, N., Lee, R. Chapter 4: The BAC1-11 windscreen accident, *in* Beyond Aviation Human Factors. (1995) Avebury

The full text of the investigation can be found in AAIB report 2/95[7] and a synopsis can be found in the AAIB website.

NTSB/SIR-94/02. Northwest Airlines, B747, N637US, Narita, March 1994

On March 1st, 1994, a B747 landed at Narita Airport, Japan, with the front of the No.1 engine touching the ground. A fire developed but was quickly extinguished and there were no casualties. During maintenance, the No.1 pylon aft diagonal brace primary retainer had been removed but not re-installed. The NTSB special investigation report[8] found that
"maintenance and inspection personnel who worked on the airplane were not adequately trained and qualified to perform the required maintenance and inspection functions. Critical functions had been taught by on-the-job training and were not standardized or formalized in an initial or recurrent training program".
"The 'OK to close' inspection of the pylon area was hampered by inadequate lighting and perceived dangers of the scaffolding".
"The CITEXT used by [the airline] was inadequate".
"The work environment for the heavy maintenance of the airplane was inadequate and contributed to an error-producing situation for the workers".

AAIB/ AAR 3/96, British Midland, B737-400, G-OBMM, Daventry, February 1995

In February1995, a Boeing 737-400 suffered a loss of oil pressure on both engines. The aircraft diverted and landed safely at Luton Airport The investigation discovered that the aircraft had been subject to borescope inspections on both engines during the preceding night and the high pressure (HP) rotor drive covers had not been refitted, resulting in the loss of almost all the oil from both engines during flight.

The line engineer was originally going to carry out the task, but, for various reasons, he swapped jobs with the base maintenance controller. The base maintenance controller did not have the appropriate paperwork with him. The base maintenance controller and a fitter carried out the task, despite many interruptions, but failed to refit the rotor drive covers. No ground idle engine runs (which would have revealed the oil leak) were carried out. The job was signed off as complete.

The full text of the investigation can be found in AAIB report 3/96[9] and in the AAIB website[10]. A detailed discussion of the incident can be found in Professor James Reason's book "Managing the Risks of Organizational Accidents"[11].

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[7] AAIB report **No:2/95** - Airbus A320-212, at London Gatwick Airport, on 26 August 1993. (Published in January 1995)
[8] NTSB Special Investigation Report 94/02. Northwest Airlines, B747, N637US, New Tokyo International Airport, Narita, Japan, 1 March 1994.
[9] AAIB report No:3/96 - Boeing 737-400, Near Daventry, on 23 February 1995. (Published in July 1996)
[10] www.dft.gov.uk/aaib
[11] Reason, J. Managing the Risks of Organisational Accidents. 1997. Ashgate.

AAIB Bulletin 5/97, British Airways, B747, GBDXK, Gatwick, November 1996

The 4L door handle moved to the 'open' position during the climb. The Captain elected to jettison fuel and return to Gatwick. An investigation revealed that the door torque tube had been incorrectly drilled/fitted. The Maintenance Manual required a drill jig to be used when fitting the new undrilled torque tube, but no jig was available. The LAE and Flight Technical Liaison Engineer (FTLE) elected to drill the tube in the workshop without a jig, due to time constraints and the operational requirement for the aircraft. The problem with the door arose as a result of incorrectly positioned drill holes.

AAIB Bulletin 7/2000. Airbus A320; G-VCED; 20/1/2000

As the A320 rotated for take-off, both fan cowl doors detatched from the No 1 engine and struck the aircraft. It is likely that the doors had been closed following maintenance but not latched. There are no conspicuous cues to indicate an unlatched condition, and no flight deck indication. Similar incident have occurred on at least 7 other occasions.

Lufthansa A320 incident, 20 March 2001[12]

During maintenance, two pairs of pins inside one of the elevator/aileron computers were cross connected. This changed the polarity of the Captain's side stick and the respective control channels, bypassing the control unit which might have sensed the error and would have triggered a warning. Functional checks post maintenance failed to detect the crossed connection because the technician used the first officer's side stick, not the pilot's. The pilots' pre-flight checks also failed to detect the fault. The problem became evident after take-off when the aircraft ended up in a 21° left bank and came very close to the ground, until the co-pilot switched his sidestick to priority and recovered the aircraft.

Air Transat incident, 24 August 2001

A problem during maintenance resulted in a fuel leak in flight. The problem was compounded by flight crew action, resulting in total fuel loss. Fortunately, the flight crew managed to glide the aircraft into an airfield in the Azores and land safely. There were numerous human factors issues associated with this incident, both on the maintenance and flight operations sides. The report had not yet been published at the time of writing issue 2 to CAP 716, but once published, should make an interesting case study for maintenance human factors.

3. Statistics

There have been many analyses carried out during the past 20 years, of accident and/or incident data, some looking at all accidents and causes, others looking just at maintenance related accidents/ incidents and their causes and contributory factors. Whilst only the summary data are presented here, the reader is strongly urged to look at the original analysis reports and to consider the results in context.

[12] Flight International Magazine, May 22-28 2001, page 14.

Sears (1986)

In a detailed analysis of 93 major world-wide accidents which occurred between 1959 and 1983, maintenance and inspection were factors in 12% of the accidents. The causes are listed in the table below, showing maintenance and inspection difficulties as the 4th highest on the list.

Table 1: Accident causes (Sears, 1986)

Causes/ major contributory factors	%age of accidents in which this was a factor
1. Pilot deviated from standard procedures	33
2. Inadequate cross-check by second crew member	26
3. Design faults	13
4. **Maintenance and inspection deficiencies**	**12**
5. Absence of approach guidance	10
6. Captain ignored crew inputs	10
7. Air traffic control failures or errors	09
8. Improper crew response during abnormal conditions	09
9. Insufficient or incorrect weather information	08
10.Runways hazards	07
11.Improper decision to land	06
12.Air traffic control/crew communication deficiencies	06

Sears[13] 1986

Boeing study of commercial jet aircraft accidents (1982 –1991)[14]

The Boeing study of 232 commercial jet aircraft accidents between 1982 and 1991 looked at the data from the perspective of accident prevention opportunities. An accident prevention strategy is where:

- a future accident might reasonably be avoided of the strategy were to be successfully employed, and
- at least one definitive action can be envisioned that will provide a substantial reduction in the frequency or probability that such an event will reoccur.

20% of the 232 accidents contained maintenance or inspection action as one of the prevention strategies.

Recent NTSB figures – analysis unpublished as yet[15]

More recently (2000), it has been stated that of the last 14 NTSB investigated large aircraft accidents, 7 of these have had maintenance as a major contributory factor (ie. 50%), either

[13] Sears, R.L. A new look at accident contributions and the implications of operational training programmes (unpublished report). Quoted in Graeber and Marx: Reducing Human Error in Aviation Maintenance Operations. (presented at the Flight Safety Foundation 46th Annual International Air Safety Seminar, Kuala Lumpur, Malaysia, 1993)

[14] Boeing (1993). Accident Prevention Strategies: Commercial Jet Aircraft Accidents World Wide Operations 1982-1991.

[15] Goglia, J. Unpublished statement at the 14th Human Factors in Aviation Maintenance Symposium. Vancouver, 2000, and Advances in Aviation Safety Conference, Daytona Beach, 2000.

suggesting that maintenance problems are on the increase or that, as improvements are made in aircraft design, pilot training, ATC, etc., the proportion of accidents attributable to these factors is lower and the proportion attributable to poor maintenance consequently higher.

UK CAA maintenance MORs analysis (1992)[16]

The UKCAA published a list, in 1992, of frequently recurring maintenance discrepancies, based on Mandatory Occurrence Reports. The problems, in order of frequency of occurrence, were:

Table 2 Maintenance MORs (CAA 1992)

• incorrect installation of components
• fitting of wrong parts
• electrical wiring discrepancies (including cross-connections)
• loose objects (tools, etc) left in aircraft
• inadequate lubrication
• cowling, access panels and fairings not secured
• landing gear ground lock pins not removed before departure

Boeing study (1993)[17]

An analysis, in 1993, of 122 documented occurrences (during 1989-1991) involving human factors errors with likely engineering relevance, found that the main categories were:

- omissions (56%)
- incorrect installation (30%)
- wrong parts (8%)
- other (8%)

Professor James Reason[18] reports a further breakdown of these figures as:

- Fastenings undone/ incomplete (22%)
- Items left locked/ pins not removed (13%)
- Caps loose or missing (11%)
- Items left loose or disconnected (10%)
- Items missing (10%)
- Tools/spare fastenings not removed (10%)
- Lack of lubrication (7%)
- Panels left off (3%)

Boeing study (1995) Graeber and Marx

A study by Boeing (1995) found that 15% (39 of 264) of commercial aviation accidents from 1982 through 1991 had maintenance as a contributing factor. More specifically, 23% of the 39 accidents had removal/installation as a contributing factor, 28% had the manufacturer or vendor maintenance or inspection program as a contributing factor, 49% had the airline maintenance or inspection

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[16] UKCAA. Maintenance Error. Asia Pacific Air Safety. September 1992.
[17] Graeber, R.C. and Marx, D.A.: Reducing Human Error in Aviation Maintenance Operations. (presented at the Flight Safety Foundation 46th Annual International Air safety Seminar, Kuala Lumpur, Malaysia, 1993)
[18] Reason, J. Managing the Risks of Organisational Accidents. 1997.

program policy as a contributing factor, and 49% had design as a contributing factor. Other important contributing factors included: manufacturer/vendor service bulletins and in-service communication (21%), airline service bulletin incorporation (21%), and missed discrepancy (15%).

AAIB paper[19] (1998)

Various analyses have been carried out on the three major UK incidents mentioned earlier which have involved maintenance error. In all three of these UK incidents, the technicians involved were considered by their companies at the time to have been well qualified, competent and reliable employees. All of the incidents were characterised by the following:

Table 3. Common factors in 3 major UK incidents/ accidents. 1998

• There were staff shortages
• Time pressures existed
• All the errors occurred at night
• Shift or task handovers were involved
• They all involved supervisors doing long hands-on tasks
• There was an element of a "can-do" attitude
• Interruptions occurred
• There was some failure to use approved data or company procedures
• Manuals were confusing
• There was inadequate pre-planning, equipment or spares

Hobbs survey of Australian LAMEs (1998)

A survey was carried out involving over 1300 Licensed Aircraft Maintenance Engineers in Australia, during 1998, to identify safety issues in maintenance, with a particular emphasis on human factors. The results included the following data, in Tables 4 and 5.

Table 4. Occurrence types. Hobbs. 1998

	Airline	Non-airline
System operated unsafely during maintenance	18%	7%
Towing event	9%	3%
Incomplete installation, all parts present	8%	9%
Person contacted hazard	7%	9%
Vehicle or equipment contacted aircraft	7%	1%
Incorrect assembly or orientation	6%	11%
Material left in aircraft	4%	5%
Part damaged during repair	4%	2%
Panel or cap not closed	3%	3%
Incorrect equipment/ part installed	3%	4%
Part not installed	3%	6%

19 King, D. Learning Lessons the (not quite so) Hard Way; Incidents - the route to human factors in engineering. In: 12th Symposium on Human Factors in Aviation Maintenance. March 1998

Required servicing not performed	3%	4%
Degredation not found	1%	5%
Other	24%	31%

Table 5. Occurrence causes and contributory factors. Hobbs. 1998

	Airline	Non-airline
Pressure	21%	23%
Fatigue	13%	14%
Coordination	10%	11%
Training	10%	16%
Supervision	9%	10%
Lack of equipment	8%	3%
Environment	5%	1%
Poor documentation	5%	4%
Poor procedure	4%	4%

CHIRP-MEMS data

Several UK maintenance organisations have pooled their Maintenance Error Management System (MEMS) data, using a common MEDA taxonomy. The initial results were presented at a MEMS-MEDA seminar in the UK in May 2003, a selection of which are listed in Table 6

Table 6. extract from CHIRP-MEMS results 2002

1. Improper Installation	**2. Improper Fault Isolation**	**3. Improper Servicing**
3 Top Items:-		
Incomplete Installation (161)	System not Re/Deactivated (60)	Service not Performed (55)
Wrong Orientation (111)	Not Properly Tested (58)	System not Re/Deactivated (24)
System not Re/Deactivated (87)	Not Properly Inspected (33)	Insufficient Fluid (11)
3 Top Factors:-		
Individual Performance Factors (94)	Individual Performance Factors (41)	Information (20)
Information (89)	Information (28)	Communications (17)
Technical Knowledge / Skills (59)	Communications (18)	Individual Performance Factors (16)

ASRS data[20] (2003)

Table 7. Maintenance Incidents - top anomalies (ASRS, Jan 1997-Dec 2002)

Anomaly	***No. of reports***
Critical aircraft problem	1098
Improper maintenance	1077
Improper documentation	751
Smoke or fire	14
Loss of aircraft control	13
Fumes	4
Unstabilised approach	3

Table 8. Maintenance Incidents - Top sub-components (ASRS, Jan 1997-Dec 2002)

Sub-component affected	***No. of reports***
Main gear wheel	43
Oil filler cap	26
Nose gear wheel	24
Cowling	21
Fan reverser	20
Normal break system	19
Passenger oxygen system	19
Fuselage skin	19
Turbine engine	18

Table 9. Maintenance Incidents - reporter cited factors (ASRS, Jan 1997-Dec 2002)

Factor	***No. of reports***
Schedule pressure	767
Non compliance with legal requirements	699
Inspection	649
Installation	551
Logbook entry	512
Repair	440
Manuals	359
Testing	341
Scheduled maintenance	302
Work cards	259
Engineering procedure	176
Fault isolation	139
Training	123
Unqualified personnel	112
Lighting	82
Non availability of parts	67

[20] as contained in a report that was distributed to all attendees of the Safety Management in Aviation Maintenance Symposium, Toronto, September 2003.

Factor	*No. of reports*
Briefing	43
Improper part installation	42
Tooling	38
Weather	37

4. Further Reading:

1. AAIB Report A320 GKMAM Accident report 2/95
2. AAIB Report B737 GOBMM Accident report 3/96
3. AAIB Report BAC 1-11 GBJRT Accident report 1/92
4. Boeing (1993). Accident Prevention Strategies: Commercial Jet Aircraft Accidents World Wide Operations 1982-1991.
5. ICAO Human Factors Training Manual. Doc 9683-AN/950. 1998. Chapter 6. (or ICAO Digest No.12.)
6. King, D. Learning Lessons the (not quite so) Hard Way; Incidents - the route to human factors in engineering. In: 12th Symposium on Human Factors in Aviation Maintenance. March 1998
7. Lloyds Register Engineering Services. Study into the potential for Human Error in the Maintenance of Large Civil Transport Aircraft. Report no R50003.1-2. November 1995
8. Maintenance and inspection issues in aircraft accidents/incidents, part II. J Danaher (NTSB). Proceedings of the First Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, 1989
9. Maintenance and inspection issues in aircraft accidents/incidents, part I. B Trotter (NTSB). Proceedings of the First Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, 1989
10. Managing the Risks of Organisational Accidents. Reason, J. Ashgate.
11. Marx, D A and Graeber, C. *Human Error in Aircraft Maintenance*; Chapter 5 in Aviation Psychology in Practice, Johnston, N., McDonald, N., Fuller, R.
12. Maurino, D., Reason, J., Johnston, N., & Lee, R. (1995). Beyond Aviation Human Factors. Ashgate.
13. NTSB accident reports relating to maintenance. *hfskyway*
14. NTSB. Aircraft Accident Report--Aloha Airlines, Flight 243, Boeing 737-200, N73711, near Maui, Hawaii, April 28, 1988. NTSB 89/03
15. Reason, J. *The BAC 1-11 windscreen accident*, Chapter 4 in Beyond Aviation Human Factors. Maurino, D., Reason, J., Johnston, N., Lee, R. 1995
16. UK CAA (1991). *Flight Safety Occurrence Document, 92/D/12, 9 June 1992.* Cited in Hobbs, A. (1995). Human Factors in Airline Maintenance, Asia-Pacifc Air Safety, Issue 8, March, 1995.
17. NTSB Aircraft Accident Report - Continental Express, Flight 2574, EMB-120RT, N33701, Eagle Lake, Texas, September 11 1991.
18. An overview of ASRS Maintenance Incidents. 17th annual CAA/FAA/TC Safety Management in Aviation Maintenance Symposium, September 2003.

Appendix E Safety Management Systems and Risk Assessment

Safety Management policies and principles are based on assessment of the safety significance of existing operations and future changes, and assurance that those operations are safe (according to specified criteria). In the case of a maintenance organisation, this would normally involve:

- An identification of the role or functions being performed within the organisation
- A high level risk assessment of the role or functions
- A process of risk management adopted for all safety related functions, such that risks remain tolerable
- Safety performance measurement
- Corrective procedures and measures that modify the original tasks or functions to address inadequate performance.

When carrying out a risk assessment, it is necessary to identify where equipment, procedures and/or people might fail. This would include identification of potential human errors and of situations where those errors may not be detected or corrected, and where they may result in a safety hazard.

CAP712 (SMS) states that "the effective identification of hazards can be achieved by brainstorming using an appropriate selection of management and staff, staff surveys and a number of pertinent accident/incident records from both internal and external sources." One should look not just at hazards in terms of potential outcomes, but also in terms of causes and contributory factors, especially in combination. There can be a tendency, when carrying out a hazard analysis, to be too linear in thinking, and to look just at single cause and effect scenarios. What is often needed is more lateral thinking, considering possible combinations of events, no matter how unlikely, which might result in a hazard. Experience, common sense, and evidence from past occurrences, incidents and accidents may then be used to assess the likelihood of such combinations of events occurring, and the consequent need to protect against such risks.

The identification of human risk areas can be difficult and time consuming. Four stages are necessary: (i) the identification of areas of potential risk (eg. missing a crack during an inspection), (ii) identification of existing controls (eg. duplicate inspections), and identification of (iii) probability of occurrence (eg. likely, rare) and (iv) likely consequences (eg. catastrophic). These four stages can be highly detailed or fairly cursory, and, in practice, will probably be limited by the available resources and expertise which the organisation has to apply to the risk assessment process. There are many consultants and companies which specialise in risk assessment, and whilst organisations are encouraged to bring in expert assistance, they should be aware that an effective risk assessment must necessarily involve staff who are very familiar with the processes and problems of the organisation concerned, ie. one's own staff. It may also be useful to involve one or more people from outside the organisation who are familiar with maintenance and the methods adopted in other companies, who may be able to spot strengths and weaknesses. Often you can become so used to the way something is done within your on organisation that you do not see the obvious flaws.

The identification of potential risk areas will usually involve the use of task analysis techniques. It should not be necessary to take this analysis down to the level of individual actions (as is sometimes done) but, rather, treat it as a means of capturing all the main tasks and processes and how they interrelate. This can then be used as a framework for the remaining stages of the risk assessment.

The identification of existing controls is an important step in the process, and can be done in parallel with the task analysis. It is useful to document why each of the controls is in place, and what it protects against. Sometimes the original reason for a control is forgotten and the control is removed, the likely consequence being that errors will no longer be detected and corrected and may result in incidents or even accidents. The majority, if not all, or these controls should already be documented. CAP 455 may be a useful reference here, since many of the AWNs contain advice as to additional protective measures which organisations should adopt as a result of a particular problem having been identified.

Last but not least comes the part of the assessment where some form of quantification or qualification is necessary, to highlight those areas which are higher risk than others. This is the most controversial part of risk assessment, since it is very difficult to assign numbers to the probability of human error. CAP 712 advocates the qualitative approach, rather than the quantitative.

It is not enough to rely upon past incident data since, in the past, incidents have often been classified only superficially, without investigating the root causes. Existing human performance data are of very limited use, generally applying only to very similar contexts to those from which the data were originally obtained (eg. The textbooks may tell us that the probability of a technician misreading a dial may be 10^{-N} , but such data, probably obtained from measurements of the performance of alert technicians in a well-lit process control room simulator, may no be so relevant for a tired maintenance technican, trying to read a dial in a poorly lit hangar). These data are more applicable to well-learned, familiar, routine tasks (skill-based behaviour), and even then, should be treated with a margin of error rather than as definitive values. Expert judgement is probably the most practical means of assessing human risk areas, and the probability of error, and there are methods of addressing the variances in human judgement such that an overall assessment from a group of experts (or people who are familiar with the tasks) has validity.

It is not necessarily essential to assign numerical probabilities to identified hazards. Depending on what is required, it may only be necessary to identify a hazard as high, medium or low, or some other similar means of determining which require further action to control the hazard, and which do not. Essentially that is what Safety Management is about.

Further reading and contacts:

1. CAP 712
2. Safety Management Systems. TP13739. Transport Canada. http://www.tc.gc.ca/CivilAviation/systemSafety/pubs/tp13739
3. Systems of Safety Management. Civil Aviation Safety Authority Australia.
4. Reducing Error and Influencing Behaviour. HSG48, 2nd Edition, 1999. Chapters 3 and 5. HSE Books. ISBN 0 7176 2452 8
5. Edwards C. Managing human factors within a Safety Management System. Proceedings of the Twelfth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, 1998
6. Reason, J. Managing the Risks of Organisational Accidents. 1997. Ashgate.

7. UKCAA. Guidance for Developing and Auditing a Formal Safety Management System. Paper presented at the UK-CAA Industry Conference, 24 May 2000; summary in CAA SRG's magazine Safeguard, issue 4.
8. Human Reliability Assessment – a Critical Overview. ACSNI Study Group on Human Factors. HSE Books 1991. ISBN 0 11 885695 2

A list of companies and consultants in the UK specialising in Human Reliability can be obtained from: The Ergonomic Society, Devonshire House, Devonshire Square, Loughborough, Leicestershire, LE11 3DW. Tel 01509 234904

Appendix F Example Safety Policy

A safety and quality policy should identify the company policy regarding safety in enough detail to make it clear that safety is considered important, and to give clear messages to employees as to the company's policy concerning safety-related issues.

The policy should be published and made known to all employees and subcontracted staff.

The policy should be applied within the company.

Each organisation will wish to have its own version of a safety policy, but some example wording is given below, as guidance:

Table 1: Example Safety Policy 1

It is our policy:

- to set our safety standards at or above the level required by the National Authority, JAA, EASA or customer, whichever is the highest.
- to seek to ensure that safety standards are not eroded by commercial drivers.
- to be an open, honest and straightforward organisation.
- to establish and promote a just culture such that staff are encouraged to report safety concerns without fear of inappropriate punitive action.
- to make effective use of our resources and do things right first time.
- to provide the working environment and incentives needed to attract, retain and develop skilled and committed staff capable of performing work to the highest safety standards.
- to provide incentives for staff to work in accordance with good safety practice, and disincentives for those working contrary to established good safety practice.
- to provide staff with appropriate tools, procedures and time to carry out tasks in accordance with procedures.
- to practice what we preach.

We will:

- establish a Safety Management System
- establish, and publish, a disciplinary policy base don just culture concepts
- establish, and publish, management safety accountabilities

Further information on Safety Management Systems can be found in Appendix E
Further information on disciplinary policy can be found in Appendices H and I.
Further information on management safety accountabilities can be found in Appendix G.

Table 2. Example Safety Policy 2 (from the GAIN Operator's Flight Safety Handbook, Issue 2, 2001[21])

CORE VALUES

Among our core values, we will include:

- Safety, health and the environment
- Ethical behaviour
- Valuing people

FUNDAMENTAL BELIEFS

Our fundamental safety beliefs are:

- Safety is a core business and personal value
- Safety is a source of our competitive advantage
- We will strengthen our business by making safety excellence an integral part of all flight and ground activities
- We believe that all accidents and incidents are preventable
- All levels of line management are accountable for our safety performance, starting with the Chief Executive Officer (CEO)/Managing Director

CORE ELEMENTS OF OUR SAFETY APPROACH

The five core elements of our safety approach include:

Top Management Commitment

- Safety excellence will be a component of our mission
- Senior leaders will hold line management and all employees accountable for safety performance
- Senior leaders and line management will demonstrate their continual commitment to safety

Responsibility & Accountability of All Employees

- Safety performance will be an important part of our management/employee evaluation system
- We will recognise and reward flight and ground safety performance
- Before any work is done, we will make everyone aware of the safety rules and processes as well as their personal responsibility to observe them

Clearly Communicated Expectations of Zero Incidents

- We will have a formal written safety goal, and we will ensure everyone understands and accepts that goal
- We will have a communications and motivation system in place to keep our people focused on the safety goal

Auditing & Measuring for Improvement

- Management will ensure regular conduct safety audits are conducted and that everyone will participate in the process

[21] www.gainweb.org

- We will focus our audits on the behaviour of people as well as on the conditions of the operating area
- We will establish both leading and trailing performance indicators to help us evaluate our level of safety

Responsibility of All Employees

- Each one of us will be expected to accept responsibility and accountability for our own behaviour
- Each one of us will have an opportunity to participate in developing safety standards and procedures
- We will openly communicate information about safety incidents and will share the lessons with others
- Each of us will be concerned for the safety of others in our organisation

THE OBJECTIVES OF THE SAFETY PROCESS

- ALL levels of management will be clearly committed to safety.
- We will have clear employee safety metrics, with clear accountability.
- We will have open safety communications.
- We will involve everyone in the decision process.
- We will provide the necessary training to build and maintain meaningful ground and flight safety leadership skills.

The safety of our employees, customers and suppliers will be a Company strategic issue.

(signed)
CEO/ Accountable Manager (as appropriate)

Appendix G Safety Accountabilities

It is good practice for a company to determine, in detail, the safety accountabilities of management staff. These accountabilities should be realistic, avoiding the situation whereby one person is accountable for too many issues (often the Quality Manager). The accountabilities should be published. The responsibilities of non-management staff may also be included, to stress that every individual holds some responsibility for safety, even if it is the Accountable Manager who holds ultimate responsibility for organisational safety issues.

Example wording is given below, for guidance:

Table 1. Example Safety Accountabilities

- The Accountable Manager is responsible for ensuring that Safety Management accountabilities are addressed appropriately within the organisation (including subcontractors).
- A clear line of safety management responsibility throughout the organisation (including subcontracted organisations and personnel) should be documented and should be consistent with job descriptions.
- The accountabilities should be considered for update annually.
- Accountabilities and dependencies should be clearly stated, with managers being empowered with the necessary authority, resources, etc to enable them to meet their accountabilities.
- Safety management accountabilities should not conflict with other job requirements or incentives.
- Performance measures, should be based on both safety management achievements and commercial targets.
- Every employee (and subcontractor) within the organisation (and its subcontracted organisations) should have a statement within their job descriptions relating to their personal contribution to safety.
- Accountabilities should be clear and at an appropriate level of detail; general high level statements which bear little resemblance to the actual job are unlikely to be effective.

Appendix H AN71: Maintenance Error Management Systems

The following text is taken verbatim from CAA Airworthiness Notice 71 (issue 1), in CAP 455, dated 20 March 2001. Readers are referred to www.caa.co.uk for the latest issue.

MAINTENANCE ERROR MANAGEMENT SYSTEMS

1 Introduction

1.1 Given the worldwide commitment to reducing the fatal accident rate, the CAA has, as one of its Human Factors initiatives, undertaken to reduce the number of maintenance errors and to mitigate the consequences of those which remain. CAA seeks to provide an environment in which such errors may be openly investigated in order that the contributing factors and root causes of maintenance errors can be addressed using a system that would complement, not supplant, the two current systems for reporting maintenance errors (MORS and CHIRP).

1.2 The already well established Mandatory Occurrence Reporting (MOR) scheme exists in order that significant safety issues are brought to the notice of the CAA. However, the MORs scheme is not intended to collect and monitor the normal flow of day-to-day defects/incidents etc. which, in remaining an industry responsibility[22], forms an important part of the overall operational safety task. This notice concerns, primarily, those events which fall below the MOR criteria but which, nevertheless, are important for an organisation to understand and control. However, the principles described in this notice may also be applied by an organisation to their own internal investigation of incidents meeting the MOR criteria (note: organisations will still be required to report MORs to the CAA)

1.3 The Confidential Human Factors Incident Reporting Programme (CHIRP) scheme provides an alternate reporting mechanism for individuals who want to report safety concerns and incidents confidentially. However CHIRP should not be considered as an alternative to implementing a MEMS scheme. A MEMS and CHIRP perform different functions albeit acting towards the same ultimate aim, i.e. improved flight safety.

1.4 Maintenance errors with serious consequences such as accidents or incidents are routinely investigated by organisations, CAA or Air Accident Investigation Branch. Operationally significant events (e.g. technical delays, cancellations, in-flight shut-downs etc.) which are not legally required to be reported externally are frequently investigated by organisations but too often only to apportion responsibility for the event. Below these levels are events without operational significance which may rarely be investigated (e.g. the omission of an oil filler cap which, by chance, is noticed and corrected before flight). In order to gain a better understanding of the problems and factors which contribute to errors it is necessary to investigate these and operationally significant events before they possibly contribute to or cause an incident or accident in the future.

[22] CAP382, para 5.4.5

1.5 It is important to examine not just *what* happened, but *why* it happened, in order to determine the root causes and problems.

2 Maintenance Error Management System

2.1 With the issue of this notice, the CAA is declaring its policy on Maintenance Error Management Systems (henceforth referred to as MEMS) such that maintenance organisations, in particular those maintaining large commercial air transport aircraft, are encouraged to adopt the concept.

2.2 Prevailing industry best practice has shown that a MEMS should contain the following elements:

- Clearly identified aims and objectives
- Demonstrable corporate commitment with responsibilities for the MEMS clearly defined .
- Corporate encouragement of uninhibited reporting and participation by individuals
- Disciplinary policies and boundaries identified and published
- An event investigation process
- The events that will trigger error investigations identified and published
- Investigators selected and trained
- MEMS education for staff, and training where necessary
- Appropriate action based on investigation findings
- Feedback of results to workforce
- Analysis of the collective data showing contributing factor trends and frequencies

2.3 The aim of the scheme is to identify the factors contributing to incidents, and to make the *system* resistant to similar errors. Whilst not essential to the success of a MEMS, it is recommended that for large organisations a computerised database be used for storage and analysis of MEMS data. This would enable the full potential of such a system to be utilised in managing errors.

2.4 For the purpose of this Airworthiness Notice a maintenance error is considered to have occurred when the maintenance system, including the human element, fails to perform in the manner expected in order to achieve its safety objectives. The human element includes technicians, engineers, planners, managers, store-keepers - in fact any person contributing to the maintenance process. The foregoing definition differs from that of a human error as it demands consideration of the system failings (e.g. inadequate staffing, organisational factors, tooling availability, ambiguous manuals etc.) as well as the error committed by a person.

3 CAA Assurances

3.1 It is recognised that the success of a MEM programme is dependent on full and free investigation without fear of action by the CAA. Accordingly, the CAA gives the following assurances:

3.1.1 The CAA will not approve a MEMS even when included in the approved Exposition. Should a MEMS be included in an Exposition, it will not be subject to auditing as part of CAA regulatory oversight of that organisation. Any interest shown in an organisation's MEMS is purely one of a desire to work with industry to enhance safety.

3.1.2 The CAA will not *require* any organisation or individual to make available to the Authority any specific reports that are submitted under a MEMS, other than information normally reported to the Authority via the MOR scheme.

3.1.3 If an Organisation, in the interests of improving safety, voluntarily elects to share with the CAA the details of a specific occurrence reported under MEMS, or the results of its investigation, the CAA will:

(a) not disclose the name of the person submitting the MEMS report, nor of a person to whom it relates, nor pass on a MEMS report to a third party, unless required to do so by law or unless the person(s) concerned authorises such disclosure.

(b) take all reasonable steps possible to avoid disclosing the identity of the reporter or of those individuals involved in the occurrence, should any follow-up action arising from a MEMS report be taken.

(c) not, as its policy, institute proceedings in respect of unpremeditated or inadvertent breaches of the law or requirements which come to its attention only because they have been reported under the MEMS scheme, except in cases involving dereliction of duty amounting to gross negligence or recklessness. Such an assurance is similar to that provided under the MOR scheme.

4 MEMS Code of Practice

4.1 The CAA encourages organisations to adopt the following code of practice regarding a MEMS:

4.1.1 Where an occurrence reported via MEMS indicates an unpremeditated or inadvertent lapse by an employee, as described below, the CAA would expect the employer to act reasonably, agreeing that free and full reporting is the primary aim in order to establish *why* the event happened by studying the contributory factors that led to the incident, and that every effort should be made to avoid action that may inhibit reporting.

4.1.2 In the context of error management it is considered that an unpremeditated or inadvertent lapse should not incur any punitive action, but a breach of professionalism may do so. As a guideline, individuals should not attract punitive action unless:

(a) The act was intended to cause deliberate harm or damage.
(b) The person concerned does not have a constructive attitude towards complying with safe operating procedures.

(c) The person concerned knowingly violated procedures that were readily available, workable, intelligible and correct.
(d) The person concerned has been involved previously in similar lapses.
(e) The person concerned has attempted to hide their lapse or part in a mishap.
(f) The act was the result of a substantial disregard for safety.

"Substantial disregard", for this purpose, means:

- In the case of a certification authorisation holder (e.g. licensed engineer or Certifying Staff) the act or failure to act was a substantial deviation from the degree of care, judgement and responsibility reasonably expected of such a person.
- In the case of a person holding no maintenance certification responsibility, the act or failure to act was a substantial deviation for the degree of care and diligence expected of a reasonable person in those circumstances.

The degree of culpability would vary depending on any mitigating circumstances that are identified as a result of the MEMS investigation. It follows that any action taken by the organisation would also be on a sliding scale varying from corrective measures such as re-training through to dismissal of the individual.

4.1.3 In the case of incidents investigated via a MEMS, irrespective of whether or not such incidents were brought to the knowledge of the CAA, the CAA expects an organisation to address the problems which contributed to these incidents. The organisation should, where possible, implement appropriate measures to prevent the problem from re-occurring, or alternatively monitor future occurrences, according to the degree of risk and likelihood of re-occurrence. A supporting database is useful in these circumstances in helping to assess the frequency of occurrence and any associated trends.

4.1.4 The CAA would expect that identified safety issues would be acted upon*. If the CAA becomes aware, by whatever means, that a significant safety problem existed and was not being addressed, it reserves the right to take appropriate action.

4.1.5 Organisations are encouraged to share their MEMS results with the CAA and with other maintenance organisations. It is hoped that by sharing such data the CAA and industry can jointly develop a better understanding of maintenance error causation and develop more focused human factors strategies. However, it is appreciated that some information in a MEMS may be considered sensitive to the organisation affected, and may need to be dis-identified before being shared with other organisations.

5 Further Information

5.1 The CAA is in the process of producing further guidance material which will assist organisations which wish to implement a MEMS. This will be made available later this year.

* The statement by an organisation that an incident is undergoing, or has undergone, a MEMS investigation, without any additional information provided to explain why the incident occurred, would not normally be an adequate basis for an MOR closure.

5.2 Maintenance Organisations requiring further information or advice on how to establish a Maintenance Error Management System should, in the first instance, contact their CAA Aircraft Maintenance Standards Department (AMSD) local Regional Office;

or:

Maintenance Requirements and Policy Section,
Aircraft Maintenance Standards Department,
CAA
Aviation House
Gatwick Airport South
West Sussex
RH6 0YR

Appendix I Example Disciplinary Policy

One of the prerequisites for a successful Maintenance Error Management System is that staff should feel that they can report occurrences and errors openly, without fear of punitive action. The reporting aspect may be accomplished by means of a confidential reporting scheme, but in order to investigate the occurrences, it is necessary to speak to the individuals involved. A blame-free approach is not the answer, since some actions are blatantly negligent and warrant punitive action. It is necessary to have clear policy stating that staff will not be punished for genuine errors. Each company will need to decide what its policy is concerning the 'grey' areas between error and negligence, where violations may have been committed but where punitive action may not be appropriate.

Some example wording and further guidance are given below:

Staff are encouraged to report safety concerns and errors, and to cooperate with investigation of incidents, the primary aim being to establish why the problem occurred and to fix it, and not to identify and punish the individual(s) concerned.

It is the company's policy that an unpremeditated or inadvertent lapse should not incur any punitive action, but a breach of professionalism may do so.

It may be necessary to stand down (suspend) an individual pending investigation. This should not be interpreted as punitive action but, rather, as a precautionary safety measure.

As a guideline, individuals should not attract punitive action unless:

(a) The act was intended to cause deliberate harm or damage.
(b) The person concerned does not have a constructive attitude towards complying with safe operating procedures.
(c) The person concerned knowingly violated procedures that were readily available, workable, intelligible and correct.
(d) The person concerned has been involved previously in similar lapses.
(e) The person concerned has attempted to hide their lapse or part in a mishap.
(f) The act was the result of a substantial disregard for safety.

This does not mean to say that individuals *will* incur puntive action if they meet one of the above conditions; each case will be considered on its merits.

"Substantial disregard", in item (f), means:

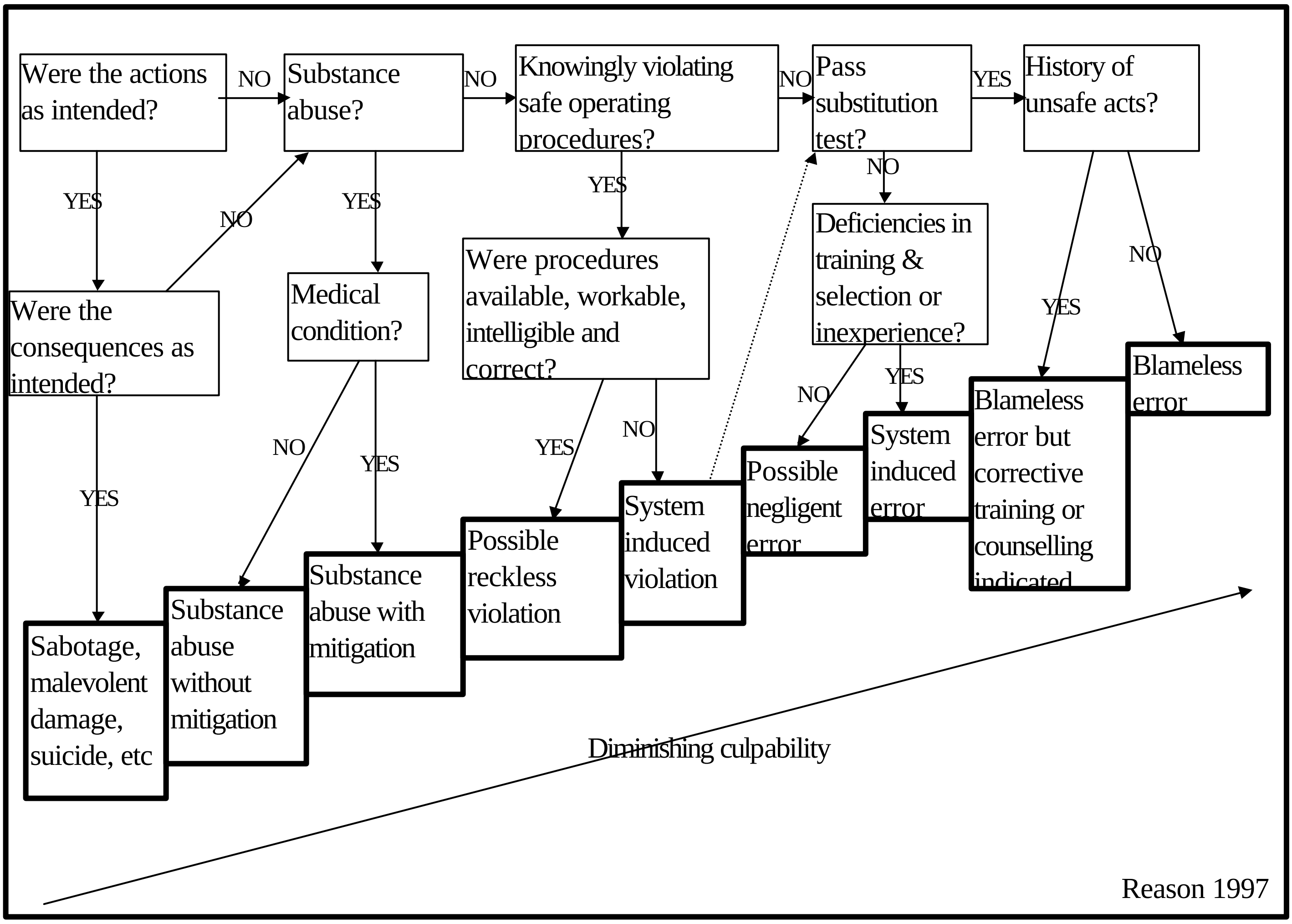
- In the case of a certification authorisation holder (e.g. licensed engineer or Certifying Staff) the act or failure to act was a substantial deviation from the degree of care, judgement and responsibility reasonably expected of such a person.
- In the case of a person holding no maintenance certification responsibility, the act or failure to act was a substantial deviation for the degree of care and diligence expected of a reasonable person in those circumstances.

The degree of culpability may vary depending on any mitigating circumstances that are identified as a result of an investigation.

If it is deemed appropriate to take action concerning an individual, this need not necessarily be punitive, nor should be considered as such. The action should always be whatever is appropriate to try to prevent a re-occurrence of the problem. Action may take the form of additional training, monitoring by a supervisor, an interview with a manager to ensure that the individual is fully aware of the implications of their actions, etc. Only in the worst case would dismissal be considered as appropriate action.

Note: an organisation may wish to use Fig 1 as a guide when drawing up a disciplinary policy, whilst remembering what they are trying to achieve by ascertaining the degree of culpability - ie, to prevent a re-occurrence of that incident, not to establish blame or to mete out punishment for its own sake.

Fig 1. A decision tree for determining the culpability of unsafe acts.



The "substitution test" is good rule of thumb when illustrating where blame is inappropriate. If an incident occurs, ask yourself whether another similar individual (with the required skill, training and experience) in the same circumstances would have done anything different. If not, then blame is definitely inappropriate. Further information on this concept can be found in the article: *"Do blame and punishment have a role in organisational risk management?". Johnston, N. Flight Deck. Spring 1995, pp 33-6.*

Further reading

1. Reason, J. Managing the Risks of Organisational Accidents. 1997. Ashgate. *ISBN 1-84014-105-0*
2. Marx, D. The link between employee mishap culpability and commercial aviation safety. . *hfskyway.faa.gov*
3. Marx D. Discipline and the "blame-free" culture. Proceedings of the Twelfth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, 1998
4. Johnston, N. *Do blame and punishment have a role in organisational risk management?".* Flight Deck. Spring 1995, pp 33-6.
5. Proceedings of the MEDA-MEMS workshop and seminar, May 2003 (email osdhf@srg.caa.co.uk for a copy).

Appendix J Occurrence Management System (OMS) concepts

Introduction

An occurrence management system is a generic name given to any system which enables the reporting and follow-up of safety related events or hazards, whether minor or major, whether voluntarily or mandatory, whether anonymous or attributable and whether computerised or not. The aim of such a system is to learn from events, and to either prevent them from happening again, or to ensure that they are unlikely to result in adverse outcomes (in the extreme case, aircraft accidents).

Occurrence management is more than just occurrence reporting; it also includes investigation of reported occurrences to an appropriate level of detail in order to discover their root causes, and follow up in terms of action and feedback to reportees. An occurrence management system should be closed-loop.

Occurrence Management System examples

There are many schemes, mechanisms and databases which fall within the description of an occurrence management system, the majority of which are described in the Global Aviation Information Network (GAIN) report (issue 2). There are many more which are just reporting schemes, and do not include investigation of occurrences, identification of remedial action, follow-up or feedback mechanisms.

Maintenance organisations will probably already have a system for reporting mandatory occurrences to the CAA, and a system for reporting quality discrepancies internally. If these systems incorporate some form of investigation of those occurrences and discrepancies, and follow up action, they will fall into the description of occurrence management systems.

This CAP is concerned specifically with internal company schemes which provide a mechanism for reporting and investigating those occurrences which might not otherwise be reported and/or investigated, in particular those where the contributory factors are likely to have been human factors related. Such schemes may also be expanded to be proactive as well as reactive, and include reporting and investigation of hazards which have not (yet) resulted in an incident or event. Alternatively, organisations may have separate proactive schemes for the identification of hazards, eg. the Maintenance Error Safety Health (MESH) scheme developed by Professor Jim Reason for British Airways. (Such schemes are not discussed further in this appendix).

The UK CAA Mandatory Occurrence Reporting (MOR) scheme is an example of an occurrence management system. Organisations report occurrences to the CAA. Each reported occurrence is assessed to determine whether it warrants further investigation or not. Investigation occurs to determine root causes. Results are recorded, and action is taken where considered appropriate. Finally, information is fedback to reportees in the form of summary data.

Internal company OMSs can go further than the MOR scheme in several respects:
(i) reporting and investigating lower level occurrences, as well as those meeting the MOR criteria
(ii) more thorough investigation of occurrences and determination of root causes

(iii) tailoring remedial action to the root causes
(iv) using the results from investigated incidents within human factors training
(v) feeding back information to company employees in an appropriate form

The term Maintenance Error Management System (MEMS) was developed by the CAA to describe the key elements of an occurrence management system in a maintenance context.

The Maintenance Error Decision Aid (MEDA), developed by Boeing and industry, has become the most commonly used type of Maintenance Error Management System across the world, in aviation maintenance. MEDA is described further in this chapter, and a copy of the MEDA form is included in Appendix K.

Maintenance Error Management System (MEMS) concepts

The elements of a Maintenance Error Management System are described in AN71 (Appendix H). They are:

- Clearly identified aims and objectives
- Demonstrable corporate commitment with responsibilities for the MEMS clearly defined .
- Corporate encouragement of uninhibited reporting and participation by individuals
- Disciplinary policies and boundaries identified and published
- An event investigation process
- The events that will trigger error investigations identified and published
- Investigators selected and trained
- MEMS education for staff, and training where necessary
- Appropriate action based on investigation findings
- Feedback of results to workforce
- Analysis of the collective data showing contributing factor trends and frequencies

A MEMS does not prescribe the use of any one particular taxonomy or method for investigating incidents. However, the MEDA system[23], and MEDA derivatives, are consistent with MEMS principles, and considered an appropriate mechanisms for investigating incidents.

Maintenance Error Decision Aid (MEDA)[24]

The following text has been adapted from an article published in Boeing AERO magazine, issue 03, with permission.

The MEDA Philosophy

Traditional efforts to investigate errors are often aimed at identifying the employee who made the error. The usual result is that the employee is defensive and is subjected to a combination of

[23] MEDA was designed for aircraft maintenance organisations. A version suitable for component maintainers is available from BainesSimmons Ltd.
[24] Whilst Boeing encourages organisations to use MEDA, and even provides its customers with free MEDA training, it had copywrited the term 'MEDA' in order to prevent organisations selling on possibly inappropriate adaptations of MEDA training. Contact Boeing for further details.

disciplinary action and recurrent training (which is actually retraining). Because retraining often adds little or no value to what the employee already knows, it may be ineffective in preventing future errors. In addition, by the time the employee is identified, information about the factors that contributed to the error has been lost. Because the factors that contributed to the error remain unchanged, the error is likely to recur, setting what is called the "blame and train" cycle in motion again.

To break this cycle, MEDA was developed in order to assist investigators to look for the factors that contributed to the error, rather than concentrate upon the employee who made the error. The MEDA philosophy is based on these principles:

- Positive employee intent (maintenance technicians want to do the best job possible and do not make errors intentionally).
- Contribution of multiple factors (a series of factors contributes to an error).
- Manageability of errors (most of the factors that contribute to an error can be managed).

POSITIVE EMPLOYEE INTENT.

This principle is key to a successful investigation. Traditional "blame and train" investigations assume that errors result from individual carelessness or incompetence. Starting instead from the assumption that even careful employees can make errors, MEDA interviewers can gain the active participation of the technicians closest to the error. When technicians feel that their competence is not in question and that their contributions will not be used in disciplinary actions against them or their fellow employees, they willingly team with investigators to identify the factors that contribute to error and suggest solutions. By following this principle, operators can replace a negative "blame and train" pattern with a positive "blame the process, not the person" practice.

CONTRIBUTION OF MULTIPLE FACTORS.

Technicians who perform maintenance tasks on a daily basis are often aware of factors that can contribute to error. These include information that is difficult to understand, such as work cards or maintenance manuals; inadequate lighting; poor communication between work shifts; and aircraft design. Technicians may even have their own strategies for addressing these factors. One of the objectives of a MEDA investigation is to discover these successful strategies and share them with the entire maintenance operation.

MANAGEABILITY OF ERRORS.

Active involvement of the technicians closest to the error reflects the MEDA principle that most of the factors that contribute to an error can be managed. Processes can be changed, procedures improved or corrected, facilities enhanced, and best practices shared. Because error most often results from a series of contributing factors, correcting or removing just one or two of these factors can prevent the error from recurring.

The MEDA Process

To help maintenance organizations achieve the dual goals of identifying factors that contribute to existing errors and avoiding future errors, Boeing initially worked with British Airways, Continental Airlines, United Airlines, a maintenance workers' labour union, and the U.S. Federal Aviation Administration. The result was a basic five-step process for operators to follow

- Event.

- Decision.
- Investigation.
- Prevention strategies.
- Feedback.

EVENT.
An event occurs, such as a gate return or air turn back. It is the responsibility of the maintenance organization to select the error-caused events that will be investigated.

DECISION.
After fixing the problem and returning the airplane to service, the operator makes a decision: Was the event maintenance-related? If yes, the operator performs a MEDA investigation.

INVESTIGATION.
Using the MEDA results form, the operator carries out an investigation. The trained investigator uses the form to record general information about the airplane, when the maintenance and the event occurred, the event that began the investigation, the error that caused the event, the factors contributing to the error, and a list of possible prevention strategies.

PREVENTION STRATEGIES.
The operator reviews, prioritises, implements, and then tracks prevention strategies (process improvements) in order to avoid or reduce the likelihood of similar errors in the future.

FEEDBACK.
The operator provides feedback to the maintenance workforce so technicians know that changes have been made to the maintenance system as a result of the MEDA process. The operator is responsible for affirming the effectiveness of employees' participation and validating their contribution to the MEDA process by sharing investigation results with them.

Management Resolve

The resolve of management at the maintenance operation is key to successful MEDA implementation. Specifically, after completing a program of MEDA support from Boeing, managers must assume responsibility for the following activities before starting investigations:

1. Appoint a manager in charge of MEDA and assign a focal organization.
2. Decide which events will initiate investigations.
3. Establish a plan for conducting and tracking investigations.
4. Assemble a team to decide which prevention strategies to implement.
5. Inform the maintenance and engineering workforce about MEDA before implementation.

MEDA is a long-term commitment, rather than a quick fix. Operators new to the process are susceptible to "normal workload syndrome". This occurs once the enthusiasm generated by initial training of investigation teams has diminished and the first few investigations have been completed. In addition to the expectation that they will continue to use MEDA, newly trained investigators are expected to maintain their normal responsibilities and workloads. Management at all levels can maintain the ongoing commitment required by providing systematic tracking of MEDA findings and visibility of error and improvement trends.

Summary
The Maintenance Error Decision Aid (MEDA) process offered by Boeing continues to help operators of airplanes identify what causes maintenance errors and how to prevent similar errors in the future. Because MEDA is a tool for investigating the factors that contribute to an error, maintenance organizations can discover exactly what led to an error and remedy those factors. By using MEDA, operators can avoid the rework, lost revenue, and potential safety problems related to events caused by maintenance errors.

Further Reading

1. Rankin, W., Allen, J., Sargent, R. Boeing introduces MEDA: Maintenance Error Decision Aid.. Airliner, April-June 1996
2. Allen J., Rankin W, Sargent B. Human Factors Process for Reducing Maintenance Errors. *http://www.boeing.com/commercial/aeromagazine/aero_03/textonly/m01txt.html*
3. Marx, D. The link between employee mishap culpability and commercial aviation safety. *http://hfskyway.faa.gov*
4. Marx D. Discipline and the "blame-free" culture. Proceedings of the Twelfth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, 1998
5. Marx D. Learning from our mistakes: A review of Maintenance Error Investigation and Analysis Systems. Jan 1998. On: FAA CD ROM "Human Factors in Aviation Maintenance and Inspection: Ten years of Research and Development" (1999) , and *http://hfskyway.faa.gov*
6. Allen, J. P. Jr., and Rankin, W. L. (1995a). *A Summary of the Use and Impact of the Maintenance Error Decision Aid (MEDA) on the Commercial Aviation Industry.* Paper presented at the Flight Safety Foundation International Federation of Airworthiness 48th Annual Air Safety Seminar, November 7-9, 1995, Seattle, WA.
7. Allen, J. P. Jr., and Rankin, W. L. (1995b). Study of the Use and Impact of the Maintenance Error Decision Aid (MEDA) on the Commercial Aviation Industry. *Boeing Technical Report #D6-81758*, Boeing Renton Document Release, P.O. Box 3707, Seattle, WA 98124-2207.
8. Proceedings of the MEDA-MEMS workshop and seminar, May 2003 (email osdhf@srg.caa.co.uk for a copy).

Appendix K Maintenance Error Decision Aid (MEDA) form (rev g)

Section I -- General Information

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

Interviewer's Name: ___________________________
Interviewer's Telephone #: __ __ __ __ __ __ __ __
Date of Investigation: __ __ / __ __ / __ __
Date of Event: __ __ / __ __ / __ __
Time of Event: _ _ : _ _ am pm
Shift of Error: ________________________________
Type of Maintenance (Circle):

1. Line -- If Line, what type? ________________
2. Base --If Base, what type? ________________

Date Changes Implemented: __ __ / __ __ / __ __

Section II -- Event

Please select the event (check all that apply)

1. Operations Process Event

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

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

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

Section III -- Maintenance Error

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

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

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

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

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

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

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

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

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

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

Section IV -- Contributing Factors Checklist

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

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

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

B. Equipment/Tools/Safety Equipment

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

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

C. Aircraft Design/Configuration/Parts

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

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

D. Job/Task

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

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

E. Technical Knowledge/Skills

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

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

F. Individual Factors

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

Describe specifically how the selected <u>factors affecting individual performance</u> contributed to the error.

G. Environment/Facilities

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

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

H. Organizational Factors

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

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

I. Leadership/Supervision

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

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

J. Communication

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

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

K. Other Contributing Factors (explain below)

Describe specifically how this <u>other factor</u> 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.

Recommen-dation #	Contributing Factor #	

(Use additional pages, as necessary)

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

Provide a brief summary of the event.

(Use additional pages, as necessary)

Appendix L UK MEMS-CHIRP Data Sharing Initiative

AN71 encourages organisations to share data from MEMS systems, stating "*Organisations are encouraged to share their MEMS results with the CAA and with other maintenance organisations. It is hoped that by sharing such data the CAA and industry can jointly develop a better understanding of maintenance error causation and develop more focused human factors strategies. However, it is appreciated that some information in a MEMS may be considered sensitive to the organisation affected, and may need to be dis-identified before being shared with other organisations"* .

Accordingly, the UK Operators Technical Group (UKOTG), in conjunction with the Confidential Human Factors Incident Reporting (CHIRP) team, set up a pilot group of UK industry participants to determine the feasibility of sharing MEMS data. This pilot study has now concluded, proof of concept has been proven, and a formal structure established to enable organisations to share disidentified data.

The following information has been extracted from the Constitution and Operating Procedures of the MEMS Group and Review Board, and the Guide to Best Practice, both of which can be found on the website: www.chirp.co.uk/mems.

General

UK operators are increasingly adopting Maintenance Error Management Systems (MEMS). The CAA(SRG) is actively promoting the creation of such Systems and it has issued Airworthiness Notice Number 71 on the subject. It has been agreed by the UKOTG and EIMG members, encouraged by the CAA, that sharing the disidentified safety information that results from the MEMS process will be helpful to all concerned. CHIRP has agreed to co-ordinate the receipt of data into a combined database, disidentify the information contained and its origin, and to produce periodic analyses and reports. It has been further agreed to establish a MEMS Review Board, representative of those organisations actively engaged in MEMS programmes, to facilitate, develop and guide this process. Organisations engaged in this Programme will be referred to collectively as the MEMS Group.

Objectives

The MEMS Review Board objectives are:

- To establish and develop a Programme for the collection of MEMS reports from UK JAR-145 accredited organisations, (the MEMS Group), into a secure central database under the independent control of CHIRP.
- To facilitate the analysis of the collected data by members of the MEMS Group and to authorise analysis of this data by other competent and accredited persons and organisations.

- To ensure production of periodic reports on the results of data analyses facilitated by the Board; to ensure that those having access to the data for purposes of analysis report their results to the Board.
- To ensure that reports are circulated to all members of the MEMS Group and other organisations concerned with Human Factors aspects of air safety.
- To facilitate the production of a periodic newsletter highlighting specific safety related occurrences, their causes and remedies, for circulation to all practising maintenance engineers and mechanics in the UK in particular and ensure availability for wider distribution to interested parties.
- To ensure that solutions to identified safety problems, highlighted through the Programme, are pursued to practicable resolution.

A Guide to Best Practice

This text is taken directly from the MEMS-CHIRP Guide to Best Practice (Issue 1. 29/9/03).

This Guide is intended for use by those individuals in organisations about to introduce MEMS for the first time and who wish to participate in the data-sharing programme run through CHIRP. It is an outline only of key features to be considered in implementing the process; every organisation will derive most benefit by adapting the general methods to suit their own company style to ensure ease of application and hence a willingness to use the procedure.

General

The overall culture of the organisation must embrace the objectives of the MEMS. It is particularly important that the most senior members of management openly endorse the programme and this acceptance is demonstrated by all levels of management through their active participation in the process whenever appropriate.

Staff should be encouraged to report errors, hence the need for a disciplinary code that recognises this element of management policy. The two elements of organisational policy, MEMS and disciplinary procedures, must, however, be clearly separate.

Errors can be caused by human failings alone. However, most frequently a procedural or system fault/error can induce the apparent human failure. It is important therefore to ensure the root causes of a maintenance error are identified and rectified. The rectification process should apply to systems and procedures as well as to individuals.

The Process

1. A formal company procedure should be produced that outlines the general principles of the MEMS, the objectives of the procedure and the benefits to the individual and to the organisation. Responsibilities of individuals for operating the MEMS process should be clearly defined. A flow chart is useful in clarifying the process.

2. All staff should be aware of the MEMS in their organisation, its aims and objectives, through a process of education. A training programme for all staff to be subject to the process is now a requirement of JAR-145. Senior management participation in this training will demonstrate their support for the System.
3. A core of staff members with appropriate communications skills should receive additional training in interviewing staff involved in incidents and compiling documentation. This is necessary to ensure that the maximum, accurate, information is obtained from the individuals involved. It also ensures consistency of application of the procedures and acquisition and treatment of data from the process. These individuals must be seen to be impartial in carrying out their duties in the programme. They should span Line, Base and Outstations as appropriate.
4. Events that will trigger an investigation should be defined and publicised to all staff involved directly in the maintenance of aircraft.
5. The reporting format to be used for MEMS should be the Maintenance Error Decision Aid, MEDA, originated by Boeing, to the latest revision standard: CHIRP has produced a CD[25] for the purpose. This is a structured process to determine factors and root causes when investigating maintenance errors and determining possible corrective actions for the future.
6. By using the CHIRP software, completed reports from participating organisations can be readily transmitted to CHIRP and collected into a common, disidentified, database for use by all the participants in the Programme. In this way individual company performance can be compared with a wider spectrum of data; overall trends can be identified and actions to remedy problems highlighted.
7. Maintenance errors should be reported initially within a defined timescale to the person with overall responsibility for the MEMS. These reports may use a common report form with MORs
8. The investigation and interview process should be directed by, and the declared responsibility of, a senior manager in the maintenance department. This is often the manager responsible for airworthiness or the Quality department manager.
9. Timescales for commencing the investigation and interview process should be part of the procedure.
10. Staff with a thorough, up-to-date, knowledge of the work area involved should be engaged in the investigation and interview process.
11. Interviews should be conducted in a calm and quiet atmosphere, free from interruptions. It is important to put the interviewee at ease and not led into a defensive posture. Where it is determined that the company disciplinary procedure should be invoked, the interview should be terminated, the interviewee advised, and the disciplinary procedure started by a member of management who has had no previous involvement with that particular inquiry.
12. Actions designed to correct identified causes of error need to be practical and effective and the results capable of being measured, wherever possible. A named individual should be responsible for their implementation with agreed timescales.
13. Recommendations from an investigation should be subject to a further independent review, within a stated timescale, at a senior, impartial, level of management for

[25] Contact either CHIRP or osdhf@srg.caa.co.uk for a free copy.

endorsement, implementation and subsequent reassessment as to the effectivity of the corrective actions taken.

14. Safety information and lessons learned from finalised reports should be widely disseminated within the organisation especially to those working in maintenance areas.
15. A company database of the information acquired in the course of carrying out these investigations should be built from the outset. This should be capable of analysis to determine significant causes of error and trends. Periodic review and comparisons with the wider CHIRP database may produce information leading to additional action to correct longer-term trends.
16. As part of an overall review of company performance, senior management, and in particular the Accountable Manager, should review periodically the results of database analyses.

Appendix M Safety Culture Tools

Safety Culture Tools

There are several tools in existence (see Table 1) which have been designed to measure a company's "safety culture", or elements thereof. The majority of these tools are fairly generic in nature, although some have been tailored for aviation. Most are based on asking staff their views on certain key issues relating to safety culture, either by means of questionnaires or interview. The tools, therefore, tend to rely upon subjective data, therefore it is extremely important to ensure that people reply honestly, and that views are not unduly influenced by temporary influences (such as industrial disputes).

Ideally, safety culture measures should be looked at in conjunction with objective data from safety audits and the company Maintenance Error Management System (MEMS) as well. Together, the results should give a truthful picture of the company's overall safety culture.

Table 1 Examples of Safety Health Tools.

name	*description*	*applicability*
HSE	Procedural violations questionnaire	
HFRG tool	Improving Maintenance - A Guide to Reducing Human Error. Written by the Human Factors and Reliability Group (HFRG) 2000. Published by HSE Books, ISBN 0 7176 1818 8	Maintenance in all industries
Human Factors Solutions CD-ROM	HSEC Human Factors Solutions CD-ROM	tailored or specific workgroups
HSEC SHoMe Tool	Safety Health of Maintenance Engineering (SHoMe)	aviation maintenance organisations
CAIR	Checklist for Assessing Institutional Resilience (CAIR)	general

Checklist for Assessing Institutional Resilience (CAIR)

This tool is described in James Reason's and Alan Hobb's book "Managing Maintenance Error". CAIR assesses the extent to which the attitudes and practices of an organisation match up to a 'wish-list' (see Table 2) of the features characterising a resilient system - or an organisation with a good safety culture. Answers score as follows: 'yes' = 1, 'don't know' = ½, 'no' = 0. Reason and Hobbs suggest that a total score of 16 to 20 is probably too good to be true, 8 to 15 indicates a moderate to good level of intrinsic resilience, and anything less than 5 indicates an unacceptably high degree of vulnerability.

Table 2. Checklist for Assessing Institutional Resilience (CAIR)

	Yes	*?*	*No*
Managers are ever mindful of the human and organisational factors that can endanger their operations.			
Managers accept organisational setbacks and nasty surprises as inevitable. They anticipate that staff will make errors and train staff to detect and recover from them.			
Top managers are genuinely committed to the furtherance of system safety and provide adequate resources to serve this end.			
Safety related issues and human performance problems are considered at high level meetings on a regular basis, not just after some bad event			
Past events are thoroughly reviewed at top-level meetings and lessons learned are implemented as global reforms rather than as local repairs			
After some bad event, the primary aim of top management is to identify the failed system defences and improve them, rather than seeking to divert responsibility to particular individuals.			
Top management adopts a proactive stance towards safety. That is, it does some or all of the following: takes steps to identify recurrent error traps and remove them, strives to eliminate the workplace and organisational factors likely to provoke errors, 'brainstorms' new scenarios of failure, and conducts regular 'health checks' on the organisational processes known to contribute to accidents.			
Top management recognises that error-provoking system factors (eg. under-manning, inadequate equipment, inexperience, patchy training, bad human-machine interfaces and the like) are easier to manage and correct than fleeting psychological states such as distraction, inattention and forgetfulness.			
It is understood that effective management of safety, just like any other management process, depends critically on the collection, analysis and dissemination of relevant information.			
Management recognises the necessity of combining reactive outcome data (ie. the near miss and incident reporting system) with proactive process information. The latter entails far more than occasional audits. It involves the regular sampling of a variety of institutional parameters (eg. scheduling, budgeting, rostering, procedures, defences, training and the like), identifying which of these 'vital signs' is most in need of attention, and then carrying our remedial action.			
Representatives from a wide variety of departments and levels attend safety related meetings.			
Assignment to a safety related or human factors function is seen as a fast-track appointment, not a dead end. Such functions are accorded appropriate status and salary.			
Policies relating to near-miss and incident reporting systems make clear the organisations stance regarding qualified indemnity against sanctions, confidentiality and the organisational separation of the data-collecting department from those involved in disciplinary proceedings.			
Disciplinary policies are predicated on an agreed (ie. negotiated) distinction			

	Yes	*?*	*No*
between acceptable and unacceptable behaviour. It is recognised by all staff that a small proportion of unsafe acts are indeed reckless and warrant sanctions, but that the large majority of such acts should not attract punishment.			
Line management encourage their staff to acquire the mental as well as the technical skills necessary to achieve safe and effective performance. Mental skills include anticipating possible errors and rehearsing the appropriate recoveries.			
The organisation has in place rapid, useful and intelligible feedback channels to communicate the lessons learned from both the reactive and the proactive safety information systems. Throughout, the emphasis is upon generalising these lessons to the system at large rather than merely localising failures and weaknesses.			
The organisation has the will and the resources to acknowledge its errors, to apologise for them and to reassure the victims (or the relatives) that the lessons learned from such accidents will help to prevent their recurrence.			
It is appreciated that commercial goals and safety issues can come into conflict and measures are in place to recognise and resolve such conflicts in an effective and transparent manner.			
Policies are in place to encourage everyone to raise safety-related issues.			
The organisation recognises the critical dependence of effective safety management on the trust of the workforce - particularly in regard to error and incident reporting programmes.			

This checklist may also be of help when writing the company's safety policy and just culture policy.

A version of the checklist is also included on the Transport Canada website (www.tc.gc.ca/civilaviation/systemsafety/pubs/menu.htm), entitled: "Score your safety culture" checklist - Transport Canada TP13844

The Safety Health of Maintenance Engineering (SHoMe) Tool

The SHoMe tool is a questionnaire based tool developed by Health and Safety Engineering Consultants Ltd (HSEC) on behalf of the UK CAA, in 2003. The tool identifies 19 key issues which potentially affect aviation safety, within an aircraft maintenance organisation. These issues are listed in table 6.

The questionnaires are based upon traditional safety culture survey concepts, but tailored specifically to aviation maintenance. The tool has been validated on several UK maintenance organisations.

The basis of the tool is a set of questionnaires. There are 3 sets questionnaires, for:

- Technical Certifying staff (engineers)
- Technical Non-certifying staff (engineers/ technicians)

- Other staff - non technicians/ engineering support (this includes all staff who are not involved in 'hands-on' maintenance of aircraft, eg. managers, QA, stores, planning, training, technical records, tech services, supply, etc.)

There are three questionnaires:

- Generic questionnaire, containing a series of statements with which staff are asked the extent to which they agree or disagree (see Table 3)
- A job difficulty questionnaire, where staff are asked what aspects of their jobs gave them particular problems during the past 6 months or so (see Table 4)
- An organisational questionnaire, asking staff whether any of the issues listed caused them, or a colleague, (i) to make an error, (ii) confusion or uncertainty, or (ii) otherwise affected airworthiness (see Table 5) during the last 6 months or so.

Technical staff complete all three questionnaires, whilst management and technical support staff complete only the generic questionnaire. The questionnaires are tailored for particular groups of staff.

In order to run the tool, you would need enough data. For small companies, this would mean that virtually all the staff would need to complete the questionnaires; for larger companies, a representative sample of staff would be adequate. The tool is not really suitable for companies with less than 40 staff.

Table 3. Generic questionnaire - example questions

Please indicate the extent to which you agree or disagree with the following statements in relation to your work <u>over the last month or so</u>	strongly agree	agree	not sure	disagree	strongly disagree
Aircraft are sometimes released even if some work can't be done due to parts shortages					
Before I start a job I'm always given the necessary information					
I sometimes go to work when I am ill or feel less than 100%					
I sometimes think my colleagues are confused over their exact roles and responsibilities					
I would be confident flying in an aircraft on which my colleagues had worked after a maintenance check					
Managers always let us know of important safety findings					
People who are prepared to cut corners seem to always get promoted					
The procedures I use are clear and easy to understand					
We have a good system for fixing problems with maintenance manuals and documentation					
We often have to rush jobs due to unrealistic deadlines					
We usually manage to complete a job despite the non-availability of the specified equipment/tools					

Table 4. Job difficulty questionnaire - example questions

	Was this part of your Job?	No problems	Some problems	Major problems
PLANNING: e.g. • Planning your work for each shift • Working to a plan developed by somebody else • Checking work previously done by other people	Y / N			
PREPARATION: e.g. • Obtaining parts / tools / equipment - for planned tasks • Obtaining parts / tools / equipment - unplanned tasks • De-panelling / removing parts for access to work areas	Y / N			
INSPECTION: e.g. • Determining the appropriate inspection standards • Physically carrying out inspections • Raising rectification and defect reports	Y / N			
ROUTINE WORK: e.g. • Routine servicing, cleaning and lubrication • Making component changes • Using specialist tools / equipment • Using facilities for working at height	Y / N			
CHECKS & FUNCTIONAL TESTING: e.g. • Daily routine checks • Checking new parts • Arranging & performing tests to be undertaken • Checking work of non-certifying staff • Housekeeping following completion of job • Checking completed repairs	Y / N			
NON – ROUTINE WORK: e.g. • Diagnosing faults • Carrying out modifications or service bulletins • Carrying out defect rectification	Y / N			
USING MAINTENANCE DATA / MANUALS: e.g. • Using maintenance data • Using work cards • Using maintenance manual • Using company maintenance procedures • Using service bulletins / airworthiness directives • Using "in house" written modifications & inspection documents • Using computer based maintenance information	Y / N			
UPDATING DOCUMENTATION & SYSTEMS: e.g. • Ensuring all work is completed before sign off • Informing others of work completed & sign off • Updating records, data bases etc	Y / N			

Table 5. Organisational questionnaire - example questions

Please read the following list and put a tick against anything which, during the last 6 months or so, has (i) caused you or a colleague to make a mistake or (ii) caused you or a colleague confusion or uncertainty over a job(s) or (iii)otherwise affected airworthiness	
Any general time pressure to meet deadlines	
Distractions and interruptions while you are working	
Effectiveness of preparation of tools, parts and data	
Systems for prioritising jobs	
The effectiveness of the temporary revisions to Maintenance Manuals (MMTR)	
The shift systems adopted by your company	
The staffing levels allocated to each job	
The temperatures you have to work in	
etc	

The tool provides outputs at 3 levels of detail, plus an output in MEDA format. The results identify strengths and weaknesses within the organisation with respect to (i) compliance with procedures and approved methods, and (ii) the 19 key issues in Table 6.

Table 6 Key issues potentially affecting aviation safety

Design & Maintenance Interface
Provision of Resources
Training
Fatigue
Complacency
Planning
Communications
Commercial Pressures
Maintenance Procedures
Roles & Responsibility
Management Attitudes
Safety Commitment of the Engineers/Staff
Job Pressure
Working Conditions
No-Blame/Fair-Blame Culture
Management of Change
Supervisor Effectiveness
Supervisor Attitudes
Competence

The tool does not offer solutions, since solutions are often very context specific. However, it does offer enough information in order to identify which solutions might be most appropriate to address the weaknesses (eg. better designed procedures in combination with improved staff training), and where they might be best targeted (eg. line maintenance at Base X).

Companies may apply the tool as a one-off measure, possibly as part of an audit, or re-apply it at a later date in order to measure any improvements over time. Whilst any improvements cannot be proven to be directly attributable to any one specific safety initiative (such as human factors training, or a MEMS system), it has been designed such that the results focus upon human factors issues, and are more likely to indicate improvements associated with the elements of a human factors and safety management programme as identified in this CAP.

Note: The tool is intended to measure the "safety health" of an organisation, not "health and safety" associated with the protection of individual staff members.

Further details concerning this tool may be found in the documents: CAAP 2003/10, : CAAP 2003/11 and : CAAP 2003/12, all free to download from the CAA website www.caa.co.uk. Copies of the software can be obtained, at no charge, by contacting the CAA Research Management Department or emailing osdhf@srg.caa.co.uk.

UKHFCAG Staff Opinion Survey on Company Safety Culture

The following survey was taken from: People, Practices and Procedures in Aviation Engineering and Maintenance: A practical guide to Human Factors in the Workplace" produced by the UK HF Combined Action Group (UKHFCAG).

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	1	2	3	4	5

(I)	The management understands the problems that I face in my job. with my supervisor.		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

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 carried out before any changes are put in place.

Maintenance Environment Questionnaire - Alan Hobbs

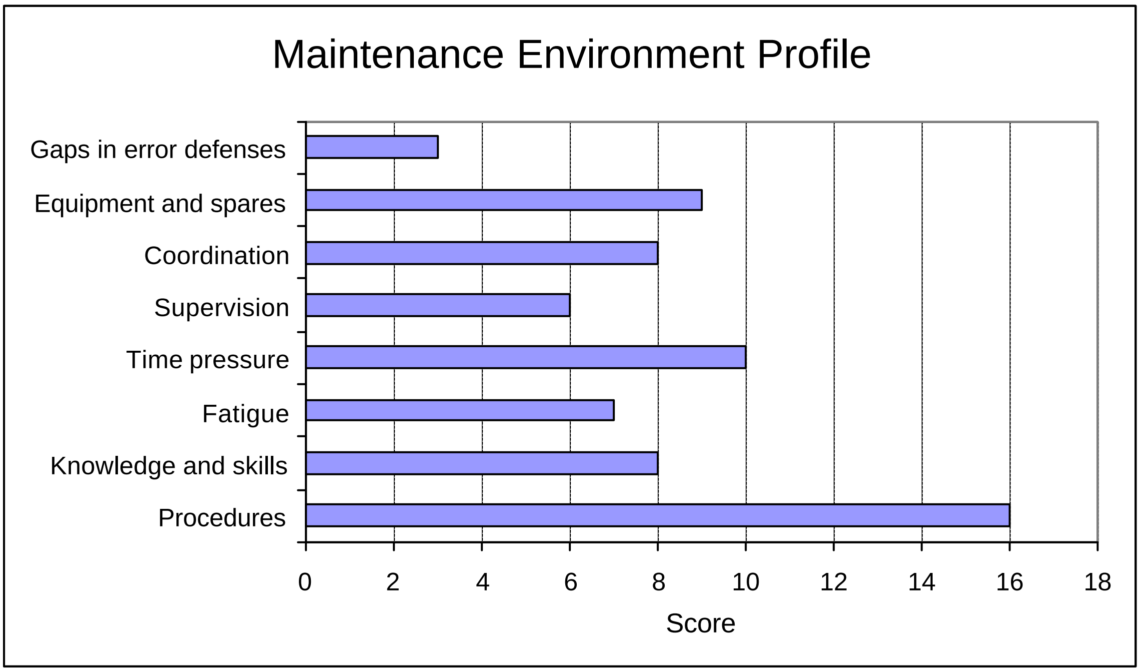
The work environment can play a significant role in provoking maintenance errors. An analysis of approximately 600 aircraft maintenance incidents in Australia identified that over 23% of incidents involved time pressure, 14% involved equipment deficiencies, while training, fatigue and coordination breakdowns were each involved in around 12% of incidents. The Maintenance Environment Questionnaire (MEQ) is designed to evaluate the level of such error-provoking conditions in maintenance workplaces.

The MEQ evaluates the following seven error-provoking conditions:

Procedures	Awkward or unworkable procedures, or inadequate documentation.
Equipment	Problems with maintenance support equipment or tools, or a lack of necessary equipment, including spare parts.
Supervision	Factors relating to the management and oversight of junior or un-licensed personnel.
Knowledge	A lack of system knowledge, training or experience.
Time pressure	Work being performed under unusual time pressure or haste, in some cases self-imposed.
Coordination	Problems with teamwork or communication between workers.
Fatigue	Factors related to a lack of adequate night time sleep or long work days.

In addition, the questionnaire contains items addressing maintenance defences, or ‘safety nets’ in the system. No amount of effort can completely eliminate maintenance error, but the impact of errors can be reduced through defences such as dual inspections and functional checks.

Each MEQ question is intended to relate to one (or in a few cases two) of the eight issues referred to above. In many cases, the action referred to in the question is relatively trivial or everyday, however the answers may indicate the presence of wider system problems. For example, using a broken ladder may point to a wider issue relating to maintenance support equipment. The eight factor scores are the main output of the survey. Once the questionnaire has been completed by a sample of maintenance personnel the ratings are combined to create a profile.



Different error producing conditions tend to provoke different unsafe acts in the maintenance environment. For example, equipment deficiencies increase the probability of violations or system workarounds. Fatigue may increase the chance of memory lapses such as access hatches not closed. Time pressure is a common factor in both violations and memory lapses. Reducing the level of error provoking conditions in the workplace, reduces the probability of maintenance errors.

It must be stressed that the MEQ is not intended to evaluate individuals. While many of the questions concern errors or violations, the focus of the questionnaire is not the behaviour itself, but the work context in which the behaviour occurred.

An early version of the questionnaire was completed by 1400 aircraft maintenance engineers in Australia. A revised questionnaire has been completed by over 1000 airline maintenance personnel in various countries. This questionnaire and survey results have not yet been published, because the work was still underway at the time if publication of Issue 2 of CAP 716.

Further Reading

1. CAAP 2003-11 - Safety Health of Maintenance Engineering (SHoMe) tool: User Guide
2. CAAP 2003-12 - Introduction to the Safety Health of Maintenance Engineering (SHoMe) tool
3. Managing Maintenance Error. Reason and Hobbs. 2003. Ashgate.
4. Unsafe Acts and Unsafe Conditions in Aircraft Maintenance. Hobbs and Williamson. Ergonomics 2002, vol45, No12, pp 866-882.

Appendix N AN47 - Personal Responsibility of LAEs When Medically Unfit or Under The Influence Of Drink Or Drugs

Although it has always been an offence for a member of the flight deck crew, an air traffic controller, or a licensed maintenance engineer to work whilst impaired through drink or drugs, there was no set limit as to the amount of alcohol that could be consumed prior to carrying out an aviation function. Similarly, there were no powers to test an individual suspected of being under the influence of alcohol or drugs.

In July 2003 Royal Assent was given to new legislation to give the police powers to test pilots for drink or drugs where there is reasonable suspicion. The legislation puts in place an alcohol testing regime similar to that already existing in other transport modes. The new powers also cover air traffic controllers and aircraft maintenance engineers. For aircrew the blood/alcohol limit set is 20 milligrammes of alcohol per 100 millilitres of blood and 80 milligrammes per 100 millilitres for licensed aircraft maintenance engineers. The different limits reflect the fact that although licensed aircraft maintenance engineers perform a safety critical role in aviation, they do not necessarily require the same speed of reaction as aircrew or air traffic controllers in an emergency situation. The new legislation came into effect in late 2003.

Note: the information below has been taken directly from CAP455, AN47 Issue 6 (October 2003). At this time, AN47 had not been updated to reflect the 2003 legislation concerning alcohol and drug testing for safety critical aviation personnel.

INTRODUCTION

1.1 The International Civil Aviation Organisation (ICAO) has introduced an amendment to Annex 1 to the convention on international civil aviation which will have the effect of extending certain standards and recommended practices to all licence holders. The changes resulting from the amendment are concerned with medical fitness and the use or abuse of intoxicating liquor, narcotics or drugs.

1.2 To implement these changes the Air Navigation No. 2 Order 1995 (ANO) introduced two new Articles. Article 13(7) which prohibits the exercise of the privileges of an aircraft maintenance engineer's licence when the holder knows or suspects that their physical or mental condition renders him or her unfit to exercise such privileges, and Article 13(8) which prohibits the exercise of licence privileges when the holder is under the influence of drink and/or drugs to such an extent as to impair their capacity to exercise such privileges.

1.3 JAR-66 (Certifying Staff-Maintenance) was adopted on 3 April 1998 and became effective on 1 June 1998. In a similar manner to the ANO Articles 13(7) and (8), JAR 66.50 imposes a requirement that certifying staff must not exercise the privileges of their certification authorisation if they know or suspect that their physical or mental condition renders them unfit. The associated Acceptable Means of Compliance (AMC 66.50) mentions alcohol and drugs. The guidance material in this Notice should be considered equally applicable to JAR- 66.

1.4 It should be noted that JAR-66 also refers to mental fitness and specifically states that the holder must not exercise the privileges of their licence/authorisation if a 'mental condition renders them unfit to exercise such privileges'. In this sense, mental condition means psychological integrity.

2 GENERAL

2.1 An aircraft maintenance engineer’s licence authorises the holder, subject to any conditions that may be specified on the licence, to issue various certificates relating to aircraft maintenance. The process of issuing these certificates (Certificates of Maintenance Review, Certificates of Release to Service and Certificates of Fitness for Flight under the 'A' Conditions) requires clear decisions to be made that directly affect the airworthiness of the aircraft to which they relate. It follows that the quality of these decisions is directly influenced by the physical and mental state of the certifier at the time of certification, and whether or not they are subject to the adverse effects of drink and/or drugs.

2.2 The corporate management of all approved maintenance orgainisations are required to review this Airworthiness Notice and implement suitable policies and procedures to make all maintenance staff aware of them – whilst the requirements of Articles 13(7) and 13(8) or JAR 66.50, by definition, fall on those who certify the completion of maintenance, the guidance material contained in this Airworthiness Notice is equally applicable to all nonlicensed personnel engaged in aircraft maintenance tasks and in principle should be adopted throughout the aviation industry as a code of practice. Organisations shall also take note of items in paragraph 3 which require their participation in the areas concerned.

2.3 All persons to whom this notice applies should be aware of the guidance material contained herein. It is the responsibility of the individual concerned to ensure that they do not report for duty or certify if they are genuinely unfit. Such persons should also be aware of an organisation’s own internal policies and monitoring procedures to verify the above.

3 GUIDANCE

3.1 Fitness

In most professions there is a duty of care by the individual to assess their own fitness to carry out professional duties. This has been a legal requirement for some time for doctors, flight crew members and air traffic controllers. Licensed aircraft maintenance engineers are also now required by law to take a similar professional attitude. Cases of subtle physical or mental illness may not always be apparent to the individual but as engineers often work as a member of a team any sub-standard performance or unusual behaviour should be quickly noticed by colleagues or supervisors who should notify management so that appropriate support and counselling action can be taken. In particular, a decrease in mental fitness in many cases may be related to stress from within the working environment or to the personal circumstances of the individual. Instances of aggressive behaviour, vagueness and slippage of personal standards (cleanliness, appearance etc.) may be indicative of more serious mental issues. Such issues may bring into question the ability of the individual to be trusted or to maintain the necessary levels of concentration to take appropriate decisions on airworthiness matters.

3.2 Fatigue

Tiredness and fatigue can adversely affect performance. Excessive hours of duty and shift working, particularly with multiple shift periods or additional overtime, can lead to problems. Whilst the safety management aspects of these matters are being addressed through the UK Operators Technical Group individuals should be fully aware of the dangers of impaired performance due to these factors and of their personal responsibilities.

3.3 Stress

Everyone is subject to various stresses in their life and work. Stress can often be stimulating and beneficial but prolonged exposure to chronic stress (high levels or differing stress factors) can produce strain and cause performance to suffer allowing mistakes to occur. Stress factors can be varied, physical – e.g. heat, cold, humidity, noise, vibration; they can be due to ill-health or worries about possible ill-health; from problems outside the workplace – e.g. bereavements, domestic upsets, financial or legal difficulties. A stress problem can manifest itself by signs of irritability, forgetfulness, sickness absence, mistakes, or alcohol or drug abuse. Management have a duty to identify individuals who may be suffering from stress and to minimise workplace stresses. Individual cases can be helped by sympathetic and skilful counselling which allows a return to effective work and licensed duties.

3.4 Eyesight

A reasonable standard of eyesight is needed for any aircraft engineer to perform their duties to an acceptable degree. Many maintenance tasks require a combination of both distance and near vision. In particular, such consideration must be made where there is a need for the close visual inspection of structures or work related to small or miniature components. The use of glasses or contact lenses to correct any vision problems is perfectly acceptable and indeed they must be worn as prescribed. Frequent checks should be made to ensure the continued adequacy of any glasses or contact lenses. In addition, colour discrimination may be necessary for an individual to drive in areas where aircraft manoeuvre or where colour coding is used, e.g. in aircraft wiring. Organisations should identify any specific eyesight requirement and put in place suitable procedures to address these issues.

3.5 Hearing

The ability to hear an average conversational voice in a quiet room at a distance of 2 metres (6 feet) from the examiner is recommended as a routine test. Failure of this test would require an audiogram to be carried out to provide an objective assessment. If necessary, a hearing aid may be worn but consideration should be given to the practicalities of wearing the aid during routine tasks demanded of the individual.

It is important to remind employers of individuals working in areas of high ambient noise of the requirement of the Noise at Work Regulations 1989 which require employers to carry out assessments of noise levels within their premises and take appropriate action where necessary.

3.6 Drug and Alcohol Abuse

Drinking problems or the use of illicit or non-prescribed drugs are unacceptable where aircraft maintenance safety is concerned and once identified will lead to suspension of the licence or company authorisation and possibly further licensing action being considered.

3.7 Medication

Any form of medication, whether prescribed by a doctor or purchased over the counter and particularly if being taken for the first time, may have serious consequences in the aviation maintenance environment unless three basic questions can be answered satisfactorily:

(a) Must I take medicines at all?

(b) Have I given this particular medication a personal trial for at least 24 hours before going on duty, to ensure that it will not have adverse effects on my ability to work and make sound decisions?

(c) Do I really feel fit for work? Confirming the absence of adverse effects may need expert advice and General Practitioners, Company Medical Officers and the Medical Division of the Civil Aviation Authority are all available to assist in this matter. Common types of medication in use and their effects are further described in Appendix 1.

3.8 Alcohol

Alcohol has similar effects to tranquillisers and sleeping tablets and may remain circulating in the blood for a considerable time, especially if taken with food. It should be borne in mind that a person may not be fit to go on duty even eight hours after drinking large amounts of alcohol. Individuals should therefore anticipate such effects upon their next duty period. Special note should be taken of the fact that combinations of alcohol and sleeping tablets, or anti-histamines, can form a highly dangerous or even lethal combination.

3.9 Anaesthetics

It should be remembered that following local, general, dental and other anaesthetics, a period of time should elapse before returning to duty. This period will vary depending upon individual circumstances, but may even extend to 24 or 48 hours. Any doubts should be resolved by seeking appropriate medical advice.

4 SUMMARY

4.1 The effects of illness, injury or medication on work performance are the direct concern of the individual. Where there is doubt about the ability of an individual to make sound technical decisions the implications of Article 13(7) and 13(8) of the ANO 2000 or JAR 66.50 must be taken into account i. e. the individual must not exercise the privileges of their licence or authorisation whilst unfit. While this notice gives some guidance on the issues to be considered it cannot be comprehensive. If individual licence holders or their managers have any doubt they should consult the medical sources mentioned for advice.

If there is any difficulty in obtaining this advice the local CAA office should be contacted in the first instance and they, in turn, may seek guidance from the CAA Medical Department. The contact details of the CAA regional offices are provided in AN29.

Appendix 1 to AN47 ***Issue 2 25 October 2002***

The following are some of the types of medicine in common use which may impair work performance. This list is not exhaustive and care should be taken in ensuring the likely effects of any prescribed drug are adequately known before taking it.

(a) Sleeping Tablets – These dull the senses, cause mental confusion and slow reaction times. The duration of effect is variable from person to person and may be unduly prolonged. Individuals should have expert medical advice before using them;

(b) Anti-depressants – These can depress the alerting system and have been a contributory cause of mistakes leading to fatal accidents. A person should stop work when starting anti-depressants and only return when it is clear that there are no untoward side-effects. It is recommended that individuals seek medical advice from their General Practitioner or appropriate medical specialist before returning to work;

(c) Antibiotics – Antibiotics (penicillin and the various mycins and cyclines) and sulpha drugs may have short term or delayed effects which affect work performance. Their use indicates that a fairly severe infection may well be present and apart from the effects of these substances themselves, the side-effects of the infection will almost always render an individual unfit for work;

(d) Anti-histamine – Such drugs are widely used in cold cures and in the treatment of hay fever, asthma and allergic skin conditions. Many easily obtainable nasal spray and drop preparations contain anti-histamines. Most of this group of medicines tend to make the taker feel drowsy. Their effect, combined with that of the condition, will often prevent the basic three questions (paragraph 3.7 of the Notice) from being answered satisfactorily. Admittedly very mild states of hay fever etc., may be adequately controlled by small doses of anti-allergic drugs, but a trial period to establish the absence of side effects is essential before going on duty. When individuals are affected by allergic conditions which require more than the absolute minimum of treatment and in all cases of asthma, one of the above mentioned sources of advice should be consulted;

(e) ‘Pep’ pills (e.g. containing Caffeine, Dexedrine, Benzedrine) used to maintain wakefulness are often habit forming. Susceptibility to each drug varies from one individual to another, but all of them can create dangerous over-confidence. Over-dosage may cause headaches, dizziness and mental disturbances. The use of ‘pep’ pills whilst working cannot be permitted. If coffee is insufficient, you are not fit for work;

(f) Drugs for the relief of high blood pressure are proving to be very effective in controlling this condition. However, antihypertensive agents all have some side effects and should not be administered before adequate assessment of the need for treatment. The prescribing practitioner should be able to advise on any side effects to be considered;

(g) Drugs when prescribed for Anti-malaria in normally recommended doses do not usually have any adverse effects. However, the drug should be taken in good time so that the question in paragraph 3.7 (b) of the Notice can be answered;

(h) Oral contraceptive tablets in the standard dose do not usually have adverse effects, although regular supervision is required;

(i) ‘SUDAFED’ is the trade name of a preparation containing pseudo-ephedrine hydrochloride. This may be prescribed by GPs for relief of nasal congestion. Side-effects reported however are anxiety, tremor, rapid pulse and headache. The preparation does not contain anti-histamines which could sedate and cause drowsiness but the effects can nevertheless affect skilled performance. Sudafed, therefore, is not a preparation to be taken when making engineering decisions or performing licenced duties.

NOTE: Although the above are common groups of drugs, which may have adverse effects on performance, it should be pointed out that many forms of medication, which although not usually expected to affect efficiency may do so if the person concerned is unduly sensitive to a particular drug. Therefore no drugs, medicines, or combinations, should be taken before or during duty unless the taker is completely familiar with the effects on him or her of the medication and the drugs or medicines have specifically been prescribed for the individual alone. Again the sources of advice mentioned earlier in this notice should be consulted in cases of doubt.

Appendix O Visual inspection and NDI.

The FAA's Advisory Circular on Visual Inspection for Aircraft defines it as follows:
"Visual Inspection is the process of using the eye, alone or in conjunction with various aids, as the sensing mechanism from which judgments may be made about the condition of a unit to be inspected."
The US Visual Inspection Research Program uses the following definition:
"*Visual inspection is the process of examination and evaluation of systems and components by use of human sensory systems, aided only by mechanical enhancements to sensory input, such as magnifiers, dental picks, stethoscopes, and the like. The visual input to the inspection process may be accompanied by such behaviors as listening, feeling, smelling, shaking, twisting, etc."*

Visual inspection is one of the primary methods employed during maintenance to ensure the aircraft remains in an airworthy condition. The majority of inspection is visual (80% to 99%, depending on circumstances); 1% to 20% is Non-Destructive Inspection (NDI). There has been a great deal of research carried out on NDI, quite a lot on visual inspection in the manufacturing industry, but, until recently, less on visual inspection in an aviation maintenance environment. The US have attempted to rectify this as part of their major research programme on human factors and aviation maintenance and inspection, with much valuable research having been carried out by Drury[26], of New York State University at Buffalo[27], and others. The UK have also carried out research on both visual inspection and NDT, both the Cranfield[28][29] work and that carried out by AEA technology[30] concentrating upon the human factors aspects of inspection. A comparison[31] has been made of the US and UK research, the conclusion being that there is much common ground in the results obtained.

One of the main reasons for the particular interest in visual inspection was the Aloha accident, where poor visual inspection was one of the main contributors to the accident. The accident report list of findings included:

- *"There are human factors issues associated with visual and nondestructive inspection which can degrade inspector performance to the extent that theoretically detectable damage is overlooked."*
- *"Aloha Airlines management failed to recognize the human performance factors of inspection and to fully motivate and focus their inspector force toward the critical nature of lap joint inspection, corrosion control and crack detection. However, reports of fleet-wide cracks received by the FAA after the Aloha Airlines accident*

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[26] Drury, C. G. (1992). Inspection performance. In G. Salvendy (Ed)., Handbook of Industrial Engineering, Second Edition, 88, New York: John Wiley and Sons, 2282-2314.
[27] Drury, C. G. (in press). Human Factors in Aviation Maintenance. In Garland, D. J., Wise, J. A. and Hopkin, V. D. (Eds.), Aviation Human Factors, Chapter 25, New York: L. Erlbaum Associates Inc.
[28] CAA Paper 85013. Reliability on In-Service Inspection of Transport Aircraft Structures. 1985.
[29] Lock, M., Strutt, J. Inspection reliability for transport aircraft structures. CAA Paper 90003.1990
[30] Murgatroyd, R., Worrall, G., Waites, C. A Study of the Human Factors Influencing the Reliability of Aircraft Inspection. AEA report AEA/TSD/0173. July 1994. (summarised in CAA Paper 96010).
[31] Murgatroyd, R., Worrall, G., Drury, C., Spencer, F. Comparison and Further Analysis of CAA and FAA Inspection Reliability Experiments. CAA Paper 96010

indicate that a similar lack of critical attention to lap joint inspection and fatigue crack detection was an industry-wide deficiency."

There are clearly specified vision standards for inspectors involved in Non-Destructive Testing (NDT). Two of the well-known standards are contained in the ATA Specification 105 (1993), and the (draft) European Standard for the Qualification and Approval of Personnel involved in NDT (1994)[32] - see Table 1.

Table1. Vision standards for NDT inspectors

Requirement	MT	ET	UT	RT
Near vision: Jaeger No.1 or equivalent, not less than 30cm, one eye, with or without correction	X			X
Near vision: Jaeger No.2 or equivalent, not less than 30cm, one eye, with or without correction		X	X	
Colour perception: Personnel shall be capable of distinguishing and differentiating colours used in the process involved. Where it is not possible to devise a suitable test, Ishihara test may be used.	X	X	X	X
NDT methods: PT= Liquid penetrant; MT= Magnetic particle; ET= Eddy current; UT= Ultrasonic; RT= Radiography				

Note: Licences issued by airworthiness authorities apply to the use and accomplishment of inspections using penetrant dye (red leaching penetrant dye) techniques, where eyetests are not a prerequisite. Therefore there is (at the time of writing this document) an anomaly between the general licence eyesight requirements (ie. AWN47) and NDT visual requirements (ie. Jaeger No.1 and colour vision).

Workplace factors which may affect inspection reliability may include:

- Access to the aircraft
- Access to the task (e.g. fuel tanks)
- Cleanliness of the inspection area
- Noise, heating, lighting
- Feeling of safety and comfort
- Equipment, eg. torch, mirror, penknife, hand lens, coin

Motivation & attitude rarely seems to be a factor which adversely affects aircraft inspection reliability. Adverse attitude more often leads to increasing the time to do the inspection and/or an inspector's snag rate goes up resulting in increased cost to the company.

Visual inspection reliability depends on two main things: (i) seeing the defect and (ii) recognising what you see is a defect. The inspection task can be broken down into distinct elements (these are detailed in the FAA literature). Knowing which of these elements is unreliable helps direct efforts towards appropriate remedial measures (see table 2).

[32] the draft European Standard for the Qualification and Approval of Personnel involved in NDT (1994) prEN 4179

There are substantial common elements between visual and NDI inspection. Both require an element of visual inspection or concentration although the NDI techniques used may well permit detection of defects below the visual thresholds for doing so. The rectification action is the same in either case. It is obvious that we must make change if we wish to improve the performance of the individual in detecting faults. This may be achieved by influencing the inspector's behaviour and/or by changing the support system that the inspector works to.

Table 2. Potential strategies for improving aircraft inspection (visual and NDI)

	Strategy	
	Training for inspectors	*System changes*
Initiate	Training in NDI calibration (Procedures training)	Redesign of job cards Calibration of NDI equipment Feedforward of expected flaws
Access	Training in area location (Knowledge and recognition training)	Better support stands Better area location system Location for NDI equipment
Search	Training in visual search (cueing, progressive-part)	Task lighting Optical aids Improved NDI templates
Decision	Decision training (cueing, feedback, understanding of standards)	Standards at the work point Pattern recognition job aids Improved feedback to inspection
Action	Training writing skills	Improved fault marking Hands-free fault recording

Source: FAA Phase I Progress report, 1991

Training should always be supported by adequate experience. Experience in both general and specific tasks is important to become proficient in:

- searching an area or system for defects
- recognising and interpreting defect indications
- making judgements on serviceability

The efficiency and effectiveness of an inspector is heavily dependent on his experience. The quality of his judgement depends not only on the number of times he has experienced the defect, but on the reinforcement he gets from feedback, eg. an external toilet leak may be considered insignificant upon first finding but feedback from Tech Services report of 'blue ice' telling him why it is significant will affect his judgement in the future.
Feed-forward improves performance as it primes the inspector of known and potential defects in the inspection area.

Repetitive tasks, eg. detailed inspections of rivets along a lap joint, are tedious, boring and lead to errors being made (missed defects). The effects are made worse when the inspector has a very low expectation of finding a discrepancy, eg. on a new aircraft. Motivation and arousal are low without the reward of a defect.

Effective detection of defects requires preparation for the task, paperwork and equipment, mental preparation, adoption of the correct attitude prior to commencing, and maintaining that attitude throughout the inspection. A consistent and appropriate inspection strategy needs to be adopted making sure that visual sweeps are comprehensive and cover the required area. Periodic breaks are essential in order to refresh the ability to concentrate. Such breaks should, however, be aligned to natural breaks in the inspection process, eg. a particular frame, lap joint, etc.

Manufacturing tolerances for aircraft materials take into account the probability of detection of cracks during visual inspection, attempting to ensure that materials are strong enough such that small cracks which are unlikely to be detected by the eye are not going to have a hazardous effect in flight. However, visual inspection performance depends on many more factors than just the size of the defect, and probability curves differ slightly depending on the nature of the task.

Studies have found that there can be large differences between individual inspectors in terms of their performance. Inspectors who were good at one aspect of inspection may not be that good at other aspects[33]. Training and experience may enable inspectors to improve performance in some areas, eg. visual search strategy, and 'visual lobe size', ie. the area which he can cover in a single glance. Further information concerning how training might improve such areas can be found in the *hfskyway* website.

There is an excellent report which provides detailed and practical human factors related to penetrant dye techniques: *Human Factors Good Practices in Flourescent Penetrant Inspection. Drury, C. FAA. August 1999.* This report describes 86 best practices in nondestructive inspection techniques and describes why each best practice should be used. This document can be used directly by maintenance engineering staff involved in NDT.

Further Reading:

1. Drury, C. Human Factors Good Practices in Flourescent Penetrant Inspection. FAA. August 1999FAA. Human Reliability in Aircraft Inspection. FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase II Report, Chapter Five. 1992
2. Drury, C. FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase V Report. Chapter 9 : Support of the FAA/AANC Visual Inspection Research Program (VIRP). In: *FAA CDROM and hfskyway website.*
3. Drury, C. Support of inspection research at the FAA Technical Center and Sandia National Laboratories. FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase VI Report, Chapter 10.
4. Drury, C. Inspection Performance. In: Salvendy, G. Handbook of Industrial Engineering, 88. John Wiley and Sons, 1992.
5. NTSB. Aircraft Accident Report--Aloha Airlines, Flight 243, Boeing 737-200, N73711, near Maui, Hawaii, April 28, 1988. NTSB 89/03

[33] Drury, C. G. and Wang, M. J. (1986). Are research results in inspection tasks specific? In Proceedings of the Human Factors Society 30th Annual Meeting, 393-397.

Appendix P Working Time Requirements and Guidelines

Introduction

There were, at the time of writing this document, no duty time limitations for maintenance personnel in the JAA or EASA requirements, the only requirement relating to fatigue being that requiring planners to take into account human performance and limitations (Part-145.A.47(b)). However, national UK legislation exists addressing duty time, based upon the EC Working Time Directive 93/104/EC, 23/11/93. Whilst the rationale behind the EU Directive, and its UK national implementation, is to protect individuals rather than to ensure aviation safety, nevertheless appropriate implementation of this requirement should mean that individuals do not work excessively long hours which may jeopardise aviation safety.

However, this legislation does not guarantee that individuals will be prevented from working excessive hours, in some cases (eg. 'opt-outs' for instance), nor will it guarantee avoidance of fatigue. For this reason, the CAA recently funded a study to produce best practice guidelines for work hours within the aviation maintenance industry which, if applied appropriately by organisations and individuals, should help reduce potential problems with fatigue among staff.

Summaries of both the UK working time regulations, and the CAA sponsored "best practice guidelines" produced by Professor Simon Folkard, have been included in this Appendix. There are also other methods of helping to reduce risks associated with fatigue, including computer models and fatigue management techniques, some of which are referenced in Chapter 4.

1. Summary of UK Government Working Time Regulations

The following information has been extracted directly from the Guidance on the Department of Trade and Industry (Dti) website www.dti.gov.uk/er/work_time_regs/index.htm

Introduction

The UK Working Time Regulations implement the European Working Time Directive

Certain sectors were originally excluded from the scope of the Regulations. However, with effect from 1 August 2003, the regulations were extended to previously excluded sectors, including all workers in aviation who are not covered by the sectoral Aviation Directive. This includes aviation maintenance personnel. Further details can be found on the DTI website.

In summary, the working time regulations introduces:

- a limit of an average of 48 hours a week which a worker can be required to work (though workers can choose to work more if they want to).
- a limit of an average of 8 hours work in 24 which nightworkers can be required to work.
- a right for night workers to receive free health assessments.
- a right to 11 hours rest a day.
- a right to a day off each week.
- a right to an in-work rest break if the working day is longer than six hours.
- a right to four weeks paid leave per year.

Working Time Limits

- Workers cannot be forced to work for more than 48 hours a week on average.
- Young Workers (under 18) may not ordinarily work more than 8 hours a day or 40 hours a week, although there are certain permitted exceptions (see Dti website for more details)
- Working time includes travelling where it is part of the job, working lunches and job-related training.
- Working time does not include travelling between home and work, lunch breaks, evening classes or day-release courses.
- The average weekly working time is normally calculated over 17 weeks. This can be longer in certain situations (26 weeks) and it can be extended by agreement (up to 52 weeks - see Dti website for more details)
- Workers can agree to work longer than the 48-hour limit. An agreement must be in writing and signed by the worker. This is generally referred to as an opt-out. It can be for a specified period or a indefinite period. There is no opt-out available from the Young Workers limits.
- Workers can cancel the opt-out agreement whenever they want, although they must give their employer at least seven days' notice, or longer (up to three months) if this has been agreed.
- The working time limits do not apply if workers can decide how long they work (ie. elect to sign an opt-out)

An individual worker may agree to work more than 48 hours a week. If so, he or she should sign an opt-out agreement, which they can cancel at any time. The employer and worker can agree how much notice is needed to cancel the agreement, which can be up to three months. In the absence of an agreed notice period, the worker needs to give a minimum of seven days' notice of cancellation.

Employers cannot force a worker to sign an opt-out. Any opt-out must be agreed to. Workers cannot be fairly dismissed or subjected to detriment for refusing to sign an opt-out.

Employers must keep a record of who has agreed to work longer hours.

Working at Night

- A night worker is someone who normally works at least three hours at night.
- Night time is between 11pm and 6am, although workers and employers may agree to vary this.
- Night workers should not work more than eight hours daily on average, including overtime where it is part of a night worker's normal hours of work.
- Nightly working time is calculated over 17 weeks. This can be longer in some situations.
- A night worker cannot opt-out of the night work limit
- Young workers should not ordinarily work at night, although there are certain exceptions (please see see Dti website fro more details).

If workers work less than 48 hours a week on average they will not exceed the night work limits. Two examples are given in Tables 1 and 2 below:

Table 1. Example 1 of night work calculation

A night worker normally works four 12-hour shifts each week The total number of normal hours of work for a 17-week reference period is: 17 weeks of 4 shifts of 12 hours 17 x (4 x 12) = 816 There are 119 days (17 weeks) and the worker takes 17 weekly rest periods, as entitled to under the regulations. Therefore the number of days the worker could be asked to work is 119 - 17 = 102 To calculate the daily average working time, the total of hours is divided by the number of days a worker could be required to work: 816 divided by 102 = 8 This equals an average of 8 hours a day

Table 2. Example 2 of night work calculation

A night worker normally works 5 days of 10 hours followed by 3 days of rest. The cycle starts at the beginning of the reference period (so there are 15 cycles of work). The worker takes 2 weeks' leave and works 6 hours overtime every five weeks. During this reference period, the overtime is worked in the fifth, tenth, and fifteenth weeks. The leave does not affect the calculation of normal hours, but the overtime does. 15 cycles of 5 shifts of 10 hours = 15 x (5 x 10) = 750 hours 6 hours overtime x 3 = 18 = 768 hours (including overtime) There are 119 days (17 weeks) and the worker takes 17 weekly rest periods, as entitled to under the regulations. Therefore the number of days the worker could be asked to work is: 119 - 17 = 102 To calculate the daily average working time, the total of hours is divided by the number of days a worker could be required to work. 768 divided by 102 = 7.53 This equals an average of 7.53 hours a day.

Special hazards

Where a night worker's work involves special hazards or heavy physical or mental strain, there is an absolute limit of eight hours on the worker's working time each day – this is not an average.

Work will involve a special hazard if it is identified:

- as such by agreement between an employer and workers in a collective agreement or workforce agreement; or
- as posing a significant risk by a risk assessment which an employer has conducted under the Management of Health and Safety at Work Regulations 1999.

Health Assessments for Night Workers

- If you are an employer you must offer night workers a free health assessment before they start working nights and on a regular basis while they are working nights. In many cases it will be appropriate to do this once a year, though employers can offer a health assessment more than once a year if they feel it is necessary.
- Workers do not have to take the opportunity to have a health assessment (but it must be offered by the employer).
- A health assessment can be made up of two parts: a questionnaire and a medical examination. The latter is only necessary if the employer has doubts about the worker's fitness for night work.

- Employers should get help from a suitably qualified health professional when devising and assessing the questionnaire. This could be from a doctor or nurse who understands how night working might affect health.
- The health assessment should take into account the type of work that will be done and the restrictions on the worker's working time under the regulations.
- If a worker suffers from problems which are caused or made worse by night work, the employer should transfer him or her to day work if possible.
- New and expectant mothers should be given special consideration.
- Special consideration should be given to young workers' suitability for night work, taking account of their physique, maturity and experience.

Health assessments must be offered before someone starts working nights. They should then be repeated on a regular basis afterwards.

If a qualified health professional advises that a night worker is suffering from health problems caused by or made worse by working at night, the worker has a right to be transferred, if possible, to suitable day work.

Further details may be obtained from the Dti website.

Time Off

Daily rest

A worker is entitled to a rest period of 11 uninterrupted hours between each working day.

Weekly rest

A worker is entitled to one whole day off a week.

Days off can be averaged over a two-week period, meaning workers can take two days off a fortnight. Days off are taken in addition to paid annual leave.

Employers must make sure that workers *can* take their rest, but are not required to make sure they *do* take their rest.

Rest Breaks at Work

If a worker is required to work for more than six hours at a stretch, he or she is entitled to a rest break of 20 minutes.

The break should be taken during the six-hour period and not at the beginning or end of it. The exact time the breaks are taken is up to the employer to decide.

Employers must make sure that workers *can* take their rest, but are not required to make sure they *do* take their rest.

'Adequate rest' means that workers have regular rest periods. These should be sufficiently long and continuous to ensure that fatigue or other irregular working patterns do not cause workers to injure themselves, fellow workers or others, and that they do not damage their health, either in the short term or in the longer term.

Paid Annual Leave

- Every worker – whether part-time or full-time – covered by these regulations is entitled to four weeks' paid annual leave.
- A week's leave should allow workers to be away from work for a week. It should be the same amount of time as the working week: if a worker does a 5-day week, he or she is entitled to 20 days' leave; if he or she does a 3-day week, the entitlement is 12 days' leave.
- The leave entitlement under the regulations is not additional to bank holidays. There is no statutory right to take bank holidays off. Therefore a worker who is not otherwise paid in respect of bank holidays may take bank holidays as part of their annual leave entitlement in order to receive payment for these holidays.
- Workers must give the employer notice that they want to take leave.
- Employers can set the times that workers take their leave, for example for a Christmas shutdown.
- If a worker's employment ends, he or she has a right to be paid for the leave time due and not taken.

More about the application of the regulations

There are four classes of exceptions where some of the rules may not apply.

1 Agreements

In general, employers and workers can agree that the night work limits, rights to rest periods and rest breaks may be varied, with the workers receiving "compensatory rest" (see below). They may also agree to extend the reference period for the working time limits up to 52 weeks.

These agreements can be made by 'collective agreement' (between the employer and an independent trade union) or a 'workforce agreement'. If a worker has any part of their conditions determined by a collective agreement they can not be subject to a workforce agreement.

A workforce agreement is made with elected representatives of the workforce in most cases (see below). A workforce agreement can apply to the whole workforce or to a group of workers. To be valid, a workforce agreement must:

- be in writing;
- have been circulated in draft to all workers to whom it applies together with the guidance to assist their understanding of it;
- be signed before it comes into effect either; - by all the representatives of the members of the workforce or group of workers; or

  - if there are 20 workers or fewer employed by a company, either by all representatives of a workforce or by a majority of the workforce;
- have effect for no more than five years.

2 Special circumstances

The night work limits (including the limit for special hazards), rights to rest periods and rest breaks do not apply where:

- A worker works far away from where he or she lives (this includes offshore work). Or he or she constantly has to work in different places making it difficult to work to a set pattern.
- The work involves security or surveillance to protect property or individuals.
- The job requires round-the-clock staffing as in hospitals, residential institutions, prisons, media production companies, public utilities, and in the case of workers concerned with the carriage of passengers on regular urban transport services or in industries where work cannot be interrupted on technical grounds.
- There are busy peak periods, such as may apply seasonally in agriculture, retail, tourism and postal services.
- An emergency occurs or something unusual and unforeseen happens.
- Where the worker works in rail transport and his activities are intermittent; he spends his time working on board trains; or his activities are linked to transport timetables and to ensuring the continuity and regularity of traffic.

In these cases, (except for the offshore sector) the reference period for the weekly working time limit is extended from 17 to 26 weeks. In addition workers are entitled to "compensatory rest".

What is compensatory rest?

"Compensatory rest" is normally a period of rest the same length as the period of rest, or part of a period of rest, that a worker has missed.

The regulations give all workers a right to 90 hours of rest in a week. This is the total of your entitlement to daily and weekly rest periods. The exceptions allow you to take rest in a different pattern to that set out in the regulations.

The principle is that everyone gets their entitlement of 90 hours rest a week on average, although some rest may come slightly later than normal.

3 Unmeasured working time

The working time limits and rest entitlements, apart from those applicable to young workers, do not apply if a worker can decide how long he or she works.

A test, set out in the regulations, states that a worker falls into this category if "the duration of his working time is not measured or predetermined, or can be determined by the worker himself".

An employer needs to consider whether a worker passes this test. Workers such as senior managers, who can decide when to do their work, and how long they work, are likely to pass the test. Those without this freedom to choose are not.

4 Partly unmeasured working time

There is an exception for workers who have an element of their working time pre-determined, but otherwise decide how long they actually work.

There is a test. This is that: "the specific characteristics of the activity are such that, without being required to do so by the employer, the worker may also do work [in addition to that which is measured or pre-determined] the duration of which is not measured or pre-determined or can be determined by the worker himself".

Any time spent on such additional work will not count as working time towards the weekly working time or night work limits. Simply put, additional hours which the worker chooses to do without being required to by his employer do not count as working time; therefore, this exception is restricted to those that have the capacity to chose how long they work. The key factor for this exception is worker choice without detriment.

Some or none of a worker's working time may meet the test. Any working time that does meet it will not count towards the 48-hour weekly working time limit or the night work limits.

This exception does not apply to:

- working time which is hourly paid;
- prescribed hours of work;
- situations where the worker works under close supervision;
- any time where a worker is expressly required to work, for example attendance of meetings;
- any time a worker is implicitly required to work, for example because of the loading or requirements of the job or because of possible detriment if the worker refuses.

Further examples, and FAQs are available on the Dti website.

2. Folkard Guidelines on Work Hours for Aircraft

Maintenance Personnel

The following recommendations for “good practice” have been taken directly from the report CAAP 2002/06 "Work Hours of Aircraft Maintenance Personnel" (March 2003). This work was carried out by Professor Simon Folkard, on behalf of the CAA.

Background

The International Context

There is widespread international concern over the safety implications of the work schedules of aircraft maintenance engineers. Studies of these schedules have been conducted, or are underway, in Australia, Canada, France, Japan, New Zealand, and the U.S.A. and it is probable that this list is by no means exhaustive. For example, a Canadian study has found that aircraft maintenance engineers typically sleep for between 6 and 7.1 hours only on workdays between long or extended shifts and it is noteworthy that this finding is in agreement with the results of this study, in which the normal sleep durations between morning/day and night shifts were found to average 6.8 and 6.5 hours respectively.

Likewise, the finding of over 100 different shift systems in the present study is similar to the French results obtained for Air France aircraft maintenance engineers. In New Zealand, the introduction of a 12-hour shift system (2D2N4R) has proved highly successful and popular with those concerned, but in Japan changes to the shift systems involving greater numbers of successive work-days have given rise to considerable concern over safety. The FAA has supported a number of research studies, and reports based on these are available from their website (http://hfskyway.faa.gov). The FAA’s overall aim, is to identify risk factors and avoidance techniques with a view to alleviating errors or incidents that could lead to an accident.

Risk and Fatigue

The basic aim of any set of guidelines for “good practice” must clearly be to minimise the risk of an error or mistake being made. There is very good evidence that the likelihood of mistakes or errors increases when individuals are fatigued. However, the objective scientific evidence on trends in risk reviewed in Section 1 and 2 indicates that these do not necessarily show the same trends as those in fatigue, and indeed may sometimes show a very different trend. This is despite the fact that many objective measures of performance, such as reaction time, have been shown to parallel subjective fatigue measures very closely. Thus models based on subjective estimates of fatigue, while clearly a potentially extremely useful tool, may thus sometimes result in spurious conclusions or recommendations. Further, it should be emphasised that individuals’ perceptions of risk do not always show the same pattern as objectively assessed risk. The approach adopted here is thus to base recommendations on the objective trends in risk where these are available, and to supplement this with evidence from studies of fatigue or sleep duration where objective risk data is unavailable.

Risk Management Programmes

Concern over risk is not confined to the aircraft maintenance industry and it would be foolish to ignore approaches to risk management that have proved successful in other sectors.

Such approaches range from a relatively simple set of limitations on the work hours of a particular occupational group, such as the CAA's own "Scheme for the Regulation of Air Traffic Controller's Hours" to more general schemes such as Western Australia's scheme for "Fatigue Management" in commercial vehicle drivers. These more general schemes include recommendations for the scheduling of work hours, but also cover wider ranging issues such as the individual's readiness to work, workplace conditions, training and education, documentation and records, and the management of incidents.

The current project was primarily concerned with issues relating to work schedules and any associated flight safety risk, and the recommendations made for best practice must thus necessarily be confined to this aspect of a risk management programme. However, it should be emphasised that although these recommendations could be implemented by themselves, they should ideally form part of a wider ranging risk management programme.

Guidelines for "Good Practice"

Underlying Principles

Wherever possible, the guidelines proposed here are based on established trends in risk. These were derived from reviewing large-scale studies of accidents and/or injuries in many different types of industry and country. However, there are many features of work schedules that may give rise to concern with respect to their impact on sleep and/or fatigue, but for which there are, as yet, no good studies showing their impact on risk. In these cases, and in the absence of objective risk data, the guidelines have been based on the available evidence relating these features to sleep and/or fatigue. The aims in these cases have been threefold, namely to:

1. Minimise the build up of fatigue over periods of work
2. Maximise the dissipation of fatigue over periods of rest
3. Minimise sleep problems and circadian disruption

Daily limits

There is good evidence that risk increases over the course of a shift in an approximately exponential manner such that shifts longer than about 8 hours are associated with a substantially increased risk. Thus, for example, it has been estimated that, all other factors being equal, the risk on a 12-hour shift system is some 27.6% higher than that on an 8-hour system. Shifts longer than 12-hours should thus clearly be considered as undesirable. For the same reason, it would seem wise to limit the extent to which a shift can be lengthened by overtime to 13 hours. Likewise, it would seem prudent to ensure that the break between two successive shifts is sufficient to allow the individual concerned to travel home, wind-down sufficiently to sleep, have a full 8-hour sleep, have at least one meal, and travel back to work. The EU's Working Time Directive sets this limit at 11 hours, and this would be consistent with a maximum work duration, including overtime, of 13 hours. Three daily limits are thus recommended, namely:

1. *No scheduled shift should exceed 12 hours.*
2. *No shift should be extended beyond a total of 13 hours by overtime.*
3. *A minimum rest period of 11 hours should be allowed between the end of shift and the beginning of the next, and this should not be compromised by overtime.*

Breaks

There is surprisingly little evidence on the beneficial effects of breaks on risk. However, there is evidence that fatigue builds up over a period of work, and that this can be, at least partially, ameliorated by the provision of breaks. There is also recent, and as yet unpublished, evidence that risk behaves in a similar manner, increasing in an approximately linear fashion between breaks. It would thus seem prudent to recommend limits on the duration of work without a break, and on the minimum length of breaks. It should be emphasised here that there is some evidence to suggest that frequent short breaks are more beneficial than less frequent longer ones. However, it is recognised that work demands may prevent the taking of frequent short breaks. In the light of this, and of the findings from the survey regarding the provision of breaks, two limits are thus recommended, namely:

4. *A maximum of fours hours work before a break.*
5. *A minimum break period of ten minutes plus five minutes for each hour worked since the start of the work period or the last break.*

Weekly Limits

Fatigue accumulates over successive work periods and it is thus necessary to limit not only the daily work hours, but also the amount of work that can be undertaken over longer periods of time. The aim here is to ensure that any accumulation of residual fatigue is kept within acceptable limits, and can be dissipated over a period of rest days. However, if these limits are simply related to the calendar week this can result in unacceptably high numbers of shifts or work-hours between successive periods of rest days. It is thus necessary to express the limits with respect to any period of seven successive days. In the light of this, and the findings from the survey, the following recommendations are made:

6. *Scheduled work hours should not exceed 48 hours in any period of seven successive days.*
7. *Total work , including overtime, should not exceed 60 hours or seven successive work days before a period of rest days.*
8. *A period of rest days should include a minimum of two successive rest days continuous with the 11 hours off between shifts (i.e. a minimum of 59 hours off). This limit should not be compromised by overtime*

Annual Limits

Some residual fatigue may accumulate over weeks and months despite the provision of rest days, therefore annual leave is important. There is, however, little evidence to indicate what might be considered an ideal number of days annual leave. Accordingly, based on the survey results it is suggested that 28 days annual leave would be appropriate. This aligns with the EU working time directive. 21 days annual leave should be the minimum. In the light of this the following recommendation is made:

9. *Wherever possible, a total of 28 days annual leave should be aimed for and this should not be reduced to less than 21 days leave by overtime.*

Limits on Night Shifts

There is good objective evidence that risk is increased at night by about 30% relative to the morning/day shift. There is also good evidence indicating that risk increases in an approximately linear fashion over at least four successive night shifts, such that it is about 45% higher on the fourth night shift than on the first night shift. However, given the increased risk on 12-hour shifts relative to 8-hour shifts, it would seem prudent to take account of shift duration in recommendations for limiting successive night work. It is also the case that a single night's sleep following a span of night shifts may not fully dissipate the fatigue that may accumulate over a span of night shifts. Finally, there is published evidence that later finish times to the night shift can result in shorter day sleeps between successive night shifts, and there was some support for this finding in the current survey. In the light of these considerations and the findings from the survey, the following recommendations are made:

10. *A span of successive night shifts involving 12 or more hours of work should be limited to 6 for shifts of up to 8 hours long, 4 for shifts of 8.1 to 10 hours long, and 2 for shifts of 10.1 hours or longer. These limits should not be exceeded by overtime.*
11. *A span of night shifts should be immediately followed by a minimum of two successive rest days continuous with the 11 hours off between shifts (i.e. a minimum of 59 hours off) and this should be increased to three successive rest days (i.e. 83 hours off) if the preceding span of night shifts exceeds three or 36 hours of work. These limits should not be compromised by overtime.*
12. *The finish time of the night shift should not be later than 08:00.*

Limits on Morning/Day shifts

There is good objective evidence that an early start to the morning/day shift can result in a substantial truncation of sleep. The extent of this truncation depends on the time at which the individual has to leave home which in turn is largely determined by the start time of the shift. Indeed, it has been reported that for each hour earlier that individuals have to leave home to travel to their morning/day shift they sleep for 46 minutes less. However, operational and local factors sometimes necessitate early start times. It is also the case that a balance needs to be achieved between later starts to the morning/day shift and earlier finishes to the night shift with a view to maximising the sleep duration between both types of shift. In the light of this and the findings from the survey, the following recommendations are made:

13. A morning or day shift should not be scheduled to start before 06:00, and wherever possible should be delayed to start between 07:00 and 08:00.

14. A span of successive morning or day shifts including 32? Or more hours of work that start before 07:00 should be limited to four, immediately following which there should be a minimum of two successive rest days continuous with the 11 hours off between shifts (i.e. a minimum of 59 hours off).. This limit should not be compromised by overtime.

Days notice of Schedule

There is no objective evidence that the number of days notice given of a schedule effects risk or fatigue, but it was perceived as influencing risk in the survey. In the light of this finding from the survey, the following recommendation is made:

15. Wherever possible aircraft maintenance engineers should be given at least 28 days notice of their work schedule.

Further Recommendations for "Good Practice"

The following recommendations are not specifically concerned with the scheduling of work hours and fall outside the area of expertise of the author. Nevertheless, it is clear that recommendations for the features of work schedules form only one part, albeit a major one, of a comprehensive risk management programme.

16. Employers of aircraft maintenance personnel should consider developing risk management systems similar to those required by Western Australia's Code of Practice for commercial vehicle drivers.

17. Educational programmes should be developed to increase aircraft maintenance engineers' awareness of the problems associated with shiftwork. In particular, it is important to draw their attention to the objective trends in risk with a view to increasing their vigilance at points when risk may be high despite the fact that fatigue may not be. It is also important to provide information on how to plan for nightwork, and to give guidance on the health risks which seem to be associated with shift work, particularly at night.

18. Aircraft maintenance personnel should be required to report for duty adequately rested.

19. Aircraft maintenance personnel should be discouraged or prevented from working for other organisations on their rest days, and hence from exceeding the proposed recommendations on work schedules despite their implementation by their main employer.

Summary of Recommendations

- *No scheduled shift should exceed 12 hours.*

- *No shift should be extended beyond a total of 13 hours by overtime.*
- *A minimum rest period of 11 hours should be allowed between the end of shift and the beginning of the next, and this should not be compromised by overtime.*
- *A maximum of fours hours work before a break.*
- *A minimum break period of ten minutes plus five minutes for each hour worked since the start of the work period or the last break.*
- *Scheduled work hours should not exceed 48 hours in any period of seven successive days.*
- *Total work , including overtime, should not exceed 60 hours or seven successive work days before a period of rest days.*
- *A period of rest days should include a minimum of two successive rest days continuous with the 11 hours off between shifts (i.e. a minimum of 59 hours off). This limit should not be compromised by overtime.*
- *Wherever possible, a total of 28 days annual leave should be aimed for and this should not be reduced to less than 21 days leave by overtime.*
- *A span of successive night shifts should be limited to 6 for shifts of up to 8 hours long, 4 for shifts of 8.1 to 10 hours long, and 2 for shifts of 10.1 hours or longer. These limits should not be exceeded by overtime.*
- *A span of nights shifts involving 12 or more hours of work should be immediately followed by a minimum of two successive rest days continuous with the 11 hours off between shifts (i.e. a minimum of 59 hours off) and this should be increased to three successive rest days (i.e. 83 hours off) if the preceding span of night shifts exceeds three or 36 hours of work. These limits should not be compromised by overtime.*
- *The finish time of the night shift should not be later than 08:00.*
- *A morning or day shift should not be scheduled to start before 06:00, and wherever possible should be delayed to start between 07:00 and 08:00.*
- *A span of successive morning or day shifts that start before 07:00 should be limited to four, immediately following which there should be a minimum of two successive rest days continuous with the 11 hours off between shifts (i.e. a minimum of 59 hours off). This limit should not be compromised by overtime.*
- *Wherever possible aircraft maintenance engineers should be given at least 28 days notice of their work schedule.*
- *Employers of aircraft maintenance personnel should consider developing risk management systems similar to those required by Western Australia's Code of Practice for commercial vehicle drivers.*
- *Educational programmes should be developed to increase aircraft maintenance engineers' awareness of the problems associated with shiftwork. In particular, it is important to draw their attention to the objective trends in risk with a view to increasing their vigilance at points when risk may be high despite the fact that fatigue may not be. It is also important to provide information on how to plan for nightwork, and to give guidance on the health risks which seem to be associated with shift work, particularly at night.*
- *Aircraft maintenance personnel should be required to report for duty adequately rested.*

- *Aircraft maintenance personnel should be discouraged or prevented from working for other organisations on their rest days, and hence from exceeding the proposed recommendations on work schedules despite their implementation by their main employer.*

The UK SMS CAG Guidelines on Work Hours

At the time of writing Issue 2 to CAP 716, guidelines were in preparation by the UK Safety Management System Combined Action Group, concerning work hours for aircraft maintenance personnel.

Transport Canada NPA on Fatigue Management

At the time of writing Issue 2 to CAP 716, Transport Canada were in the process of preparing a Notice of Proposed Amendment to their aviation requirements, to include fatigue management. Please consult the TC website (www.tc.gc.ca) for further details, during 2004.

Computer Models of fatigue

There are some computer models whereby employers may input rosters and the software will indicate whether these would appear to be reasonable, and where fatigue is likely to result. These models are based upon scientific principles.

The UK CAA has sponsored the development, by Qinetiq, of a fatigue model known as the System for Aircrew Fatigue Evaluation (SAFE). Whilst this has been primarily designed with aircrew in mind, the principles would also apply to maintenance engineers. Further details of this model are available from the CAA Research Management Department.

The Centre for Sleep Research at the University of Southern Australia has also developed a fatigue model, again not specifically for maintenance personnel, but nevertheless applicable, details of which may be obtained from www.unisa.edu.au/sleep or www.interdyne.com.au.

Appendix Q Environmental Factors & Tooling

1. General

Aviation maintenance has many features in common with other industries. The physical facilities in which aviation technicians work, however, are unique. No other industry uses quite the combination of facilities, including exposed aprons, aircraft hangars, workshops, offices, inspection rooms, etc. The primary reason for using hangars is obvious, of course. Aviation maintenance technicians work on aircraft, and hangars are often needed to shelter aircraft and workers from the elements for certain maintenance activities.

Aircraft hangars present a range of human factors issues. They are generally quite large and are built so that most of the floor area is unobstructed by structural support members. This design allows large aircraft to be moved and parked in the building. Their vast areas and high ceilings make hangars difficult to light properly. Their large, unobstructed volume makes public address systems difficult to hear. Large, open doors make controlling temperature and humidity problematic. The use of extensive and elevated, multi-level access platforms is common due to the sizes of today's aircraft and the varying heights of component locations. Access requirements vary according to the nature of the work being carried out. In some cases, the close proximity of different pieces of equipment to each other bring its own problems. Individual workspaces tend to be clustered around certain areas of the aircraft, eg. undercarriage bays and engines.

This section of the document provides guidance concerning those elements of the physical environment which we can control, to a certain extent, including temperature, noise and lighting.

2. Regulatory requirements

The EASA requirements have attempted to address some of the environmental factors affecting performance, in particular Part-145.A.25 (c)[34]: *"The working environment must be appropriate for the task carried out and in particular special requirements observed. Unless otherwise dictated by the particular task environment, the working environment must be such that the effectiveness of personnel is not impaired"*

AMC-145.A.25(c) expands upon this as follows:

- Hangars used to house aircraft together with office accommodation should be such as to ensure the working environment permits personnel to carry out work tasks in an effective manner.
- Temperatures should be maintained such that personnel can carry out required tasks without undue discomfort.
- Dust and any other airborne contamination should be kept to a minimum and not be permitted to reach a level in the work task area where visible aircraft/component surface contamination is evident.

[34] JAR145.25(c) 10 July 1998

- Lighting should be such as to ensure each inspection and maintenance task can be carried out.
- Noise levels should not be permitted to rise to the point of distracting personnel from carrying out inspection tasks. Where it is impractical to control the noise source, such personnel should be provided with the necessary personal equipment to stop excessive noise causing distraction during inspection tasks.
- Where a particular maintenance task requires the application of specific environmental conditions different to the foregoing, then such conditions should be observed. Specific conditions are identified in the approved maintenance instructions.
- The working environment for line maintenance should be such that the particular maintenance or inspection task can be carried out without undue distraction. It therefore follows that where the working environment deteriorates to an unacceptable level in respect of temperature, moisture, hail, ice, snow, wind, light, dust/other airborne contamination, the particular maintenance or inspection tasks should be suspended until satisfactory conditions are re-established.
- For both base and line maintenance where dust/other airborne contamination results in visible surface contamination, all susceptible systems should be sealed until acceptable conditions are re-established.

Maintenance personnel should be able to expect that the requirements for the provision of access equipment, the adequacy of the environment and the other related issues are such that the requirements for Part-145 and AMC-145 are met. The organisation is responsible for such provision. Where the individual requires specific support in order to adequately carry out an inspection or to work on aircraft systems, the job should ideally wait until the necessary equipment is available.

Further Reading:

1. Part-145.25(c) and AMC-145.25 (c)
2. Maddox M, Ed. Human Factors Guide for Aviation Maintenance 3.0 (1998) . Chapter 5: Facility design.
3. Meghashyam, G. Electronic Ergonomic Audit System for Maintenance and Inspection. Proceedings of the Tenth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, 1996
4. Ergonomic audit for visual inspection of aircraft. S Koli, C Drury, J Cuneo, J Lofgren. Chapter 4, FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase IV Progress Report, 1995. *hfskyway.faa.gov*
5. Environmental requirements of maintenance organisations. F Workley (Manager Maintenance Operations, National Air Transportation Association) Proceedings of the Eighth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, 1993

3. ERgoNomic Audit Programme (ERNAP)

The following information has been extracted from "Electronic Ergonomic Audit System for Maintenance and Inspection. G Meghashyam (Galaxy Scientific Corporation, Atlanta, Georgia) Proceedings of the Tenth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, 1996". This document and the associated ERNAP tool may be found on *http://hfskyway.faa.gov*. Note: the tool was developed in the USA therefore some of the descriptions may reflect the North American maintenance culture and terms; however, the principles should also be applicable to Europe and the UK.

Introduction to ERNAP

This Ergonomic Audit Program was developed at Galaxy Scientific Corporation, in cooperation with the State University of New York at Buffalo, for the Federal Aviation Administration (FAA), Office of Aviation Medicine (AAM). The purpose of the development task was to integrate a variety of ergonomic audit tools into a comprehensive package. This ergonomic auditing system called "ERgoNomic Audit Program" (or ERNAP), can be used to carry out an ergonomic evaluation of maintenance and inspection operations. ERNAP also can be used to guide designers to build ergonomically efficient procedures and systems. ERNAP is simple to use and applies ergonomic principles to evaluate existing and proposed tasks and setups. It also suggests ergonomic interventions.

The audit program

From detailed task descriptions and task analyses of maintenance and inspection activities, a generic function description was developed. An audit program involves data collection, data analysis, data storage, and results presentation. Data is collected through a series of observations and readings. This data collected is then analysed based on guidelines and standards. The analysis is then presented to the user in a suitable and useful format. All the data collected, the data analyses, and its results can be saved for later reference if necessary. This entire process can be performed using a manual (paper-based) method or a computer-based method.

Table 1 Classification of Modules in ERNAP

	Data Collection phases		
Human Factors Grouping	Pre-Maintenance phase	Maintenance phase	Post-Maintenance phase
Information Requirements	1. Documentation 2. Communication	6. Documentation 7. Communication	23. Feedback
Environment	3. Visual Characteristics	8. Task Lighting 9. Thermal Characteristics 10. Thermal Perception 11. Auditory Characteristics	
Equipment / Job Aids	4. Equipment Design 5. Access Equipment	12. Equipment Availability 13. Access Availability	
Physical Activity / Workspace		14. Hand Tools 15. Force Exertion 16. Manual Materials Handling 17. Vibration 18. Repetitive Motion 19. Physical Access 20. Posture 21. Safety 22. Hazardous Materials	

ERNAP data can be collected directly by using a portable computer, or by using the paper form of the checklists. Data collection is classified into three phases:

- · Pre-maintenance
- · Maintenance
- · Post-maintenance.

The Data Collection module consists of twenty-three checklists. A brief description of each checklist is given below:

Pre-maintenance phase

1. Documentation: Concerns itself with information readability, information content: text & graphics and information organization.
2. Communication: Between-shift communication and availability of lead mechanics/ supervisors for questions and concerns.
3. Visual Characteristics: Overall lighting characteristics of the hanger: overhead lighting, condition of overhead lighting, and glare from the daylight.
4. Electrical/pneumatic equipment issues: Evaluation of the equipment which uses controls: ease of control, intuitiveness of controls, and labelling of controls for consistency and readability.
5. Access Equipment: Evaluation of ladders and scaffold for safety, availability and reliability.

Maintenance Phase

6. Documentation: Physical handling of documents and the environmental conditions affecting their readability, i.e., weather and light.
7. Communication: Communication issues between co-workers and supervisors, and whether or not suggestions by mechanics are taken into consideration.
8. Task lighting: The overall lighting available to the mechanic for completing the task. Evaluates the points such as light levels, whether personal or portable lighting is used, and whether the lighting equipment is causing interference with the work task.
9. Thermal issues: The current conditions of thermals in the environment in which the task is being performed.
10. Operator perception: Operator perceptions of the work environment at present, during summer, and during winter.
11. Auditory issues: Determine if the sound levels in the current work environment will cause hearing loss or interfere with tasks or speech.
12. Electric and pneumatic issues: The availability of any electrical/pneumatic equipment, whether the equipment is working or not, and ease of using the equipment in the work environment.
13. Access equipment: Availability of ladders and scaffolds, whether the equipment is working or not, and ease of using the equipment in the work environment.
14. Handtools: Evaluates the use of hand tools, whether or not the hand tools are designed properly to prevent fatigue and injury, and usability by both left and right handed people.
15. Force requirements: Forces exerted by the mechanic while completing a maintenance task. Posture, hand positioning, and time duration are all accounted for.
16. Manual Material Handling: Uses NIOSH 1991 equation to determine if the mechanic is handling loads over the recommended lifting weight.
17. Vibration: Amount of vibration a mechanic encounters for the duration of the task. Determines if there are possible detrimental effects to the mechanic because of the exposure.
18. Repetitive motion: The number and frequency of limb angles deviating from neutral while performing the task. Takes into consideration arm, wrist, shoulder, neck, and back positioning.
19. Access: Access to the work environment; whether it is difficult or dangerous, or if there is conflict with other work being performed at the same time.
20. Posture: Evaluates different whole-body postures the mechanic must assume in order to perform the given task.
21. Safety: Examines the safety of the work environment and what the mechanic is doing to make it safer, e.g., meaning of personal protective devices.
22. Hazardous material: Lists the types of chemicals involved in the maintenance process, whether or not the chemicals are being used properly, if disposal guidelines are being followed, and if the company is following current requirements for hazardous material safety equipment.

Post maintenance

23. Usefulness of feedback information to the mechanic.

4. Climate and temperature.

Humans can operate within quite a wide range of temperatures and climatic conditions, but performance is adversely affected at extremes, and is best within a fairly narrow range of conditions. Although this text refers mainly to maintenance carried out in hangars, it is realised that some work must take place outside hangars, often in extreme heat, cold, wind, snow, rain or humidity. This may be unavoidable, but technicians and mangers should be aware of the effects of extremes in temperature and climatic conditions upon their performance, both within and outside the hangar.

Environmental conditions outside the comfort zones can affect performance directly (eg. limiting manual dexterity in cold conditions, affecting concentration, etc.), or indirectly (eg. if a technician is working outside in the cold, it may not affect his cognitive or physical performance but he may rush the task in order to get back to a warmer hangar or rest room). This text concentrates upon the more direct performance affects, particularly those relating to the cooler European climates, but the indirect effects should not be dismissed.

There is little degredation in cognitive task performance in hot conditions, the physiological heat stress limitations taking effect before any significant cognitive decrements. Some studies have found that mental performance is affected by cold, but the evidence is not conclusive. It is probable that, in normal maintenance environments, the effect of low temperatures upon manual dexterity is the factor most likely to affect work. If a technician has to wear gloves for warmth, this is not particularly conducive to manual dexterity, and is a good indication that the hangar is too cold.

It is difficult to strictly control temperatures in hangars due to the large expanses of space to heat or cool, and the fact that the hangar doors need to be opened and closed from time to time, to let aircraft and large equipment in and out of the hangar. It may be expensive to continually reheat the air in a hangar each time the heat is lost, but it is important that technicians are able to work in a reasonable temperature environment. Indeed, many Countries have legislation which requires that the working environment is within a certain temperature range, to protect the workers.

The UK legislation[35] covering 'workplaces' (and an aircraft hangar would appear to be included within this definition) requires that temperatures be *"reasonable"* (at least 16°C) during working hours, or, where impractical (such as an aircraft hangar which has to be open to the outside), temperatures should be *"as close as possible to comfortable"*. HSC L24 gives more detailed guidance concerning workplace temperatures. The UK legislation states that "*Where, despite the provision of local heating or cooling, workers are exposed to temperatures which do not give reasonable comfort, suitable protective clothing and rest facilities should be provided. Where practical there should be systems of work (for example, task rotation) to ensure that the length of time for which individual workers are exposed to uncomfortable temperatures is limited*".

[35] HSC L24. Workplace (Health, safety and Welfare) Regulations, 1992. HMSO

Further Reading:

1. Health and Safety Commission. Workplace Health, Safety and Welfare; approved code of practice. L24. 1992. London HMSO. ISBN 0 111 886333 9
2. HSC Approved Code of Practice and Guidance L24.
3. Sanders, M., McCormick, E. Human Factors in Engineering and Design. 1993 Chapter 5
4. Maddox M, Ed. Human Factors Guide for Aviation Maintenance 3.0 (1998) . Chapter 3: Workplace Safety.
5. Salvendy, G. Handbook of Human Factors and Ergonomics. 1997 Chapter 28.
6. Smith, A. P., Jones, D. M. Handbook of Human Performance (Vol I - Physical environment -Chapters 4 and 5).

5. Noise

Noise is covered, to a certain extent, in CAP715, in connection with hearing. It can detrimentally affect human performance in terms of damaging hearing, interfering with speech communication, and affecting concentration and performance on cognitive tasks. It can also be fatiguing. Effects vary between individuals, and noise of a certain type and level may be good for one individual but bad for another, in terms of task performance and errors.

Noise intensity is measured in decibels (dB). Noise frequency is measures in hertz (Hz). Sound pressure is expressed in pascals (1 Pa= 1 newton/m^2). Although noise intensity and frequency can be fairly easily measured, and guidelines set, it is not a simple matter to determine, or predict, the effects of noise upon human performance, and, more particularly, upon errors. The effects on performance must be distinguished from subjective annoyance and changes in physiological state. These three types of measure often do not agree. A person can find noise annoying, yet perform well (and vice versa). A person's perception and control (or perceived control) over the noise can be more important than the actual noise level or intensity.

It is also important to realise that various sources of noise can give rise to situations where the combination of frequencies and volumes produce resonant harmonies. These my be particularly fatiguing, especially where low frequencies are involved, ie. multiple riveting action during structural repair. Noise cannot be eliminated altogether.

Many studies have been carried out looking at what types of tasks are affected by noise, and what types of errors occur. One study[36], for instance, discovered that noise improved the speed of assembling an air conditioner but reduced the speed of assembling a carburettor. The two tasks involved different skills and noise impaired tasks involving a high mental load and high control precision, had no effect on manual dexterity, and facilitated tasks involving physical strength. The variety of tasks undertaken on aircraft may be similarly affected

[36] Levy-Leboyer, A and Moser, G. Noise effects on two industrial tasks. In: Proceedings of the 3rd international congress on noise as a public health problem. 1983

Noise can affect motivation, reduce tolerance for frustration and reduce levels of aspiration. It can lead to the choice of certain strategies (eg. in memory recall or problem solving) in preference to others, and often reinforces use of the dominant strategy. This should not be particularly relevant in normal or routine maintenance tasks where the Maintenance Manual clearly specifies a series of individual steps or actions to accomplish the job. Where the Maintenance manual also requires an element of assessment to be made by the individual as part of the activity, methodology or work strategy, there may be an impact upon the individual's ability to think. It is almost certainly likely to affect inspection or troubleshooting activities where the strategy used is left to the individual, being primarily assessment- rather than activity-based, possibly reducing the likelihood of successfully thinking laterally under such circumstances. How many of us can recall, when concentrating hard on a task, shouting "Stop that noise; I can't think straight!"?

In summary, the effects of noise on performance are extremely complex, with no clear guidance emerging as to what noise levels are likely to adversely affect performance in relation to aviation safety. As a rule of thumb, in the absence of more detailed guidelines, if noise levels are kept within the bounds to protect hearing damage (see Chapter 8- Hearing), this should also avoid situations where noise is likely to have a significantly detrimental affect on performance in general terms. This may not, however, be sufficient to avoid breaking someone's concentration.

The FAA Human Factors Guide for Aviation Maintenance provides advice as to how to measure noise level, particularly in the context of a facility audit. Noise measurement methodologies are also covered in many textbooks, especially those dealing with ergonomics and health and safety at work.

The UK Health and Safety at Work regulations requires a noise assessment to be carried out by a competent person, if noise is above specified levels (simplified, this is about 85 dB(A) for daily personal noise exposure, or 200 pascals for peak sound pressure). There is then a responsibility upon the employer to put in place measure to reduce noise, and to provide employees with advice and equipment concerning noise protection. Further information concerning the noise at work regulations (1989) can be obtained by reading the appropriate legislation or any of the explanatory publications[37].

If noise levels are (likely to be) too high, the best remedial action is to mask the noise source (eg. cover with noise proofing insulation) or move the noise source further away, preferably outside the hangar (see Table 2).

Table 2. Methods for reducing facility noise.

Method	Description
Location	Place noise-producing equipment far away from locations where workers are performing their jobs. Example: Placing air compressors outside the facility

[37] Stranks, J. The handbook of Health and safety Practice, Edn 5. 2000. Pearson Education Ltd.

Insulation	Place sound-absorbing material between the noise source and the workers. Isolate the noise source from the structure of the facility Example: Mount rotating equipment on vibration isolators. Surround equipment with enclosed, sound-absorbing housings
Reflective Absorption	Place sound-absorbing materials on large, flat, and hard reflecting surfaces, such as ceilings, walls, and floors. Example: Use acoustic tile on suspended ceilings. Mount eggcrate foam panels on walls

Although it is preferable to control source noise, this is not always not always practicable, in which case ear protection should be worn, despite the communication difficulties which may arise as a result. Consideration should be given to using active noise cancellation devices, which may protect hearing but reduce the communication problems associated with wearing ear muffs, caps or plugs. This can be particularly important during engine runs or push backs, where good situational awareness is needed to ensure the safety of the individual.

Further Reading:

1. Part-145.A.25(c) and AMC-145.A.25 (c)
2. Maddox M, Ed. Human Factors Guide for Aviation Maintenance 3.0 (1998) . Chapter 5: Facility design.
3. Handbook of Human Performance (Vol I - Physical environment - Chapter 1). Smith, A. P., Jones, D. M.
4. Salvendy, G. Handbook of Human Factors and Ergonomics. 1997 Chapter 24.
5. Sanders, M., McCormick, E. Human Factors in Engineering and Design. 1993. Chapter 18.

6. Illumination.

According to Drury et al[38], visual inspection accounts for almost 90% of all inspection activities; thus, it is imperative that the task be performed in the most suitable work environment. Studies in aircraft inspection have shown that poor illumination, glare and other adverse lighting conditions could be important reasons for "eye strain" or visual fatigue. Visual fatigue causes a deterioration in the efficiency of human performance during prolonged work. Much of the recent literature on lighting requirements is concerned with costs of providing the light, whether purchase costs, operating costs or maintenance costs. However, the purpose of lighting is to allow rapid and effective human performance. The costs of personnel time and the potential cost of even a single human error are orders of magnitude higher than the costs of providing the lighting. Thus, adequacy of lighting should be the major criterion for lighting choice. This Chapter, and Appendix L, aim to provide some guidance concerning lighting.

[38] Evaluating the Visual Environment in Inspection: A Methodology and a Case Study. Chapter 6. FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase III vol I Progress Report, 1993. *hfskyway.faa.gov*

Lighting units are measured according to either the International System of units (SI) or the older US Customary System (USCS). Luminous flux is the rate at which light energy is emitted from a source. The unit of luminous flux is the *lumen* (lm). Luminous intensity is measured in *candelas* (cd); this measures the luminous flux emitted in a given direction. Illuminance, or illumination, is measured in lumens (1 lumen/m² = 1 lux; 1 lumen/ ft² = 1 footcandle), and is used to quantify the amount of light striking a surface. Luminance is the amount of light per unit area leaving a surface, and is measured in cd/m² (or foot-Lamberts (fL), using the old USCS units). For instance, a piece of white paper lying on a table illuminated by 300 lux will have a luminance of about 70-80 cd/m².

The FAA Human Factors in Aviation Maintenance and Inspection, Research Phase Report II, includes guidance for area and task lighting levels. The reader is referred to this document (which can be found on *hfskyway*) for further information. A methodology for evaluating the visual environment in inspection, extracted from the FAA Human Factors Guide, is contained in Appendix B.

The Illuminating Engineering Society recommends illumination levels for area and task lighting for different types of work and situations, eg. 200 to 500 lux for task illumination for 'medium bench and machine work', and an area illumination of 50 to 100 lux. For highly difficult inspection tasks, or for reading poorly reproduced material, they recommend task illumination levels between 1000 and 2000 lux. Some recommendations for lighting levels for aircraft maintenance environments are given at the end of this Chapter. A useful overview of the IES recommendations, and other information concerning lighting levels, can be found in the textbook: Human Factors in Engineering and Design, by Sanders and McCormick.

The UK Health and Safety Executive (HSE) publish guidance on lighting levels (see Table 3). Whilst this guidance is not specifically for aviation maintenance environments, parallels can be drawn with similar work environments.

Table 3. HSE minimum lighting recommendations

Activity	Typical locations/ types of work	Average illuminance (lux)	Minimum measured illuminance (lux)
Movement of people, machines and vehicles	Lorry park, corridors, circulation routes	20	5
Movement of people, machines and vehicles in hazardous areas: rough work not requiring any perception of detail	Construction site clearance, excavation and soil work, loading bays, bottling and canning plants	50	20
Work requiring limited perception of detail	Kitchens, factories, assembling large components, potteries	100	50
Work requiring perception of detail	Offices, sheet metal work, bookbinding	200	100
Work requiring perception of fine detail	Drawing offices, factories assembling electronic	500	200

	components, textile production		

Even though proper levels of illumination are provided, task performance can be degraded if glare sources are present. Glare is of two types. Direct glare is produced when a bright light source falls within the visual field. Indirect glare, often called reflected glare, is reflected from the work surface and reduces the apparent contrast of task materials. Either direct or indirect glare can degrade task performance masking small defects, cracks or imperfections during visual inspections. Table 4 offers suggestions concerning ways to control the effects of glare sources.

Table 4. Techniques for Controlling Glare

To control direct glare:	To control indirect glare:
• Position lighting units as far from the operator's line of sight as practical • Use several low intensity lights instead of one bright one • Use lights that produce a batwing light distribution and position workers so that the highest light level comes from the sides and not from the front and back • Use lights with louvres or prismatic lenses • Use light shields, hoods and visors at the workplace if other method are impractical	• Avoid placing lights in the indirect glare • Use lights with diffusing or polarising lenses • Use surfaces that diffuse light, such as flat paint, non-gloss paper and textured finishes • Change the orientation of a workplace, task, viewing angle, or viewing direction until maximum visibility is achieved.

Adapted from Rogers, 1987

The type of lighting used can also affect colour perception, various types of lighting strengthening some colours but subduing others. This may not be overly important for aircraft exterior maintenance tasks, but may be relevant for visual discrimination between different coloured wiring, or other work where colour differences are important.

The goal of controlling human error in aviation maintenance requires that maintenance be conducted under proper lighting conditions. This is true both for area lighting, that which illuminates the full working area, and task lighting, that directed toward specific work activities. Improper or insufficient lighting can lead to mistakes in work tasks or can simply increase the time required to do the work. In a program directed toward proper lighting conditions, the following guidelines should be observed:

- Area lighting within a maintenance facility should be a minimum of 750 lux. A level of 1000-1500 lux is preferred.
- Care must be exercised to see that the light level available for night maintenance activities in particular does not drop below recommended levels. Any lighting studies must be conducted both during the day and at night.
- Task lighting for aircraft inspection requires a minimum of 1000 lux of illumination. For difficult inspections or fine machine work, 2000-5000 lux of illumination may be necessary.

- Supplemental lighting must be adequate for the task at hand, best judged by the worker. Task lighting should be placed close to the work being done and, if feasible, should leave both of the worker's hands free for the work. If systems must be manipulated, lights mounted on headbands are preferred to flashlights.
- If the workforce contains a substantial percentage of older workers, i.e. those greater than 45 years of age, recommended lighting levels should be increased, probably of the order of 50 percent.
- Glare sources should be controlled. Supplemental lighting should be placed as far from a worker's line of sight as practical. Reflected glare can be changed by reorienting the work surface or changing the position of lights. Worker complaints are the best means for identifying offending glare sources.

It is the responsibility of the organisation to ensure that the workplace lighting is adequate, but individual technicians should not hesitate to draw inadequate lighting to the attention of the management, and to request improvements. The cost of replacing burnt-out bulbs is far less than the cost of an aircraft accident, if a technician fails to notice a problem due to inadequate lighting. It should be a joint responsibility to ensure that portable lighting is adequate, the responsibility being upon the technician to notice when torch batteries are running low, with the organisation normally supplying the necessary equipment and batteries.

Further Reading:

1. Kaufman, J.E., Haynes, H. Eds. IES Handbook 1981. Application Volume. Chapter 9. Illuminating Engineering Society of North America.
2. HSE. Lighting at Work (HSG38). 1997. ISBN 0 7176 1232 5.
3. CIBSE Lighting Guide; the Industrial Environment (LG01). 1989. ISBN 0 900 953 38 1.
4. CIBSE Lighting Guide; the Outdoor Environment (LG06). 1992. ISBN 0 900 953 53 5.
5. Parker, J. The Work Environment in Aviation Maintenance. Human Factors Issues in Aircraft Maintenance and Inspection Meeting 5. 1991. *http://hfskyway.faa.gov*
6. Maddox M, Ed. Human Factors Guide for Aviation Maintenance 3.0 (1998) . Chapter 5: Facility design *http://hfskyway.faa.gov*
7. Salvendy, G. Handbook of Human Factors and Ergonomics. 1997 Chapter 26.
8. Sanders, M., McCormick, E. Human Factors in Engineering and Design. 1993 Chapter 16
9. Smith, A. P., Jones, D. M. Handbook of Human Performance (Vol I - Physical environment -Chapter 11).
10. Design of the aircraft inspection/maintenance visual environment. J Reynolds, A Gramopadhye, C Drury (State University of New York at Buffalo, Department of Industrial Engineering) Proceedings of the Seventh Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, 1992

Appendix R A methodology for evaluating the visual environment in inspection

The following information has been extracted from: "Evaluating the Visual Environment in Inspection: A Methodology and a Case Study". Chapter 6. FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase III vol I Progress Report, 1993. http://hfskyway.faa.gov

1. Introduction

The following information is extracted from a study by Drury et al[39], and represents guidance to develop a methodology which allows adequate lighting equipment to be selected in order to provide an improved visual environment.

The basic principles of lighting and lighting system design, as related to aircraft inspection, are described in this Appendix.

The study, on which this appendix is based, carried out site visits to assess the existing visual environment in aircraft inspection. An evaluation was undertaken at a single facility in order to acquire detailed data and to demonstrate how to perform a human factors investigation of a visual environment. This investigation included photometric evaluations of the ambient and task lighting as well as input from inspectors at four different facilities. Concurrently, alternative portable and personal lighting sources were evaluated at the same facility and in the laboratory. Recommendations were offered based upon the information obtained. This information is not included here, but may be found by consulting the original document on *http://hfskyway.faa.gov*.

The study illustrates the utility of using an organised approach to structure the various components which comprise a visual environment in order to allow adequate light sources to be suggested.

The methodology which was derived from the study is detailed in this appendix.

2. Light characteristics/lighting system design

Four fundamental light characteristics (i.e., light level, colour rendering, glare and reflectance), the principles of specialised lighting, and the basic requirements of lighting design need to be considered in relation to aircraft inspection.

Light Level

The recommended illumination depends upon the type of task and whether the visual task is of high or low contrast. General lighting requirements for different tasks can be found in Eastman Kodak (1983) and Illuminating Engineering Society (IES). Vision can be improved

[39] Evaluating the Visual Environment in Inspection: A Methodology and a Case Study. Chapter 6. FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase III vol I Progress Report, 1993. *hfskyway.faa.gov*

by increasing the lighting level, but only up to a point, as the law of diminishing returns operates. Also, increased illumination could result in increased glare. Older persons are more affected by the glare of reflected light than younger people, and inspectors are often senior personnel within a maintenance organisation.

According to IES (1987), direct, focused lighting is recommended for general lighting in aircraft hangars. Inspection of aircraft takes place in an environment where reflections from aeroplane structures can cause glare so that low brightness luminaries should be installed. Often, additional task lighting will be necessary when internal work, or shadowed parts around the aircraft, result in low illumination levels.

Table 1 presents the required illumination levels for aircraft maintenance and inspection tasks (IES, 1987). Generally, most maintenance tasks require between 750 lux and 1000 lux, although more detailed maintenance tasks may require additional illumination. General line inspections (e.g., easily noticeable dents) may only require 500 lux; however, most inspection tasks demand much higher levels. From the site observations of actual defects, it is apparent that many difficult inspection tasks may require illumination levels up to or exceeding 5000 lux. Based upon the current IES standards, it is recommended that the ambient light level in a maintenance hangar be at least 750 lux in order to perform pre- and post-maintenance/inspection operations and some general maintenance/inspection tasks without the necessity for additional task lighting. Furthermore, adequate illumination levels may be obtained in a majority of inspection tasks and many maintenance tasks through the utilisation of task lighting.

Table 1. Levels of Illumination Required in Aircraft Inspection/Maintenance (IES, 1987)

TASK	*lux*
Pre-/post-maintenance and inspection	300-750
Maintenance	750-1000
Inspection	
Ordinary	500
Detailed	1000
Fine	2000

Colour Rendering

Colour rendering is the degree to which the perceived colours of an object illuminated by various artificial light sources match the perceived colours of the same object when illuminated by a standard light source (i.e., daylight). The colour rendering of task lighting is important for inspection because "change in colour" of sheet metal is often used as a clue to detect corrosion, wear or excessive heating. The difference in the spectral characteristics of daylight, incandescent lamps, fluorescent lamps, etc., have a large effect on colour rendering. Such effects are described in detail in IES (1984). Table 2 presents some of the commonly used lighting sources and their characteristics (adapted from Eastman Kodak, 1983).

Table 2 Commonly Used Lighting Sources

TYPE OF LIGHT SOURCE	*COLOUR*	*COMMENTS*
Incandescent	Good	Commonly used, but prone to deterioration over time. High energy lost, but convenient and portable. Lamp life about 1 year.
Flourescent	Fair to good	The efficiency and colour rendering capabilities vary greatly depending upon tube type. Problems of flicker may have an annoying effect while performing inspections. Can be dangerous with rapidly cycling machinery. Lamp life 5-8 years
Mercury vapour	Very poor to fair	Green/blue coloured light; output drops rapidly with age. Lamp life 9-12 years.
High pressure sodium lamp	fair	Monochromatic yellow light. High efficiency lamp ranging from 80-100 lumens per watt. Lamp life 3-6 years.
Low pressure sodium lamp	Poor	Highly efficient light source but yellow in colour. Lamp life 4-5 years.

Glare

Direct glare reduces an inspector's ability to discriminate detail and is caused when a source of light in the visual field is much brighter than the task material at the workplace. Thus, open hangar doors, roof lights, or even reflections from a white object such as the workcard can cause glare. Glare can also arise from reflections from the surrounding surfaces and can be reduced by resorting to indirect lighting. The lighting system should be designed to minimise distracting, or disabling glare, using carefully designed combinations of area lighting and task lighting.

Reflectance

Every surface reflects some portion of the light it receives as measured by the surface reflectance. High reflectance surfaces increase the effectiveness of luminaires and the directionality of the illumination. Specula, or mirror-like, reflectance should be avoided as it produces glare. Diffuse reflection, for example, from a semi-matte surface is preferred. Thus, for an aircraft hangar, it is important that the walls and floors are of high diffuse reflectance (i.e., light paint, patterned plastics) so that they help in reflecting light and distributing it uniformly. This is more critical under the wings and fuselage where there may not be adequate lighting, due to aircraft shadows. Table 3 presents recommended surface reflective values to assist in obtaining an adequately uniform visual environment.

Table 3 Recommended Diffuse Reflective Values (Adapted from IES, 1987)

SURFACE	*REFLECTANCE*

Ceiling	80-90%
Walls	40-60%
Equipment	25-45%
Floors	Not less than 40%

Specialised Lighting

During visual inspection of an aircraft fuselage the inspector is looking for multiple defects, including corrosion, ripples, hairline cracks in the metal components, dents in the fuselage, missing rivets, damaged rivets ("pooched," "dished" rivets), and rivet cracks.

It is possible that no one single lighting system is suitable for detecting all defects. Therefore, the use of specialised lighting systems which make each class of defect more apparent may be necessary. However, the use of special light systems implies that the area must be examined for each class of defects sequentially rather than simultaneously, which could involve time and expense. For example, the diffused nature of general illumination tends to wash out the shadows while surface grazing light relies upon showing shadows to emphasise objects that project above or below the surface. Task visibility is distinctly better for surface topography with grazing light even though a lower level of illumination is used. An example of this scenario is the inspection of the fuselage for ripples. Ripples are easier to detect using surface-grazing lighting because general illumination tends to wash them out. However, normal-incidence lighting may mask important textural and colour differences. The lighting should be compatible with the visual objective regarding the form and texture of the task object. Grazing light reinforces an impression of the texture while normal incident light allows the discrimination of colour and surface, but minimises the perception of surface variations.

Design Requirements For Lighting

Literature on visual search has shown that the speed and accuracy with which the search process can be accomplished is dependent on the conspicuity of the defect which in turn is dependent on size of the defect, defect/background contrast, and lighting intensity (Drury and Fox, 1975).

Lighting design also has broader requirements to fulfil. In order for the inspection to be successful, the lighting should be such that the following tasks can be performed satisfactorily and preferably optimally: inspecting (visual search) the aircraft structure for defects, reading the workcard/instructions, moving around the aircraft (using the scaffolding, or equipment, e.g., cherrypicker), and special purpose lighting should not interfere with any other parallel task (e.g., access or maintenance) in progress.

The inspection task is frequently difficult because of the heavy perceptual load present. In designing the lighting system, the objective must be to reduce visual fatigue caused by poor illumination and poor contrast. In designing lighting systems, one must consider the minimum lighting requirements for each task and subtask, the type of artificial light sources that can be used to illuminate the work surface, the amount of task lighting that can be provided and the available methods to minimise glare. These factors must be balanced with implementation and operating costs (IES, 1987); however, the total cost of installing, running and maintaining lighting is a small fraction of the cost of either the employment of personnel or of rectifying lighting-induced human errors.

3. Guide for visual environment evaluation

A methodology by which to evaluate and design a visual environment may be advanced based upon the techniques employed in the above demonstration project. A four-step methodology is presented below.

1. Evaluate existing visual environment. The first step requires an investigation of the visual environment in order to obtain an understanding of the existing conditions and to focus the investigation on problem areas. Ambient and task lighting conditions and task analyses should be performed in order to determine the task demands and associated visual requirements. In addition, personnel should be consulted to obtain additional information regarding the light characteristics and utilisation and adequacy of the currently used lighting sources.

2. Evaluate existing and alternative lighting sources. An evaluation of the existing and alternative lighting sources is performed in order to identify the capabilities of each source. Manufacturers' catalogues can be consulted to determine the current status of lighting source technology. These alternative sources, in addition to the sources currently being used, can be evaluated. Evaluations performed to date, including the present one, have used various criteria to judge visual environments (e.g., light output, glare, luminance, etc.). There is a need for standard criteria which allow visual environments in aircraft maintenance/inspection operations to be evaluated in a consistent manner and which insure that important components of the process are not over-looked. An attempt has been made to identify the most important components which need to be considered in the evaluation of an aircraft inspection/maintenance visual environment and a guide has been developed to indicate important considerations in the selection of adequate lighting sources (Table 4). Requirements are given for both personal and portable lighting.

Table 4 Lighting Source Design Considerations

CHARACTERISTICS	*PERSONAL*	*PORTABLE*
Light	Output/ brightness Glare/ brightness control Distribution/ focus Colour rendering Contrast Alternative sources Flicker Power source (battery type) Bulb type	Output/ brightness Glare/ brightness control Distribution/ aim Colour rendering Contrast Alternative sources Flicker
Ease of handling	Weight/ size Accessories	Weight/ size Accessories

	Power source	Set-up
Durability	General Safety requirements Bulb life Battery life	General Safety requirements Bulb life
Flexibility	Task demands Fault types	Task demands Fault types
Other attributes	Cost Space Individual differences	Cost Space Individual differences

3. Selection of lighting sources. Once steps 1 and 2 are completed, lighting sources can be selected based upon a comparison of the lighting requirements with the various lighting sources. An investigation of the existing visual environment (step 1 above) will allow the determination of the lighting requirements to be based upon the task demands. These results can be directly compared with the capabilities of the various lighting sources (step 2 above), to determine which lighting sources provide the most appropriate visual environment for each task analysed.

4. Evaluate and address general visual environment factors. In addition to attending to the specific task conditions, there are factors relevant to the overall environment which need to be addressed. A guide has been developed to indicate relevant considerations in the design of an adequate visual environment (Table 5). The assessment of these considerations should result in additional improvements in the overall visual environment.

Table 5 General Visual Environment Design Considerations

CHARACTERISTICS	VISUAL ENVIRONMENT
Light	Light level Glare Distribution Colour rendering Contrast Flicker
Work shift	Light (day/night) Shiftwork
Maintenance	Paint Hangar cleanliness
Other attributes	Access devices Availability of lighting sources

This methodology does not provide guidelines which dictate how to design a visual environment. Instead, it provides a flexible process which may be followed to allow each practitioner to tailor the methodology to meet their individual needs. For example, this demonstration emphasised consideration of lighting requirements, handling, and space restrictions in advancing recommendations. However, dependent upon each facility's needs and associated tasks, other factors identified in this study (steps 1 and 2) may be given stronger consideration (e.g., safety requirements, power sources).

Further Reading

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7. FAA/AANC Visual Inspection Research Program (VIRP). C Drury. Chapter 9, FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase V Progress Report, 1995. *hfskyway.faa.gov*
8. Design of the aircraft inspection/maintenance visual environment. J Reynolds, A Gramopadhye, C Drury (State University of New York at Buffalo, Department of Industrial Engineering) Proceedings of the Seventh Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, 1992
9. Ergonomic audit for visual inspection of aircraft. S Koli, C Drury, J Cuneo, J Lofgren. Chaper 4, FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase IV Progress Report, 1995. *hfskyway.faa.gov*
10. The Information Environment in Inspection. C Drury (University at Buffalo) Proceedings of the Second Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, 1989

Appendix S Procedures and work instructions

1. Introduction

One of the main factors contributing to maintenance incidents is failure to comply properly with procedures. So why don't technicians follow procedures? Is it a problem with the technicians or with the procedures?

Failure to comply with maintenance procedures may be divided into two types:
- Failure to comply with good maintenance procedures
- Failure to comply with bad maintenance procedures

Ignoring for the present, the 'grey' area between the two, the general principle should be that:
- The former ought to be addressed by educating and training maintenance staff to comply with procedures, to resist pressure to cut corners, and to discipline maintenance staff when they fail to comply with good procedures. Note: this assumes that enough time is provided to enable the technician to be able to comply with the procedures
- The latter should be addressed by improving the procedures such that they are accurate, appropriate, the best means of doing a task, easy to interpret, well presented, well designed, etc.

Violations are covered in Chapter 3. Human Factors training is addressed in Chapter 12. Such training should constantly emphasis the importance of following procedures in aircraft maintenance engineering. This Appendix will concentrate on why people violate procedures and how procedures might be better designed to prevent this.

2. Requirements standards

The regulatory requirements for procedures are stated in JAR Ops 1.905, Part-21, and in Part-145.A.65.

3. Issues and problems

In many jobs, maintenance engineering being no exception, technicians often rely on their memory or ask their peers rather than consult manuals all the time. Maintenance manuals tend to be used as a secondary source of information. Research shows that the users of procedures often feel that they are 'written in stone' and they are not able to instigate changes, so they work around poor procedures rather than try to get them changed.

The primary system causes of procedural non-compliance can be summarised under the following headings:
- Absence of a clear process for systematically developing optimised working practices ('best practice')
- Official procedures which are out of date and impractical and therefore lack credibility with the workforce

- Lack of a culture which develops ownership of procedures by a process of active participation in their development, thus giving rise to 'buy-in' and compliance without the need for repeated motivational campaigns.
- Lack of communication channels in an organisation to allow procedures to be frequently updated in line with organisational learning.

4. Feedback processes

It is important to have a workable and trusted method for the maintenance engineering staff to be able to highlight problems with procedures (whether those produced by the manufacturer or those produced by the maintenance organisation) and to see those problems acted upon in the form of changes to the procedures. This should already be part of an organisations Quality Assurance program but is more effective in some areas than in others. Chapter 10 discusses incident and problem area reporting and investigation systems, of which highlighting problems with procedures, manuals, etc., should be a part.

5. Guidance for the design of procedures

How can we improve the design of procedures so that technicians will use them? People are often more inclined to use a procedure if they are advised why a particular method or sequence should be followed. Minor variations to sequence (eg. installing pipe connection B first instead of A), where it has no relevance to safety, should be worded in a manner which would allow for variation. Where a particular step is critical to the integrity of the installation then it should be clearly identified as such. It is also commonly accepted that plain English should be used.

Much work has been carried out concerning guidelines for good procedures design, and a list of the salient points can be found in Appendix A, attachment 4. Ultimately it depends upon the willingness of the maintenance organisation (and manufacturer) to apply such principles, preferably with the involvement of the staff who will actually be using the procedures. The Boeing 777 programme was a good example of where maintenance personnel were involved in writing the Maintenance Manual procedures and validating that these procedures were workable. The fact that approximately 1000 changes had to be made during the validation process illustrates the importance of validating procedures before operational use, rather than leaving it up to line experience to detect the inaccuracies and ambiguities in the Maintenance Data, with the associated risk that an incident may occur as a result of such inaccuracies or ambiguities .

6. FAA Document Design Aid (DDA).

The FAA have sponsored research into procedures design, culminating in the development of a product known as the Document Design Aid (DDA). The background research, and the product itself, can be found on *http://hfskyway.faa.gov*. The following paragraph, taken from the report describing the DDA background research[40], summarises the main guidance material which exists.

This project is not the first to bring together human factors research findings and good practice into codified guidelines. Simpson and Casey's[41] Developing Effective User Documentation come from the nuclear power industry, while Wright's Information Design[42] was based on requirements for design of forms and documents for use by the general public. There has even been software written, e.g., the Communication Research Institute of Australia's Forms Designer[43], to help users design effective forms. A monthly newsletter (Procedures Review) is devoted entirely to design of work control documentation. As a final example, the guidelines of Patel, et al[44]., and Patel, Prabhu and Drury (1992)[45] on paper and computer information design, respectively, were most closely adapted to the aircraft maintenance environment. *http://hfskyway.faa.gov* contains a bibliography of the major sources used to develop the DDA, and is a useful secondary source for further document design information.

7. CARMAN

The Consensus based Approach to Risk Management (CARMAN), developed by Human Reliability Associates, attempts to make preferred practice match actual practice, and to get the correct balance between job aids and procedures. The original impetus for CARMAN came from a number of procedures improvement projects where the main focus was on improving the usability or procedures by applying ergonomics design standards to issues such as readability, layout and formatting. However, it was found that even when the usability of procedures was considerably improved, their level of usage was sometimes still low, and procedural violations still occurred. This led to work aimed at understanding the causes of procedural non-compliance and the development o the CARMAN approach that combined insights from task and risk analysis, group processes, and work on organisational learning. This approach was gradually refined by being applied to a number of organisations.

8. AMPOS

The Aircraft Maintenance Procedure Optimisation System (AMPOS) is an IT based continuous improvement system designed to provide a feedback loop of human factors information to critical personnel within the aircraft maintenance organisation and the aircraft

[40] Documentation design aid development. C Drury, A. Sarac, D Driscoll. Chapter 4, FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase VII, Progress Report, 1997.
[41] Hartley, J. (1984). Information design: the design and evaluation of signs and printed material, Space and Structure in Instructional Text, pp. 497-513, New York: John Wiley and Sons.
[42] Simpson, H. and Casey, S. M. (1988). Developing Effective User Documentation: A Human Factors Approach, New York: McGraw-Hill.
[43] Wright, P. (1988). Functional literacy: reading and writing at work, An International Journal of Research and Practice in Human Factors and Ergonomics, pp. 1-25.
[44] Patel, S., Drury, C. G. and Lofgren, J. (1994). Design of workcards for aircraft inspection. Applied Ergonomics 1994, 25(5), pp. 283-293.
[45] Patel, S., Prabhu, P. and Drury, C. G. (1992). Design of work control cards. In Meeting Proceedings of the Seventh Federal Aviation Administration Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, Atlanta, GA, pp. 163-172.

manufacturer. This should enable problems with procedures to be identified and appropriate solutions to be implemented.

9 Summary-

If procedures are written well, reflect best practice, and if there is enough time to use them properly, there should be no excuse for procedural violations. Design improvements and education concerning the importance of using procedures must go hand-in-hand.

Further Reading

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2. Drury, C. Effective Documentation Techniques. Proceedings of the 17th Safety Management and Aviation Maintenance Symposium, Toronto, September 2003.
3. Documentation design aid development. C Drury, A. Sarac, D Driscoll. Chapter 4, FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase VII, Progress Report, 1997. *http://hfskyway.faa.gov*
4. Human Centred Management for Aircraft Maintenance. Report of the ADAMS work. 1999.
5. CAP 676. Guidelines for the Presentation of Aircraft Checklists.
6. Embrey D. Creating a procedures culture to minimise risks using CARMAN. Proceedings of the Twelfth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, 1998
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Appendix T Communication, Handovers and Teamwork

These subjects are grouped together because, whilst communication (whether verbal, written or other) is important all the time, it is especially important at task and shift handover in maintenance engineering.

1. Communication

'Communication' is defined in the Penguin Dictionary of Psychology as "*The transmission of something from one location to another. The 'thing' that is transmitted may be a message, a signal, a meaning, etc. In order to have communication both the transmitter and the receiver must share a common code, so that the meaning or information contained in the message may be interpreted without error*".

Communication can be formal, i.e., written, or informal. In the cockpit environment, efficient verbal communication among crew members has received a great deal of emphasis over the past 20-plus years, as airlines and regulators have adopted Crew Resource Management (CRM) programs. CRM training has developed in response to accidents where there has been a breakdown in crew coordination and communication. Verbal communication between crew members, and also between air crews and air traffic controllers has significant safety implications. Because of these safety considerations, a formal structure and restricted vocabulary have evolved to ensure that unambiguous messages are sent and received. This is particularly important when communicating using radio frequencies (especially when transmitting air traffic control clearances), where the correct enunciation of words is vital to the clarity of the message.

Communication in the aircraft maintenance environment is somewhat different to that of flight operations. Although verbal communication still important to discuss work in progress, confirm actions or intentions, or to ensure that others are informed of maintenance state at any particular time, written communication and records are far more prominent. When verbal communication is used, it tends to be far less formalised in the hangar than verbal communication over a radio frequency. Despite an informality, the message tends to be far more complex and involved, dealing with completed work, part completed work, work yet to be started, and problems and issues relating to the work. However, some common problems exist with communication in both the flight operations and the maintenance engineering contexts, and there have been several maintenance related accidents and incidents where poor communication has been cited as a factor or finding.

Formal communication within the aviation maintenance domain is defined and regulated. A hierarchy of written correspondence is defined in the regulations of most States. This formal structure includes maintenance manuals, work cards, and other types of information that are routinely used within maintenance organisations. In an attempt to improve written communication, the international aviation maintenance community has recently adopted the use of a restricted and highly-structured subset of the English language. There are several readily available guides for standardised simple English. This will probably make little difference to technicians whose first language in English, but can be a significant improvement for technicians with English as their second language.

Further Reading:

1. Maddox M, Ed. Human Factors Guide for Aviation Maintenance 3.0 (1998). Chapter 13: Communication.
2. Drury, C.G., Ouellette, J.P., and Chervak, S. (1996). Field evaluation of Simplified English for aircraft workcards. In: Meeting Proceedings Tenth Federal Aviation Administration Meeting on Human Factors Issues in Aircraft Maintenance and Inspection: Maintenance performance enhancement and technician resource management (pp. 123-136).
3. AECMA Simplified English Standard (1995). A guide for the preparation of aircraft maintenance documentation in the international aerospace maintenance language, AECMA Document PSC-85-16598, Belgium: The European Association of Aerospace Industries.

2. Written Communication

This is one of the more critical aspects of aviation maintenance, in terms of human factors, since inadequate logging or recording of work has been cited as contributor to several incidents. In the B737 double engine oil loss incident[46] in February 1995, for instance, one of the AAIB conclusions was: "*…the Line Engineer…had not made a written statement or annotation on a work stage sheet to show where he had got to in the inspections*". Granted, the reason for this was because he had intended completing the job himself and, therefore, did not consider that detailed work logging was necessary. However, this contributed towards the incident in that "*the Night Base Maintenance Controller accepted the tasks on a verbal handover [and] he did not fully appreciate what had been done and what remained to be done*".

It is not unusual for shift handovers to take place after the technicians concerned have left, in which case it is vital that unfinished work is recorded in detail for the benefit of the incoming shift. Even if technicians think that they are going to complete the job, it is always necessary to keep the record of work up-to-date just in case the job has to be handed over.

AWN3 states:
" In relation to work carried out on an aircraft, it is the duty of all persons to whom this Notice applies to ensure that an adequate record of the work carried out is maintained. This is particularly important where such work carries on beyond a working period or shift, or is handed over from one person to another. The work accomplished, particularly if only disassembly or disturbance of components or aircraft systems, should be recorded as the work progresses or prior to undertaking a disassociated task. In any event, records should be completed no later than the end of the work period or shift of the individual undertaking the work. Such records should include 'open' entries to reflect the remaining actions necessary to restore the aircraft to a serviceable condition prior to release. In the case of complex tasks which are

[46] AAIB report No:3/96 - Boeing 737-400, Near Daventry, on 23 February 1995.

undertaken frequently, consideration should be given to the use of pre-planned stage sheets to assist in the control, management and recording of these tasks. Where such sheets are used, care must be taken to ensure that they accurately reflect the current requirements and recommendations of the manufacturer and that all key stages, inspections, or replacements are recorded."

AWN12 contains material issued as a result from experience from incidents. Appendix 52 states:
"*A certificate of release to service shall only be issued………when the signatory is satisfied that the work has been properly carried out and accurately recorded".*

AWN12, Appendix 53 was issued as a result of a serious incident[47] where incorrect and incomplete documentation was cited as a contributory factor. It reminds technicians and organisations of their responsibilities regarding *"the need to prepare complete documentation prior to the work being accomplished which clearly and accurately defines the non-scheduled maintenance task(s) to be undertaken".*

AWN12, Appendix 53 also states:
"The [UK] CAA endorses the use of stage sheets which is good maintenance practice as it enables personnel to record work to be carried out and provide a record of the accomplishment of that work. Human Factors studies in engineering repeatedly show that the use of properly prepared stage sheets when carrying out tasks considerably reduces the opportunity for maintenance errors occurring".

New technology may help technicians to record work more easily and effectively. ICAO Digest No.12: *"Human Factors in Aircraft Maintenance and Inspection",* referring to modern technologies such as hand held wireless computers and the Integrated Maintenance Information System (IMIS), stated*: "If such [technology] had been in place and available to the technicians working on the EMB-120 aircraft*[48]*. . . . . the accident might possibly have been prevented because work performed and work yet to be accomplished would have been filed properly and on time, making it clear to the incoming shift what work still needed to be completed".*

In October 1994 there was an incident[49] involving a Chinook helicopter where the drive shaft connecting bolts were removed in two places but only recorded as having been taken out in one. The result was that the drive shafts desynchronised during ground runs and the intermeshing blades collided. If this had happened in-flight (as it did later, with this same aircraft[50], in 1986), the results would have been catastrophic.

Difficulties can arise when translating material from the Maintenance Manuals into worksheets. It is important to ensure that errors or ambiguities do not creep in during the

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[47] AAIB report No:3/96 - Boeing 737-400, Near Daventry, on 23 February 1995.
[48] Continental Express Flight 2574, Embrayer 120. NTSB accident report NTSB/AAR-92/04.
[49] Incident, Chinook, GBWFC, Aberdeen Scotland, 25/10/99.
[50] AAIB report 2/88. Accident to Boeing Vertol 234 LR, G-BWFC, off Sumburgh, Shetland Isles, 6 November 1986.

translation process, and that standard practices required by regulation (eg. duplicate inspections) and control and management methods, correlate. A contributory factor in the B737 double engine oil loss incident[51] was that the information, prompting the technician to carry out a post-inspection idle engine run to check for leaks, was in the Maintenance Manual but not in the task cards.

Hfskyway contains a lot of further information on new technologies and how they might help both with access to information and with recording and logging of completed work elements. There has also been research carried out on the improved design of workcards, which encourages work elements to be logged as work progresses, rather than complete jobs to be signed off at the end.

Modern technology and methods to improve workcard design and information content are being used in several organisations, including Crossair, who generate workcards (including diagrams) directly from the Maintenance Manual, for the Saab 340. Another US company uses a system where they link in their MEDA results to workcard production, in order to highlight known error-prone areas associated with a particular task, on the workcard.

Although the manner in which work should be logged tends to be prescribed by the company procedures, and tends to be in written form, there is no logical reason why symbols and pictures should not also be used to record work or problems, especially when used for handovers. There is an old saying that ‘a picture is worth a thousand words’ and whilst this may not be literally true in maintenance engineering, there are many cases where it may be clearer to draw a diagram rather than to try to explain something in words. Again, new technology should be able to help, if photographs or formal diagrams can be easily annotated, either on a computer or on clear printouts or copies.

Further Reading:

1. AWN3
2. AWN12, Appendix 52 and 53
3. Human Factors Digest No. 12: Human Factors in Aircraft Maintenance and Inspection. (ICAO Circular 253) 1995
4. FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase III Report; Chapter 7: Design of Workcards 1993.
5. AAIB report on Incident to B737 near Daventry, 23 February 1995. AAIB report No 3/96.

3. Shift Handover

It is universally recognised that at the point of changing shift, the need for effective communication between the out-going and in-coming personnel in aircraft maintenance is extremely important. The absence of such effective communication has been evident in many accident reports from various industries, not just aircraft maintenance. Well known examples are the Air Accidents Investigation Branch (AAIB) report 2/95 on the incident to Airbus

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[51] AAIB report No:3/96 - Boeing 737-400, Near Daventry, on 23 February 1995.

A320 G-KMAM at Gatwick in 1993 which highlighted an inadequate handover, and the Cullen Report for the Piper Alpha disaster which concluded that one of the factors which contributed to the disaster was the failure to transmit key information at shift handover.

Whilst history is littered with past experiences of poor shift handover contributing to accidents and incidents there is little regulatory or guidance material regarding what constitutes a good handover process relevant to aircraft maintenance. This chapter attempts to provide guidelines on such a process and is drawn from work performed by the UK Health and Safety Executive (HSE), US Department of Energy (DOE) and the Federal Aviation Administration (FAA).

Concepts

Effective shift handover depends on three basic elements:

a) The outgoing person's ability to understand and communicate the important elements of the job or task being passed over to the incoming person.
b) The incoming person's ability to understand and assimilate the information being provided by the outgoing person.
c) A formalised process for exchanging information between outgoing and incoming people and a place for such exchanges to take place.

The DOE shift handover standards stress two characteristics that must be present for effective shift handover to take place: ownership and formality. Individuals must assume personal ownership and responsibility for the tasks they perform. They must want to ensure that their tasks are completed correctly, even when those tasks extend across shifts and are completed by somebody else. The opposite of this mental attitude is "It didn't happen on my shift", which essentially absolves the outgoing person from all responsibility for what happens on the next shift.

Formality relates to the level of recognition given to the shift handover procedures. Formalism exists when the shift handover process is defined in the Maintenance Organisation Exposition (MOE) and managers and supervisors are committed to ensuring that cross-shift information is effectively delivered. Demonstrable commitment is important as workers quickly perceive a lack of management commitment when they fail to provide ample shift overlap time, adequate job aids and dedicated facilities for the handovers to take place. In such cases the procedures are just seen as the company covering their backsides and paying lip service as they don't consider the matter important enough to spend effort and money on.

Aids to effective communication at shift handover

Research has shown that certain processes, practices and skills aid effective communication at shift handover.

a) People have to physically transmit information in written, spoken or gestured (non-verbal or body language) form. If only one medium is used there is a risk of erroneous transmission The introduction of redundancy, by using more than one way of communicating i.e. written, verbal or non verbal, greatly reduces this risk. For this reason information should be repeated via more than one medium. For example verbal and one other method such as written or diagrams etc.
b) The availability of feedback, to allow testing of comprehension etc. during communication increases the accuracy. The ability for two-way communication to take place is therefore important at shift handover.
c) A part of the shift handover process is to facilitate the formulation of a shared mental model of the maintenance system, aircraft configuration, tasks in work etc. Misunderstandings are most likely to occur when people do not have this same mental 'picture' of the state of things. This is particularly true when deviations from normal working has occurred such as having the aircraft in the flight mode at a point in a maintenance check when this is not normally done. Other considerations are when people have returned following a lengthy absence (the state of things could have changed considerably during this time) and when handovers are carried out between experienced and inexperienced personnel (experienced people may make assumptions about their knowledge that may not be true of inexperienced people). In all these cases handovers can be expected to take longer and should be allowed for.
d) Written communication is helped by the design of the documents, such as the handover log, which consider the information needs of those people who are expected to use it. By involving the people who conduct shift handovers and asking them what key information should be included and in what format it should be helps accurate communication and their 'buy-in' contributes to its use and acceptance of the process.

Barriers to effective communication at shift handover

Research has also shown that certain practices, attitudes and human limitations act as barriers to effective communication at shift handover.

a) Key information can be lost if the message also contains irrelevant, unwanted information. We also only have a limited capability to absorb and process what is being communicated to us. In these circumstances it requires time and effort to interpret what is being said and extract the important information. It is important that only key information is presented, and irrelevant information excluded.
b) The language we use in everyday life is inherently ambiguous. Effort therefore needs to be expended to reduce ambiguity by:
    i. carefully specifying the information to be communicated e.g. by specifying the actual component, tooling or document.
    ii. facilitating two-way communication which permits clarification of any ambiguity (e.g. do you mean the inboard or out board wing flap?)
c) Misunderstandings are a natural and inevitable feature of human communication and effort has to be expended to identify, minimise and repair misunderstandings as they occur. Communication therefore has to be two-way, with both participants taking responsibility for achieving full and accurate communication.

d) People and organisations frequently refer to communication as unproblematic, implying that successful communication is easy and requires little effort. This leads to over-confidence and complacency becoming common place. Organisations need to expend effort to address complacency by:
   i. emphasising the potential for miscommunication and its possible consequences
   ii. developing the communication skills of people who are involved in shift handovers

Guidelines

In considering the theories of communication and the research that has been performed the following guidelines apply for operations that are manned on multiple shifts to allow for continuous 24 hour maintenance. When shifts are adopted which do not cover a full 24 hour period, for example early and late shifts with no night shift, the handover where face to face communication is not possible posses an inherent risk. In such cases organisations should be aware that the potential for ineffective and inefficient communication is much higher.

Shift Handover Meetings

It could be said that the primary objective of the shift handover is to ensure accurate, reliable communication of *task-relevant* information across the shifts. However this does not recognise the users needs for other information which may also be required to enable a complete mental model to be formed which will allow safe and efficient continuation of the maintenance process. Examples of such information could be manning levels, Authorisation coverage, staff sickness, people working extended hours (overtime), personnel issues etc.

An important aspect related to individual shift handover is when it actually begins. The common perception is that shift handover occurs only at the transition between the shifts. However, DOE shift handover standards make the point that shift handover should really begin as soon as the shift starts. Throughout their shift people should be thinking about, and recording, what information should be included in their handover to the next person or shift.

Table 1 lists the sort of topics that should be covered in the managers'/supervisors' handover meeting.

Table 1 Topics for managers' shift handover meeting

Status of the Facility
- Workstands/Docking
- Visitors
- Construction work
- Health & Safety issues

Work Status
- Aircraft being worked
- Scheduled aircraft incoming/departing
- Deadlines
- Aircraft status against planned status

Manning Levels and Status
- Authorisation coverage
- Certifying staff
- Non certifying staff
- Numbers and names of personnel working overtime
- Numbers and names of contract staff
- Sickness
- Injuries
- Training
- Other personnel issues

Problems
- Outstanding/in work/status
- Solved

Information
- AD's, SB's, etc.
- Company technical notices
- Company policy notices

The shift handover process should comprise at least two meetings. It starts with a meeting between the incoming and outgoing shift managers/supervisors. This meeting should be conducted in an environment free from time pressure and distractions.

Shift managers/supervisors need to discuss and up-date themselves on tactical and managerial matters affecting the continued and timely operation of the maintenance process. The purpose of this meeting is therefore to acquaint themselves with the general state of the facility and the overall status of the work for which they are responsible. Outgoing managers/supervisors should summarise any significant problems they have encountered during their shift, especially any problems for which solutions have not been developed or are still in progress.

Walkthroughs

After the meeting between shift managers, and assignment of tasks, there is a need for Supervisors and certifying staff to meet and exchange detailed information related to individual jobs and tasks. The most effective way to communicate this information is for the affected incoming and outgoing personnel to go over the task issues while examining the actual jobs on the hangar floor or at the workplace. A mutual inspection and discussion of this nature is called a “Walkthrough”.

Table 2 lists the sort of topics that should be covered in the supervisors/certifying staff’s walkthrough meeting.

Table 2. Topics for the Supervisors/Certifying Staff walkthrough meeting

Jobs/tasks in progress
Workcards being used
Last step(s) completed
Problems encountered
Outstanding/in work/status
Solved
Unusual occurrences
Unusual defects
Resources required/available
Location of removed parts, tooling etc.
Parts and tools ordered and when expected
Parts shortages
Proposed next steps
Communication with Planners, Tech Services, workshops
Communication with managers etc.

4. Task handover

The handing over of tasks from one person to another does not always occur at the point of changing shifts. Tasks are frequently required to be handed over during a shift. This Section deals with two common situations. When a task is being handed over to someone who is present at the time, and when a job is being stopped part way through and it is not certain who will pick this up at a later stage. This section on task handover should be read in conjunction with the section on Non-Routine Tasks and Process Sheets.

Handing over a task directly to another person

When the task is being directly handed over to someone who is present at the time the process and concepts are the same as for a Walkthrough described in the Shift Handover Section of this handbook. That is to say it is done face to face using verbal and written communication. In these cases the written element is normally by ensuring that the task cards or non routine process sheets are accurately completed clearly identifying at what stage in the task the job has reached. Any deviations from normal working practices or procedures must be clearly highlighted during the Walkthrough. An example of this would be if in changing a valve, a clamp, not required to be removed by the maintenance manual, is disturbed to aid removal and installation. Many mishaps have occurred in these circumstances as the person taking over the job assumes that the task was being performed as per the maintenance manual, drawings, procedures etc. It is a CAA requirement that this deviation is recorded by the outgoing person, and it is essential from a communication effectiveness point of view that this is reinforced during the Walkthrough.

Handing over a task for somebody to complete at a later stage

It is not uncommon that a job is left incomplete during a shift, say in the case of someone being called away to attend to a more urgent task on another aircraft. In these cases it is often not known who will eventually pick up the job of completing and certifying the release to service. These situations present a far greater risk and challenge to effectively communicate the stage of task accomplishment and what is required to complete the job. Face to face communication is not possible therefore total reliance has to be placed on written communication, a single medium with no redundancy and opportunity to question and test a true understanding by the person expected to finish the job.

Scheduled tasks

The paperwork normally associated with scheduled tasks are the Task Cards that are issued at the beginning of the maintenance input. These may have been written by the manufacturer, maintenance organisation or the operator of the aircraft. In all cases the card and associated task breakdown written on it, assume that the same person will start and finish the job. It was not *designed* to be used as a handover document. That is not to say that it could not be the handover, or that it could not form part of one. It really depends on the circumstances.

Task Cards break down jobs in to discrete stages, and ideally jobs should always be stopped at one of these stages so that the last sign off on the card is the exact stage of the job reached. In this case the card is the handover. However, a job is sometimes stopped at a point which is between the stages identified on the card, the stage sequencing has not been followed, or a deviation from normal working has occurred (such as in the example of disturbing the additional clamp to aid removal and installation of a valve). When this occurs additional written information must be used to clearly identify the point of exit from the task and what is required to complete the job and restore serviceability. Non-routine cards or sheets should then be used to record and transmit the relevant information necessary. Fig 1 is an example of a Task Card.

Fig 1: Task Card

GO FAST AIRWAYS A/C type: B737 MP ref: MS/B737/668 Aircraft Reg: G-OFST			
Flight Controls			
Additional work card raised: Yes/No			
27-00-56	**Flap synchronising system**	Mechanic	Inspector
	a) Check the cable tensions are correct (mm 27-50-02)	*B Bloggs*	T stamp
	b) With the flaps selected up, disconnect the operating link from one transmitter gearbox only.	*B Bloggs*	T stamp
	c) Pressurise the hydraulic system and select flaps down	*B Bloggs*	T stamp
	d) Make sure that the flaps start to move and then the system cuts out.	*B Bloggs*	T stamp
	e) Depressurise the hydraulic system and connect the transmitter operating link.		
	f) Pressurise the hydraulic system and make sure that the flaps operate correctly.		

In the case above, the job has been accomplished fully up to stage d), but the hydraulics have been depressurised therefore only part of stage e) has been accomplished. A supplementary card, worksheet or non routine sheet (the terminology will vary from one company to another) must be raised to communicate that the Task Card does not reflect the true state of the aircraft. In this case the wording could be:

Fig 2. Supplementary card

Defect	Action Taken	Mechanic	Inspector

Reference card 27-00-56. Card completed fully up to stage d). Hydraulic system depressurised but the transmitter operating link is not reconnected. Operating link to be reconnected prior to performing stage f).			

The combination of both documents provides sufficient information for the person picking up the job to know what stage the work is up to and what is required to complete it.

Non-scheduled tasks

Complex or lengthy non-scheduled tasks should always be broken down in to a number of discrete steps using stage or process sheets (the terminology will vary from one company to another). CAA Airworthiness Notice No. 12 Appendix No. 53 endorses the use of these as a good maintenance practice and necessary to comply with Part-145.A.50(b). However many incidents have occurred when people have started a straight forward job but had to exit the task part way through without anybody to handover to. These situations by their nature are unplanned and are normally associated with time pressure or emergency situations. In spite of this it is vital that time is taken by the person leaving the job to comprehensively record what activities have taken place and what is required to complete the job. This would be recorded on stage sheets and should emphasis any deviations from the normal or expected way of working. Management and supervisors have a responsibility to ensure that adequate time is given to maintenance staff to record their work if they require tasks to be suspended for any reason.

5. Non-routine task and process sheets

Airworthiness Notice No. 12 Appendix No. 53 was issued as a result of a serious incident[52] where inaccurate and incomplete maintenance documentation was cited as a contributing factor. It highlights the need to prepare complete documentation prior to the work being accomplished which clearly and accurately defines the non-scheduled maintenance task(s) to be undertaken.

Task Cards for scheduled maintenance are an everyday document for aircraft engineers. They not only identify the job to be performed, but they also break down the task in to stages to allow for individuals to sign or certify the various stages The reasons for breaking down the job in to discrete tasks is often wrongly seen as record keeping, and of being able to identify who did what part of a job so that if there is an incident the employer or regulator can take action against the person. Whilst it does confer accountability for the work this

[52] AAIB report 2/95

could be achieved by other means. The primary purpose of a job card is to identify the task to be performed but then act as a job aid to *help* the engineer plan, complete the task fully, and in the correct sequence.

Maintenance Programmes today are frequently based on the principles of Condition Monitoring. Most components on the aircraft therefore have no specific period defined as to when they will be removed for repair, overhaul etc. The time to remove them is determined by a reliability programme or scheduled inspections which assess their serviceability. Operator's Task Cards are normally derived, or copied from those provided by the aircraft manufacturer. Unfortunately these are usually only the required tasks and do not include those tasks which have to be performed as a consequence. An example of this is an engine change. The manufacturer will have written cards describing the break down of various inspections such as borescope, oil sampling and magnetic chip detectors but not a card on changing the engine. This had led to the situation whereby many jobs, often long and complex, have no pre-printed task cards or process sheets which break down the job in to stages and so help the engineers.

This Section of the Appendix describes the types of tasks that need Non-Routine Task Cards or Process Sheets, and what the goals are from a human factors perspective.

Developing Non-routine Task Cards or Process Sheets

If a task contains any one of the attributes in the left hand column then an Operator or maintenance organisation should develop pre-printed task cards; or process sheets if the task stages are particularly numerous or lengthy. The right hand column provides the reasons and goals that are to be achieved by the documentation.

Table 3. Non-routine task cards

Task Attributes	Reason and Goals to be Achieved
Task is Complex	1. Helps to structure the sequence that the various sub tasks will be performed. 2. Identifies the significant stages in the process. 3. Provides cues and prompts. 4. Helps prevent errors of omission because:- • The greater the amount of information in a procedural step, the more likely that items within the step will be omitted. • Procedural steps that are not obviously cued by preceding actions, or that do not follow in a direct linear sequence are more likely to be omitted.
Task involves multiple Trade disciplines	1. Identifies what tasks require specialist task disciplines to perform and certify the work. 2. Ensures that specialist trades are called upon to perform their task at the correct point in the process. 3. Provides evidence that the specialist task has been performed.

Task that could extend over shifts	1. Provides clear evidence of what tasks have been performed and what is outstanding. 2. Compliments the task or shift handover process. 3. Helps prevent errors of omission because:- • The larger the number of discrete steps in an action sequence, the greater the probability that one or more will be omitted.
Well practised, routine tasks where the consequence of error is unacceptably high (safety or economic impact).	1. Well practised or routine tasks are susceptible to 'slips' and 'lapses'. Errors of omission are most common in these circumstances. Examples are: • Distraction causing the person to 'lose his place' upon resumption of the task. People tend to think they are further along in the task than they actually are and therefore miss a step out. • Premature exit. This is moving on to the next job before the previous one is complete. The last activity in the task is frequently the one omitted. We are particularly vulnerable to this sort of error when under time pressure. Examples are not torque tightening a pipe coupling, wire locking or calling up an engine run for leak checks 2. Written sheets serve as 'mind joggers' to prevent forgetting a step
Task involves the recording of measurements or calculations	1. Measurements which are required to be recorded are more likely to be captured if pre-supplied paperwork is readily available with the facility to do so. It makes compliance easy. 2. Provides a prompt that recording of data is required. 3. If calculations are required, as in the case of taking measurements and then selecting shims. Recording the measurements and providing a place for doing the calculation augments the limited capacity of the working memory.

Further reading

1. FAA Human Factors Guide for Aviation Maintenance (1998). Chapter 4 Shiftwork and Scheduling Guidelines. Author - Michael E Maddox
2. Offshore Technology Report - OTO 96 003. Effective Shift Handover - A Literature Review. Health and Safety Executive. Author - Ronny Lardner
3. Guidelines in producing an effective shift and task handover system. R Miles (UK Health And Safety Executive) Proceedings of the Twelfth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, 1998
4. Department of Energy (1990). Conduct of operations requirements for DOE facilities, DOE 5480.19. Washington, DC: Author.
5. Department of Energy (1993). Guide to good practices for operations turnover, DOE-STD-1038-93. Washington, DC: Author.
6. Department of Energy (1993). Guide to good practices for shift routines and operating practices, DOE-STD-1041-93. Washington, DC: Author
7. Koenig, R.L. (1996). Team of maintenance inspectors and human factors researchers improves shift-turnover log. Flight Safety Foundation Aviation Mechanics Bulletin, November-December, 1996, pp. 1-16.

Appendix U Training Needs Analysis Example

The examples given in this Appendix are by no means difinitive, and should merely be used as guidance to illustrate how to put together a TNA, not necessarily what number to put in it for your company. The structure is not fixed - Example 1 happens to be based on the JAA MHFWG report (Appendix A) syllabus topics; Example 2 illustrates how those topics have been adapted by a trainer, and for a particular company; Example 3 shows how a very small organisation might put together a TNA, loosely based on the syllabus items in GM-145.A.30(e).

You may decide that it is easier to put all staff on a full version of human factors training, in which case a detailed TNA may not be needed, although you will still need a statement to the effect that this effectively constitutes your TNA. Organisations are encouraged to put together a TNA, since it should help them not only with determining what they need in the way of initial human factors training, but also what will be appropriate for recurrent training, taking account of changes over the years. It may also help determine what training may have been covered already, elsewhere, and therefore not need to be repeated.

1. Example TNA for a large aircraft maintenance organisation.

No actual example from industry was available at the time of writing Issue 2 to this CAP, therefore a hypothetical example was compiled. This is shown in Table 1, and is based on the JAA MHFWG expanded syllabus items (Appendix 1, Attachment 7, Table 1. This is an extract only - the full TNA would cover all the expanded syllabus items.

Key:
0 = don't need to know
1 = basic appreciation
2 = standard
3 = in-depth
* = specific to job/ context

Table 1a. TNA hypothetical example for a large aircraft maintenance organisation - module 1

	HF trainers	Training Needs Analysts	HF/ Safety Programme managers/ coordinators	MEMS investigators	Health & safety manager	Tech certifying staff	Tech non-certifying staff	Post holders/ senior managers	Managers/ QA	Supervisors	Planners/ production control	Tech records/ tech services/ design	Purchasing/ supply chain	Stores	Tech trainers	HR/ personnel	Loaders/ drivers/ etc
General / Introduction to human factors																	
Need to address Human Factors	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Statistics	3	2	3	3	2	2	1	2	2	2	2	1	1	1	1	0	0
Incidents	3	2	3	3	2	2	1	2	2	2	2	1	1	1	1	0	0

Table 1b. TNA hypothetical example for a large aircraft maintenance organisation - module 2

	HF trainers	Training Needs Analysts	HF/ Safety Programme managers/ coordinators	MEMS investigators	Health & safety manager	Tech certifying staff	Tech non-certifying staff	Post holders/ senior managers	Managers/ QA	Supervisors	Planners/ production control	Tech records/ tech services/ design	Purchasing/ supply chain	Stores	Tech trainers	HR/ personnel	Loaders/ drivers/ etc
Human Error																	
Error models and theories	2	0	2	2	0	1	0	1	1	1	0	0	0	0	0	0	0
Types of errors in maintenance	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2
Violations	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2
Implications of errors	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2
Avoiding and managing errors	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2
Human Reliability	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 1c. TNA hypothetical example for a large aircraft maintenance organisation - module 3

Human Performance & Limitations	HF trainers	Training Needs Analysts	HF/ Safety Programme managers/ coordinators	MEMS investigators	Health & safety manager	Tech certifying staff	Tech non-certifying staff	Post holders/ senior managers	Managers/ QA	Supervisors	Planners/ production control	Tech records/ tech services/ design	Purchasing/ supply chain	Stores	Tech trainers	HR/ personnel	Loaders/ drivers/ etc
Vision	3	2	2	2	3	2*	2	0	1	2*	1	1	1	1	1	0	1
Hearing	3	1	1	1	3	1	1	0	1	1	0	0	0	0	0	0	1
Information-Processing	3	1	1	1	0	1	1	0	1	1	1	1	1	0	0	0	0
Attention and Perception	3	1	1	1	1	1	1	0	1	1	1	1	1	1	0	0	2
Situational awareness	3	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	1
Memory	3	1	1	1	0	1	1	0	1	1	1	1	1	0	0	0	0
Claustrophobia/ physical access	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0
Motivation	2	1	1	1	0	2	2	0	0	2	0	0	0	0	0	0	0
Fitness/Health	2	1	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0
Stress	2	1	1	1	2	1	1	1	1	1	0	0	0	0	0	1	0
Workload management	2	1	1	1	0	1	1	0	0	1	1	0	0	0	0	0	0
Fatigue	3	2	2	2	3	2	2	1	1	2	3	1	1	1	1	2	1
Alcohol, medication, drugs	2	1	1	1	2	1	1	0	1	1	1	1	1	1	1	2	1
Physical work	1	0	0	0	1	0	0	0	0	0	0	0	00	0	0	1	0
Repetitive tasks / complacency	1	0	0	1	0	1	1	0	0	1	0	0	0	0	0	0	0

Table 1d. TNA hypothetical example for a large aircraft maintenance organisation - module 10

Organisation's HF Program	HF trainers	Training Needs Analysts	HF/ Safety Programme managers/ coordinators	MEMS investigators	Health & safety manager	Tech certifying staff	Tech non-certifying staff	Post holders/ senior managers	Managers/ QA	Supervisors	Planners/ production control	Tech records/ tech services/ design	Purchasing/ supply chain	Stores	Tech trainers	HR/ personnel	Loaders/ drivers/ etc
Reporting errors	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Disciplinary policy	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Error investigation	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Action to address problems	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Feedback	3	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1

2. Example TNA for a large component maintenance organisation.

The following example of an extract from a Training Needs Analysis was developed by BainesSimmons Ltd on behalf of Smiths Aerospace Customer Services, and has been reproduced with permission. The detail is proprietory to BainesSimmons Ltd., and applicable only to Smiths Aerospace, but the principles may be freely used and adapted to context.

The [EASA GM-145.A.30(e)] syllabus may be adjusted to meet the particular nature of the organisation. The syllabus may also be adjusted to meet the particular nature of work for each function within the organisation. For example:

- Small organisations not working in shifts may cover in less depth subjects related to teamwork and communications
- Planners may cover in more depth the scheduling and planning objective of the syllabus and in less depth the objective of developing skills for shift working.
- Personnel being recruited from another JAR 145 approved maintenance organisation and temporary staff should be assessed for the need to receive any additional Human Factors training to meet the new JAR 145 approved maintenance organisation's Human Factors training standard.
- The following table is the high-level generic tool that will help you complete a training needs analysis. Depending of the result of this evaluation, initial training should be provided to personnel within 6 months of joining the maintenance organisation, but temporary staff may need be trained shortly after joining the organisation to cope with the duration of employment.
- The training syllabus identifies the topics and subtopics to be addressed during the Human Factors training.
- The maintenance organisation may combine, divide, change the order of any subject of the syllabus to suit its own needs, so long as all subjects are covered to a level of detail appropriate to the organisation and its personnel
- Some topics may be covered in separate training (health and safety, management, supervisory skills etc.) in which case duplication of training is not necessary. In other words cross credits may be claimed for other complementary training such as management teamwork training if the content meets the general syllabus requirement.
- The duration of training will vary depending on the category of personnel involved, for example a typical training course duration would range from 1 day for managers and up to 3 days for certifying staff.
- Although training courses may be tailored for certain categories of personnel, consideration should also be given to the benefits of having combination of personnel from different functional groups during training sessions

For each training topic specific objectives are defined. These objectives are specified in term of knowledge (to know), skills (how to do), and attitude.
Depth of knowledge criteria , as listed below, have been entered into the TNA Tables as applicable to Smiths Industries.

Level 0 - Not applicable to this functional group or company does not require it (e.g. don't work shifts).
Level 1 - General appreciation of theory and basic principles appropriate to job role.

Level 2 - In-depth knowledge and the ability to apply to other people under their control. **Level 3** - Full theoretical knowledge and competence to apply in their job role.

High-level syllabus for human factors in aircraft maintenance

The syllabus is included in GM-145.A.30(e), and expanded in the JAA MHFWG report (see Appendix A). The BainesSimmons Ltd modules equate to those of the requirement as listed in Table 1 below.

Table 1. Syllabus Modules coverage.

Human Factors syllabus module titles	**Baines Simmons Ltd Module number**	**EASA GM-145.A.30(e) syllabus module number**
Introduction to human factors	1	1
Human error	2	2, 9
Human Error – slips and lapses	3	3, 9
Human Error - violations	4	3, 6, 9
Avoiding and managing error	5	3
Human performance and limitations	6	4
Environmental factors	7	5, 6
Teamwork	8	8, 9
Communication and handovers	9	7
Organisation's HF Program	10	10

Table 2. Module 1 TNA - General / Introduction to human factors

	Accountable manager	Senior Managers	Managers & Supervisors	Certifying staff.	Non certifying	Planners & production control staff	Tech. services & Design	Human factors staff/ instructor	Quality assurance Engineer/ surveyor	Technical record staff	Purchasing staff	Store department	Ground equipment operators/
The need to address Human Factors	1	1	1	1	1	1	1	2	2	1	1	1	1
Affects of Human Factors on airworthiness	1	1	1	1	1	1	1	1	1	1	1	1	1
Statistics and incidents	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 2 Module 2 TNA - Human Error

	Accountabl e manager	Senior Managers	Managers & Supervisors	Certifying staff.	Non certifying	Planners & production control staff	Tech. services & Design engineers	Human factors staff/ instructor	Quality assurance Engineer/ surveyor	Technical record staff	Purchasing staff	Store department staff	Ground equipment operators/
Types of errors in maintenance	1	2	2	1	1	2	1	3	3	1	2	0	0
When we are most prone to error	1	2	2	1	1	2	1	3	3	1	0	0	0
Organisational accidents	2	2	2	1	1	2	1	3	3	1	2	0	0
System defences	2	2	2	1	1	2	1	3	3	1	2	0	0

Table 2 Module 10 TNA - Organisation's HF Program

	Accountable manager	Senior Managers	Managers & Supervisors	Certifying staff inc.	Non certifying staff	Planners & production control staff	Tech. services & Design engineers	Human factors staff/ instructor	Quality assurance Engineer/ surveyor	Technical record staff	Purchasing staff	Store department staff	Ground equipment operators/
All elements to be covered by all staff	3	3	3	3	3	3	3	3	3	3	3	3	3

3. Example TNA for a small maintenance organisation.

No actual example was available from industry, therefore a hypothetical example was compiled and is shown in Table 3. It should be stressed that this is only an example to illustrate that a complex TNA is not necessary for a small organisation, and that it is not necessarily critical to cover all syllabus items (if agreed by the company CAA surveyor). It should not be taken as a template.

Table 3. Hypothetical TNA for a small organisation

Topic	All staff will undergo this training at a similar level, including the Accountable Manager
General / Introduction to human factors	Show the "Every Day" video to give staff a feel for what human factors is all about, and talk about a few relevant incidents
Safety Culture / Organisational factors	Facilitate a discussion about the company's safety culture, and what people think
Human Error	Discuss some examples of human error as relevant to our business and work
Human Performance & Limitations	Remind staff of their personal responsibilities, as per AN47
Environment	Give some examples of where poor lighting can affect performance, and ask staff what they think of the working conditions here.
Procedures, Information, Tools and Practices	Give some examples of where poor procedures can affect safety, and ask staff what they think of the procedures, information and tools they are using, and where improvements could be made
Communication	N/A - not considered necessary due to the small size of the company, absence of task and shift handovers, and the fact that the company has a good incident reporting system where communication has never been cited as a problem
Teamwork	N/A
Professionalism and integrity	N/A
Organisation's HF Program	Describe the machanisms within the company for reporting incidents, errors, problems, potential hazards, poor procedures, etc - discuss if necessary. Stress that fact that staff will not be inappropriately penalised for reporting problems - put this in writing if necessary. Describe any other company processes relating to human factors

Appendix V Guidelines for trainers

1. Introduction to Facilitation Skills

The following text was produced by LMQ Ltd, for CAP 737 (Crew Resource Management), and has been included in CAP 716 issue 2, with permission, since the principles are applicable to maintenance human factors trainers as well as to CRM instructors. The text has been slightly modified to refer to "human factors" as opposed to "CRM" throughout.

The following aims to explain why there is a need for facilitation, what facilitation is and some of the skills required to use this training technique, plus some general guidelines.

To be competent in any job a person requires a certain amount of knowledge, an adequate level of skills, and the right set of attitudes. This is true for doctors, hotel receptionists, lawyers, footballers, soldiers, artists and of course flight crew, air traffic controllers and maintenance engineers. The role of a trainer in any discipline is to help people develop their knowledge, their skills and their attitudes so that they are able to do their jobs well. In many of the professions the formal training emphasis is often on developing knowledge and skills, with the examination of competence almost exclusively concerned with measuring knowledge and skills against a set of standards.

In aviation it is no different. The vast majority of training resources and all formal examination have been aimed at ensuring people have the appropriate knowledge and skills, rather than the right attitudes. The fact that attitudes are fundamental to competence has not been officially recognised, even though incorrect attitudes are suspected to have contributed to many of the major accidents - the ultimate consequence of a lack of competence. The reason for this omission is uncertain, but a reasonable assumption may be because training and examining ‘attitudes’ have been less precise and more difficult to carry out successfully.

Human factors training has attempted, with variable success, to try and redress the imbalance. Most experts and practitioners are in agreement that the variability in the effectiveness of human factors training is largely linked to the quality of the delivery and not the content, and that training with a high degree of facilitation has been more successful.

This can be explained by exploring the two main techniques that are available to trainers, namely instruction and facilitation. Instruction can be described as being primarily a telling activity, where knowledge and skills are developed in trainees through either direct communication or demonstration, with questioning primarily used to check understanding or reinforce key messages. Facilitation on the other hand, can be described as a technique that helps trainees to discover for themselves what is appropriate and effective, in the context of their own experience and circumstances.

Both techniques are useful and have their place. In order to transfer knowledge and many skills, instruction is the most efficient technique to employ; it would be laborious and unnecessary to teach a straightforward and precise subject such as an electrical system using facilitation. Furthermore, instruction can be used to train larger numbers of people, and is particularly useful if only certain answers are acceptable.

On the other hand, trying to change people's attitudes using instruction as the technique, normally has limited success. People, particularly adults, do not like being told how to behave and what to think. There are rare occasions when a sharp 'kick up the backside' delivered by the right person at the right time has the desired effect, but in general, telling people to change their attitude is not usually effective. This is particularly so if the person doing the telling does not have the respect of the recipient, or represents an authority that lacks credibility. Ironically, this is also consistent with the instruction of positive behaviour, such as 'keep up the good work' which has been known to produce an adverse reaction.

The reason for this is that a person's behaviour is based on their past experiences, values and beliefs which will be different from those of others. Therefore, telling people to behave differently carries the implication that their values and beliefs are wrong, and this is not convincing. People generally behave in a way that they think is rational, and often find it easy to justify their behaviour to themselves and others. However, what they may not be aware of is the effects of their behaviour on other people or the operation; and that an alternative behaviour, which does not question their values but has a more positive effect, may be something they might wish to consider.

The technique of facilitation allows this process to occur, although it is not just for the poor performer nor for the development of attitudes. Facilitation can be equally used to reinforce effective behaviour because it gives people an understanding of why they are good which encourages their continued development. Furthermore it can be used in the development of skills and even knowledge, because it is an effective tool for allowing self analysis and in depth thought, which is an easier way for people to learn, as there is less recourse to memory techniques. The skills of self analysis are not just to get the most from the training session, but can also be continually used for self development on the line.

Table 1. Differences between Instruction and Facilitation

	INSTRUCTING	FACILITATING
1. What do the words imply?	Telling, showing	Making easy, enabling
2. What is the aim?	Transfer knowledge and develop skills	Gain insight / self analysis to enable an attitude change
3. Who knows the subject?	Instructor	Both
4. Who has the experience	Instructor	Both
5. What is the relationship?	Top down	Equal
6. Who sets the agenda	Instructor	Both
7. Who talks the most?	Instructor	Student
8. What is the timescale?	Finite	Infinite
9. Where is the focus?	Instructor / task	Student / attitudes / behaviour
10. What is the workload?	Medium / high	Intense
11. What are trainers thoughts?	Judgemental	Non-judgemental
12. How is progress evaluated?	Test	Observation / self assessment

Dr Guy Smith NWA

Notes on Table

1. Although instructors have used facilitation techniques naturally for many years; in its purest sense instructing has a lot to do with telling, demonstrating and checking that the task is being done in accordance with a standard. Whereas facilitation means that students are given the opportunity to discover what they are doing and the effect it has on others and the task, so that they can make the decision themselves to alter their behaviour or even reinforce any positive behaviour. This process should be made as easy as possible.

2. The principle purpose of instructing is to transfer knowledge and skills efficiently, whereas with facilitation the principle purpose is to encourage a change in attitude or behaviour by the student gaining insight or becoming aware of what they are doing, and being motivated to change. People tend to only do things that they want to do; so telling people that they are wrong and need to change is rarely effective. People generally do not behave in a way that *they* think is wrong. They are aware that others might disapprove, but they will rationalise their behaviour as being appropriate under the circumstances. Telling them that you think they are wrong gives them no new information and often motivates them to continue their current behaviour. The key is for them to understand why others disapprove and the consequences of continuing as they are.

3/4. When instructing, the trainer knows the subject and has the experience, otherwise it would be a pointless exercise. When facilitating both parties know the subject and have the experience, particularly when discussing behaviour. In fact, very competent facilitators are quite capable of being effective without knowing the subject or having any experience of it. In many respects this can be a useful pointer to know when to change hats from being an instructor to a facilitator. If you are certain that only you have the relevant knowledge, and the student would find it difficult to work it out for themselves in the time available, then instructing is probably the most appropriate technique to employ.

5. The relationship when instructing can be perceived as being top down in that the instructor knows more than the student, whereas when facilitating it must be apparently equal. A common mistake by inexperienced trainers when facilitating is to create the impression that they are in some way superior, by implying they know more or have a better attitude.

6. The agenda when facilitating must be set by both parties if the process of buy-in is to get the right start. Agreeing what you are going to talk about and how you will go about it is an important first step. The trainer can greatly assist the learning of the session by summarising and giving meaning to the students' discussions. It is still the trainer's responsibility to ensure that all the training requirements are included in the facilitative session.

7. One of the best measures of identifying which technique you are using, whether it is instructing or facilitating, is to note who is doing most of the talking. When facilitating, students need to be clear in their own minds and be able to self assess what they are doing and the benefits of changing. It is difficult to do this whilst trying to listen to a trainer passing multiple messages.

8. The time taken to cover a subject when instructing tends to be finite and consistent; whereas with facilitation the timescale is indefinite. This does not mean that it takes forever, but that the process of facilitation must be given sufficient time to achieve its aim. The human factors instructor should not be worried about longer debrief or exercise times, because the student's concentration period is much

longer when they are actively involved in the thinking and discussion rather than passively listening. In a limited time period such as a debrief, the process may need to continue afterwards, while students try out new options back at work. Conversely, if the aim is achieved in a few minutes, the job is done and there is no point dragging out the discussion.

9. The focus when instructing is often on the task and the instructor – how well they are doing, did they get things in order, are they being clear, is the equipment working, are they on time. With facilitation the focus must be solely on the student, their attitudes and behaviour, and whether they are learning and are comfortable with the process that is being used. The focus should also be on the student demonstrating an understanding and willingness to change.

10. Because each student is different and it is difficult to read people's minds, the workload whilst facilitating is intense, and more so in a group. The facilitator in this respect is having several conversations simultaneously, both verbally and non verbally, and having to think on their feet in reaction to what is being said. With instructing the workload is high in preparation and initial delivery, but then reduces over time as the instructor becomes more familiar with the material.

11. Although the trainer's observations and training objectives are inevitably judgemental; in order to prompt a student's self analysis, the attitude of the trainer when facilitating a debrief should be non-judgemental. In other words, he or she must be prepared to accept that the opinion of the student is valid and not necessarily wrong, even though the trainer's own experience dictates otherwise. This attitude is the most difficult to genuinely achieve, particularly for trainers who have spent many years instructing and ensuring things are right.

12. The evaluation of an instructing session is relatively simple and measured by test, where a judgement is made whether the standard has been achieved. When facilitating evaluation is made by observation only and the student's self assessment.

2. Facilitation Skills

The skills required to use facilitation as a technique are as follows:-

Questioning

Asking the right questions at the right time is a fundamental skill of facilitation and these are the type of questions that can be used.

Type	**Purpose**	**Response**	**Example**
Open	To get a more accurate and fuller response.	Unknown but they will say more than a few words.	'What, when, why, where, who, how….'
Closed	To check understanding and to control the discussion.	Can be 'Yes', 'No' or specific data.	'Did you, were you, had you'….
Probing / building	To obtain further information	More in depth response.	'Tell me more, why was that, explain….'
Summarising	To confirm agreement	Yes	'Is what you mean, have you agreed …'

Avoid:
a. Leading:- 'You did do that didn't you, wouldn't you agree that……'
b. Multiple.
c. Rhetorical:- 'Who cares?'
d. Ambiguous

Listening

It has often been said that hearing is done with your ears wheras listening is done with your mind. In this respect the term active listening means that a person is concentrating carefully on what is being said, so that they can really understand the other person. This mnemonic helps to capture some key points:

- Look interested
- Inquire with questions
- Stay on target
- Test understanding
- Evaluate the message
- Neutralise your thoughts, feelings and opinions

Body language

Reading body language and managing your own are essential when facilitating. A trainer should be able to know when a student is uncomfortable, confused, interested, distracted or bored. Furthermore it is important that a trainer is able to manage their own body language so that the messages they are giving are accurate and consistent.

Observation of behaviour

The ability to observe and discuss behaviour and attitudes rather than technical issues is an important skill that trainers need to develop to become effective at facilitation. Also trainers should have the ability to observe behaviour objectively against established standards.

Role modelling

As attitude is an imprecise part of competency, there is no better way of demonstrating appropriate behaviour than role modelling. This is because the student can observe at first hand what this behaviour is and experience the positive effects on themselves. Furthermore, in order to maintain credibility as a trainer in human factors, it is important that you behave to the highest level of CRM standards.

Giving and receiving criticism

A trainer should be able to receive criticism well in order to develop and be approachable. Furthermore, there may be occasions when it is appropriate and constructive to give students direct criticism and this must be carefully handled.

Continuous development

In order to ensure that you are able to continuously improve your facilitation skills, the recommended method is to seek feedback from those you are training. This must be done regularly and genuinely, otherwise you may not be given anything useful - and a measure of whether you are doing this well is whether you do in fact get any criticism. If you find that people are not giving you any criticism then the following may be occurring:-

a. You are perfect.
b. You have developed a reputation as someone who has difficulty receiving criticism.
c. You are not respected enough to deserve being told.

Facilitation skills; Trainer Checklist

DO:

Give an introduction

- Purpose - to encourage self analysis (research says that it is the best for of learning)
- Participation from them is needed
- Allow pilots to set the agenda order by asking
  - Which bits of the session they want to discuss
  - What went well

Use open questions (who, where, when, what, why, how)

Deepen the discussion with supplementary questions - let them analyse.

- What happened/ why it happened/ what could we improve on?

Listen and encourage

- use names, node, smiles, eye contact
- sit forward to show interest

Use silence/ pauses (sit back and allow them time to think for several seconds)

Mix instruction with facilitation for issues on which they don't have the knowledge themselves

Summarise discussion to meet training aims

DON'T:

Miss the introduction - it is the most common way to spoil facilitative training

Lecture

Use your chronological agenda

Short change high performing crews with quick debrief

Interrupt

Don't train them not to discuss by:

- Answering your own questions (better to reword the question)
- Just use question and answer

Do the thinking for them

Self Check:

- Who is talking most - you or them?
- Have you used at least 2 questions per issue (to deepen discussion)

- Are the students doing the analysis themselves
- Are the training points being covered
- Have the students spoken to each other
- Has positive behaviour been reinforced

Appendix W Competency Framework

1. Introduction

The following framework was developed by Tony Hines, of the Aviation Training Association, as a result of research, including a consultation workshop involving industry experts (maintenance managers, quality assurance engineers, trainers, regulators and trade union representatives), and has been reproduced with permission. The framework was validated by the completion of a questionnaire by a wide range of Licensed Aircraft Maintenance Engineers (LAMEs) and Managers not involved in the original consultation workshop

Further information will be included in future issues of CAP 716, as the issue of competence is more widely researched.

The example below describes the competencies which may be appropriate to Licensed Aircraft Maintenance Engineers. A different set of competencies would be applicable to, say, maintenance managers or stores staff.

2. Competency Framework for LAMEs

1 Decision taking and judgement making (Acting decisively to resolve issues satisfactorily)

a) Does not jump to conclusions, but bases decisions soundly on factual evidence, using all available information,
b) Anticipates problems in advance and takes action to deal with them,
c) Weighs up alternative options and chooses the most practicable for the circumstances,
d) Ensures that their decisions are realistic, workable and permissible,
e) Does not allow personal preconceptions and opinions to cloud their views and arrives at objective judgements,
f) Follows through decisions but remains open to persuasion and reappraisal.

2 Professionalism *(Inspiring confidence in others of one's capabilities and soundness of judgement)*

a) Assesses accurately and objectively their own strengths and limitations, seeking advice when out of their depth or unsure,
b) Accepts responsibility for health and safety and accountability for their own actions and decisions,
c) Resists the temptation to give "popular" responses and to lower standards when under pressure,
d) Explains, with conviction, the consequences of decisions and the implications of actions to customers so that they understand the risks involved
e) Remains calm, efficient and objective when under pressure.

3 Integrity *(Not sacrificing high standards for immediate gains)*

a) Understands the implications of commercial imperatives,
b) Maintains consistently high standards of work, loyalty, honesty and commitment,
c) Never cuts corners nor jeopardises the safety of others by taking "the soft option",

d) Stands by their decisions and principles even in the face of strong opposition or threats,
e) Has the courage and strength to admit mistakes and weaknesses and to act on them,
f) Diligently pursues work to the end to ensure the optimum service to internal and external customers.

4 Adaptability *(Being flexible with change)*

a) Accepts the need to adapt and face change positively,
b) Learns from their mistakes and those of others,
c) Considers a problem from all aspects and improvises resourcefully yet systematically when dealing with unfamiliar situations,
d) Alters their approach, attitude and methods of working to deal with new and changing situations,
e) Regularly makes constructive suggestions for continuous improvement to processes,
f) Consistently exhibits a positive and constructive attitude.

5 Leadership *(Inspiring teams and individuals to better performance)*

a) Does not wait to be told what to do but energetically gets on with the job in hand, needing little or no supervision,
b) Actively encourages others to achieve or exceed their objectives, guiding them through challenging situations and difficult problems and publicly applauding their efforts and successes,
c) Motivates others by setting a role model to others through exemplary behaviour and quality of work,
d) Is not afraid to ask for help when needed and accepts advice constructively,
e) Takes personal responsibility for ensuring that tasks are fully completed.

6 Teamworking *(Collaborating positively with others for mutual benefit)*

a) Puts team considerations before their own individual needs,
b) Shows respect to all team members at all levels by treating them with equal courtesy and consideration and exemplifies corporate culture and values,
c) Understands the effects of their actions and words on other people and modifies their behaviour to achieve results,
d) Minimises conflict and takes active steps to relieve tension and stress within the team, exhibiting rapport and compassion to build effective working relationships,
e) Offers support and help to others beyond what is required,
f) Coaches and trains less experienced colleagues and shares ideas, information and solutions for the team's benefit,
g) Considers the needs of other people beyond their own team.

7 Self Development *(Growing with the job by keeping up to date with individual skills, knowledge and business practices)*

a) Recognises the need to keep their skills and knowledge up to date,
b) Takes personal responsibility for developing themselves and their career,
c) Accepts criticism constructively and takes action to correct areas of personal weakness,
d) Keeps abreast of wider technical, business and commercial developments which might the team's and the company's work,

e) Seeks to understand the business environment and the financial implications of their decisions and actions,
f) Is mindful of costs and seeks to work efficiently and economically,
g) Asks for opportunities to take on new challenges in order to develop their personal and social skills.

8 Communication *(Ensuring clear and common understanding on both sides)*

a) Listens actively and carefully to what others are saying and appreciates their point of view, even when it contradicts their own,
b) Checks to ensure that they have correctly understood what is being communicated,
c) Structures what they want to communicate and expresses themselves clearly, consisely and assertively to non-technical people so that they can understand the implications of an issue,
d) Adapts their style, expression and choice of words according to the audience to ensure clarity of understanding,
e) Negotiates diplomatically and seeks to find compromises and mutually acceptable solutions in disagreements,
f) Shares information openly with others to ensure lessons are learned for future benefit.

9 Methodical *(Planning and organising to maximise the resources available)*

a) Systematically draws up plans and distinguishes urgent from other priorities, juggling tasks and priorities to meet deadlines,
b) Allocates clearly roles and responsibilities within the team as a whole,
c) Sets personal goals and targets to keep on top of their own work,
d) Organises work logically so as to make the best use of time, people and equipment available to complete the task on time,
e) Completes the necessary documentation accurately,
f) Refers to manuals and instructions when necessary and does not rely on memory,
g) Makes back-up plans to allow for scheduled and unscheduled maintenance, contingencies and any unforeseen situations.

3. Further information

Further information concerning the Competency Framework may be found in the paper "Proving the Competence of the Aircraft Maintenance Engineer", Hines, A. UK Aviation Training Association. presented at the International Air Safety Seminar, Washington DC, November 2003.

Appendix X Introducing an Error Management Programme into an Organisation

This Chapter has been adapted from "People, Practices and Procedures in Aviation Engineering and Maintenance: A practical guide to Human Factors in the Workplace." It was written in 1999, when there was no requirement to have a human factors programme, therefore the emphasis was upon how to persuade a senior manager of the value of such a programme. Whilst there is now a requirement for such a programme, it is still crucial to the success of such a programme to obtain senior management 'buy in' and support, hence the decision to include this text as an additional appendix in CAP 716 issue 2. The text is as follows:

1. Introducing an Error Management Programme into an Organisation

This Appendix offers a six point plan for the introduction of a human factors programme into aircraft maintenance organisations, but especially for those which have yet to embark on a human factors programme. It should not to be regarded as a *definitive* programme which will cover all human factor areas within all companies; rather it gives a starting point and benchmark which companies may choose to adopt.

It is appreciated that many companies have already embarked upon a human factors programme, or already have elements of such a programme (eg. within their Quality System). This guidance material might be useful to act as a checklist to see whether any of the elements are missing in the existing programme and if so, why? It might also act as a reminder of the reason why each element is important, as there is sometimes a tendency for the original reasons for initiatives to be forgotten once the detail of running the programme takes over.

The six key steps are:
- Know why you are embarking on a human factors programme, and gather evidence to support the need for such an initiative.
- Obtain top management commitment to improving Human Factors awareness and performance within the aircraft maintenance system.
- Conduct a review of the current culture, procedures, systems and work practices within aircraft maintenance
- Communicate the report findings to all personnel. Human factors general awareness briefings should then be provided to reinforce the need for any change.
- Implement a change programme and conduct Maintenance Resource Management (MRM) training.
- Develop an evaluation and monitoring programme.

It is important to know why you are doing this, and to have belief and commitment that implementing such a programme, or elements of the programme, ***will*** improve safety. It is not enough simply to do it because it meets a regulatory requirement. If this is the only reason, and there is no true belief and support that such a programme is necessary, it is likely that this message will filter down to the workforce and the programme will not be effective. Many such initiatives succeed because they have a “champion” - usually someone at senior management level within the organisation who has personal commitment to the success of the human factors programme.

It is also important to consider this as a long-term initiative, and not just a temporary “fashion”. There is often a great deal of enthusiasm at the start of such programmes, but this enthusiasm may tail off if the management or workforce see no positive changes arising as a result. Feedback is vital to the continued success of a human factors programme. Care should also be taken to ensure that a maintenance error management programme is not a ‘victim of its own success’. Some programmes have failed because there has been such a positive response from the workforce after training, and an associated increase in reporting of problem areas and errors, that the programme and those responsible for running it, have been overwhelmed with workload and collapsed as a result. Resourcing such a programme is discussed later.

There may also be support from the senior management team until there is a conflict of interest between commercial drivers and recommendations arising from the human factors programme. This is the real test of management commitment, and can result in the failure of the programme if commercial issues are seen to take precedence over safety issues. Whilst it is appreciated that every organisation is in the business to make money, the balance has to be appropriate between commercial and safety objectives. Professor James Reason describes this well in his book “Managing the Risks of Organisational Accidents”

2. Prepare your case

Know why you are doing this - to improve safety - and prepare your case to persuade those who need to be persuaded - senior management, accountants, workforce, unions, 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!” may not be enough. Contacting other companies in order to determine the effectiveness of their human factors programmes or projects can also be quite useful. You should prepare a ‘sales pitch’ using Return on Investment (ROI) evidence where appropriate and/or using a recent incident, preferably from your own organisation, to present to the management. It is important to keep management interest and commitment for long enough for the programme to start proving itself successful, which may not be for a year or two.

The information on accidents and incidents contained in Appendix D. This data will be useful to help you formulate your case.

Whilst the main reason for implementing such a programme should always be safety, the argument used to justify its need or continued existence might include:

- Existing or future ICAO requirements (which, in turn, should exist to promote safety)
- Existing or future JAA/EASA requirements (which, in turn, should exist to promote safety)
- Existing or future NAA requirements (which, in turn, should exist to promote safety)
- Human Factors and error management should be an integral part of any SMS initiative.
- Some of the Health and Safety legislation may also be useful in supporting such a programme
- Evidence from well-known accident and incidents that human factors problems exist
- Evidence from own accident, incidents and anecdotes that human factors problems exist
- Evidence from research and case studies that human factors problems can be addressed

- Return on Investment arguments, based on US case-studies, that human factors programmes can not only improve safety but can save money in the long run.

More information on Return on Investment (ROI) case studies can be found on the website *hfskyway.faa.gov*.

It will also be useful at this point to develop a framework document suggesting where in the organisation the error management co-ordination responsibilities will lie, from responsibility at top management level to the day-to-day responsibility of implementing the programme, running any courses, investigating incidents, etc. There are likely to be resourcing implication, so a strong case needs to be made if the adoption of an error management programme is going to need additional staff. It may be the case that the programme can be implemented and run, at least initially, by existing staff, until its worth is proven to the extent where a case can be made for additional staff. Some performance indicators should be agreed whereby the new team can shift focus to their new role as it develops (which it will). The programme is not likely to be effective if it is merely added to the existing burden of an unwilling and probably already overstretched Quality Manager, nor is it likely to succeed if it is 'contracted out' to a training agency which knows nothing about the workings of your organisation. It must be stressed that in order for the programme to succeed, it must be properly resourced.

3. Obtain top management commitment to improving Human Factors awareness and performance.

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 terms 'human factors' and 'error management' and giving a general commitment towards increasing the company's awareness or performance with regard to human factors issues. Alternatively, 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 aircraft maintenance human factor issues - and would be continually reinforced by departmental communications such as team briefings, meetings, internal memos, etc. Commitment needs to be long term, and it needs to be emphasised that this is not just the latest management 'fad'. It should be stressed that "this is the way we do business from now on".

4. 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? 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.

Staff surveys are a useful tool to determine what kind of culture currently. The HSE have published a report entitled "Improving Compliance with Safety Procedures: reducing industrial violations" which includes a survey tool which may be appropriate to use. Note: a software version of this tool is also available. Also, the UK Human Factors Combined Action Group (UKHFCAG) document "People, Practices and Procedures in Aviation Engineering and Maintenance: A practical guide to Human Factors in the Workplace" includes a succinct staff opinion survey (see Appendix N).

'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 mentioned 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 (ERNAP) (Appendix Q)

5. Communicate the report findings 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 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 terms 'Human Factors' and 'Error Management'.
- 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.
- The approach which the company is adopting

These briefings should be used as an opportunity to ask the workforce what they think, ensuring that any ideas and suggestions which are offered are recorded and fed back into the process.

6. Implement a change programme and conduct Human Factors training if appropriate.

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 recommendations, such as changing the typeface on a workcard, are relatively easy to accomplish. However other recommendations, 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:

1. 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 a strong personal interest in human factors or who has had previous experience of project work or human factors, and who is respected by the workforce. In order to gain workforce support it would also be advantageous to consult with the workforce over the final selection.

2. Consideration of resource levels, from management level to administrative support level. For instance, data will need to be entered and analysed from both the initial review and any ongoing investigations. Where possible, this function should be integrated with other existing systems and forums such as Quality/ resolution meetings, 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.

3. Implementation of a Human Factors Programme. This should include Human Factors training (ideally, for all of the staff, including managers, supervisors, planners, administrative staff, etc), an incident reporting scheme (if there is not such a scheme running already, or changes to an existing scheme), an incident investigation mechanism, the publication of an appropriate disciplinary policy, etc.

4. Development of a 'Change Plan'. The plan will include details of the changes to be made, the people responsible for implementing the changes and the specific timescales involved. Dependent 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.

5. 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

6. 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.

7. 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 any Human Factors training and whether, as a result of the changes implemented, any further changes are necessary. It is also important to start analysing the data arising from incident investigations, bearing in mind that this may only begin to show trends after a few years (depending on the size of the database).

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.

Evaluation of the effectiveness of Human Factors training can be difficult. The attitudes can be evaluated by using post course critiques, but determining whether behaviour has actually changed (if, indeed, any change was necessary) is more difficult to measure.

Care should be taken if using incidents as a performance measure of the success of a human factors programme or human factors training. Part of the programme will encourage staff to report incidents which they may not have reported previously, so the apparent number of incidents is likely to increase in the short term. However, this may be a valuable measure in the longer term.

Good performance in human factors issues can not be sustained merely by introducing a human factors / error management 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 and error management is one that be ongoing, and not merely a passing 'fad'.

8. Further reading

1. People, Practices and Procedures in Aviation Engineering and Maintenance: A practical guide to Human Factors in the Workplace. UKHFCAG. 1999. *www.raes.org.uk*
2. ATA 113 Specification for Maintenance Human Factors Program Guidelines. *http://www.air-transport.org/public/publications/57.asp*
3. Reason, J. Managing the Risks of Organisational Accidents. 1997. Ashgate

4. ICAO Human Factors Manual.
5. Maurino, D., Reason, J., Johnston, N., & Lee, R. (1995). Beyond Aviation Human Factors.
6. Meghashyam G. Electronic Ergonomic Audit System for Maintenance and Inspection. Proceedings of the Tenth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, 1996 *hfskyway.faa.gov*
7. UKCAA AN71
8. Return on Investment ppt presentations *hfskyway.faa.gov*

Appendix Y Sources of further information - summary

Further information on each of these documents, videos and websites is provided in this Section. Note: information was correct at the time of publication, but since websites are dynamic by nature, the addresses or information may change with time.

Many of these documents can be found on the website *http://hfskyway.faa.gov*

Key documents

Document	***website reference***	***Appendix Z ref***
CAP 716 Aviation Maintenance Human Factors	www.caa.co.uk	20
JAA Maintenance Human Factors Working Group Report (May 2001)	www.jaa.nl	22
ICAO. Human Factors in Aviation Maintenance. Doc 9824-AN/450. (2003)		2
ICAO. Human Factors Training Manual, Doc 9683-AN/950 (Edition 1 1998)(amendment 1, 30/9/03)		1
ICAO. Human Factors Digest No. 12: Human Factors in Aircraft Maintenance and Inspection. (Circular 253-AN/151) 1995. reprinted as CAP 718.		3
Managing Maintenance Error. Reason, J and Hobbs, A. Ashgate. 2003. *ISBN 0 7546 1591 X*		7
CAP712 Safety Management Systems for Commercial Air Transport Operations. 2001		20
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Human-Centred Management Guide for Aircraft Maintenance: Aircraft Dispatch and Maintenance Safety (ADAMS). (2000)	*http://www.tcd.ie*	*9*
"Every Day" – video.	*http://www.ifairworthy.org/thevideo.htm*	*12*

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Proving the Competence of the Aircraft Maintenance Engineer, Hines, A. November 2003. International Air Safety Seminar		
Vision on Training. CAA May 1999.		
Human Factors Guide for Aviation Maintenance. Version 3.0 (1998). Editor. Dr. Michael Maddox.	*http://hfskyway.faa.gov*	*15*
MRM Handbook.	*http://hfskyway.faa.gov*	*15*
Airline Maintenance Resource Management; Improving Communication. Taylor, J C., Christensen, T D.		
"Engineering Solutions to Human Problems" - videos and training package.	*http://www.ifairworthy.org/thevideo.htm*	*13*
Learning from our mistakes: A review of Maintenance Error Investigation and Analysis Systems. Marx D Jan 1998.	*http://hfskyway.faa.gov*	*15*
Documentation Design Aid.	*http://hfskyway.faa.gov*	*15*
Electronic Ergonomic Audit System for Maintenance and Inspection (ERNAP).	*http://hfskyway.faa.gov*	*15*
Drury, C. Human Factors Good Practices in Flourescent Penetrant Inspection. FAA. August 1999.	*http://hfskyway.faa.gov*	*15*

Document	***website reference***	***Appendix Z ref***
AECMA Simplified English Guide for the Preparation of Aircraft Maintenance Documentation		

Key websites

www.caa.co.uk	UK CAA website	20
hfskyway.faa.gov	Key site for virtually all Human Factors in Maintenance and Inspection research, reports, software tools, proceedings, maintenance human factors accident reports, etc	15
www.jaa.nl	Joint Aviation Authorities	22
www.tc.gc.ca	Transport Canada	19
www.casa.gov.au	Civil Aviation Safety Authority Australia	21
www.easa.eu.int	European Aviation Safety Agency	23
www.chirp.co.uk	Confidential Human Factors Incident Reporting scheme	
www.chirp.co.uk/mems	Confidential Human Factors Incident Reporting scheme	
www.raes-hfg.com	Royal Aeronautical Society Human Factors Group, Engineering Maintenance Standing Group (EMSG)	17,18
www.dft.gov.uk/aaib	Air Accidents Investigation Branch	25
www.ifairworthy.org	International Federation of Airworthiness	11,12
www.marss.org	Maintenance and Ramp Safety Society – from where you can order the MARSS videos and “dirty dozen” posters.	14
www.tcd.ie	Trinity College Dublin – for information on ADAMS, STAMINA, AMPOS, SCARF, AITRAM.	9,10
www.ntsb.gov	National Transportation Safety Board	26
www.air-transport.org	Air Transport Association (ATA) of America	
asrs.arc.nasa.gov	USA’s confidential Aviation Safety Reporting System	
www.camc.ca	Canadian Aviation Maintenance Council – with details of maintenance human factors computer based training products	
www.gainweb.org	Global Aviation Information Network	
www.hse.gov.uk	Health and Safety Executive	
www.icao.int	ICAO	
www.nlr.nl	Dutch National Aerospace Laboratory	
www.tsb.gc.ca	Canadian Transportation Safety Board	27
www.atsb.gov.au	Australian Transport safety Bureau	28

Appendix Z Key Documents, Videos, Tools and Products

1. ICAO Human Factors Training Manual - Doc 9683-AN/950

Brief Description:
This manual is essentially an edited compilation of the series of ICAO Human Factors Digests. Its target audience includes senior training, operational and safety personnel in industry and regulatory bodies. It comprises two parts:
Part 1 - General. Introduces the concept o aviation human factors, presents a systemic and contemporary view of aviation safety, outlines the basic principles of workstation design and reviews the fundamental human factors issues in the various aviation domains, including air traffic control and maintenance.
Part 2 - Training Programmes for Operational Personnel. Outlines human factors training issues and proposes the contents of sample training curricula for pilots, air traffic controllers maintenance technicians and accident investigators.

The ICAO Digests pertinent to maintenance engineering which the Training Manual replaces are:

1	Fundamental Human Factors Concepts (ICAO Circular 216)
3	Training of Operational Personnel in Human Factors. 1991 (ICAO Circular 227)
6	Ergonomics. 1992 (ICAO Circular 238)
10	Human Factors, Management and Organisation. 1993 (ICAO Circular 247)
12	Human Factors in Aircraft Maintenance and Inspection. 1995 (ICAO Circular 253)

To obtain a copy, contact:
Airplan Flight Equipment Ltd (AFE),
1a Ringway Trading Estate,
Shadowmoss Road,
Manchester M22 5LH.
Tel no 0161 499 0298
Email: enquiries@afeonline.com,
website www.afeonline.com

Price available on request

2. ICAO Human Factors Guidelines for Aircraft Maintenance - Doc 9824-AN/450 (Issue 1 - 2003)

Brief Description:

This manual addresses organisational human factors issues in maintenance, and includes chapters on the following:

- Why human factors in aircraft maintenance - background information and justification
- Key issues related to maintenance errors
- Countermeasures to maintenance errors
- Reporting, analysis and decision making
- Training

- Regulatory policy, principles and solutions
- Additional reference material

To obtain a copy, contact:
Airplan Flight Equipment Ltd (AFE),
1a Ringway Trading Estate,
Shadowmoss Road,
Manchester M22 5LH.
Tel no 0161 499 0298
Email: enquiries@afeonline.com,
website www.afeonline.com

Price available on request

3. ICAO Human Factors Digest No. 12 Human Factors in Aircraft Maintenance and Inspection - Circular 253-AN/151 (1995)

Brief Description:

This Digest contains chapters on:

- Human factors - aircraft maintenance and inspection
  - contemporary maintenance problems
  - the SHEL model
  - the Reason model
  - human error
- Human error in aircraft maintenance and inspection - an organisational perspective
- Human factors issues affecting aircraft maintenance
  - information exchange and communication
  - training
  - the aircraft maintenance technician
  - facilities and work environment
- Teams and organisational issues in aircraft maintenance
  - team work
  - job design
  - reward systems
  - selection and staffing
  - training
- Automation and advanced technology systems
  - automation and computerisation
  - advanced job aid tools
- Error prevention considerations and strategies
- List of recommended reading

To obtain a copy:
This document is now out of print as an ICAO Digest, since the series of Digests have been replaced by the ICAO Human Factors Manual.
However, it has been re-published, with permission from ICAO, as CAP 718, and may be downloaded at no charge from www.caa.co.uk/publications

4. People, Practices and Procedures in Aviation Engineering and Maintenance: (A Practical Guide to Human Factors in the Workplace) (January 1999)

Introduction
In the document, the United Kingdom Human Factors Combined Action Group (UKCAC) has put together a five-point plan for all aviation engineering and maintenance facilities 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 everyone to use.

Produced by:
This document was produced by the UKCAG. This group was created to co-ordinate UK activity on the subject of Human Factors in Engineering and Maintenance within the Aviation Industry. The UKCAG has now moved on to look at Safety management Systems.
The group is comprised of 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
- UKCAA

Copies can be obtained from:

www.raes-hfg.com

5. Specification 113 for Maintenance Human Factors Program Guidelines (1999)

Brief description:
It is well known that Human Factors issues, which can be causal factors, are involved in aviation accidents. The purpose of these guidelines is to set forth voluntary standards suitable for adoption by companies engaged in aircraft and aircraft component maintenance for developing and maintaining a maintenance human factors program to enhance safety and aid maintenance personnel in preventing aviation accidents and incidents.
This guidance material was developed by the ATA Maintenance Human Factors Subcommittee made up of, among others, Human Factors representatives from Airbus, BF Goodrich Aerospace, The Boeing Company, Continental Airlines, FedEx, Flight Safety International, The International Association of Machinists and Aerospace Workers (IAM), The Federal Aviation Administration

(FAA), National Aeronautics and Space Administration (NASA), Northwest Airlines, United Airlines, US Airways, and ATA.
This ATA Guideline does not, in itself, impose any performance obligations on any airline, or any other entity. For this reason, any entity, which contractually performs maintenance for an airline must determine from that airline which provisions of these guidelines, if any, are applicable to the specific situation.

Contents

Copies can be obtained from:

Air Transport Association of America
1301 Pensylvania Avenue
NW - Suite 1100
Washington DC 20004-1707
USA
tel: (202) 626 4000
e-mail www.air-transport.org

or downloaded free from:
http://www.air-transport.org/public/publications/57.asp

6. Human Error - James Reason (1990)

The following text has been taken from the cover of the book:

Modern technology has now reached a point where improved safety can only be achieved through a better understanding of human error mechanisms. In its treatment of major accidents, "Human Error" spans the disciplinary gulf between psychological theory and those concerned with maintaining the reliability of hazardous technologies. This is essential reading not only for cognitive scientists and human factors specialists, but also for reliability engineers and risk managers. No existing book speaks with such clarity to both the theorists and the practitioners of human reliability.

The book contains chapters on:

- The nature of error
- Studies of human error
- Performance levels and error types
- Cognitive underspecification and error forms
- A design for a fallible machine
- The detection of errors
- Latent errors and systems disasters
- Assessing and reducing the human error risk

Whilst this book is not specific to error in aviation maintenance, it would nevertheless form useful background theory for human factors instructors.

Cambridge University Press
ISBN 0-521-31419-4

7. Managing Maintenance Error - Reason and Hobbs (2003)

The following text has been taken from the cover of the book:

This is a down-to-earth practitioner's guide to managing maintenance error. It deals with human risks generally and the special human performance problems in maintenance, as ell as providing en engineer's guide to understanding and addressing the threat of maintenance error. After reviewing the types of error and violation and the conditions that provoke them, the authors set out the broader picture, illustrated by examples of three system failures.

Central to the book is a comprehensive review of error management, followed by chapters on:

- Managing the person, the task and the team
- The workplace and the organisation
- Creating a safe culture

Chapters include:

- Human performance problems in maintenance
- The human risks
- The fundamentals of human performance
- The varieties of error
- Local error-provoking factors
- Three system failures and a model of organisational accidents
- Principles of error management
- Person and team measures
- Workplace and task measures
- Organisational measures
- Safety culture
- Making it happen: the management of error management

This book is specific to error in aviation maintenance, and it would form useful background theory for human factors instructors, whilst also providing them with practical examples and data with which to illustrate theoretical points.

Ashgate
ISBN 0-7546-1591-X

8. Improving Maintenance: a guide to reducing human error. HSE Books.

The following information has been taken directly from the press release:

Major accidents and near-misses resulting from human error in industrial maintenance operations are on the increase, says the Health and Safety Executive (HSE), but new guidance can reduce such incidents significantly.

Overall, the general accident trend in Britain is downwards but the role of maintenance error as a root or contributory cause to major accidents has increased. There have been many high-profile examples, both in Britain and elsewhere, e.g. Clapham Junction, Bhopal, Piper Alpha and a number of aviation accidents. Recent near-misses resulting from errors during maintenance include a large release of natural gas from an offshore production platform and a spillage of 17 tonnes of highly flammable liquid at an onshore refinery. Fortunately, in both cases there was no ignition.

Dr Paul Davies, HSE's Chief Scientist and Head of Hazardous Installations Directorate, said: "Traditional approaches to safety have focused on engineering and process risks, and sought hardware solutions to them. However, studies show that 'human factors' contribute to up to 80% of workplace accidents and incidents. HSE is actively tackling this area by developing its own human factors guidance and expertise, and applying it directly in its inspection and enforcement activities." Dr Davies' comments coincide with HSE's publication of new guidance providing practical step-by-step methods, which if applied, can help industry reduce error significantly by identifying and assessing issues that impact on the performance of maintenance staff.

The guidance, which is aimed at all industries - chemical, nuclear, railway, aviation etc.- and all sizes of business, was developed by a specialist Maintenance Sub-group from the Human Factors in Reliability Group (HFRG), a long-standing forum for individuals from industry, regulatory bodies and academia with an interest and expertise in 'human factors'. HSE contributed to, and sponsored the project. The guidance gives an overview of the importance of human factors and lists the main issues that management control. It goes on to provide a method, based on readily collectable information, for identifying the key issues adversely affecting maintenance in any particular organisation. Useful questionnaires and guidelines on ranking the relative importance of issues from information on underlying incident causes are included.

"The key message from the guidance is that human error in maintenance is largely predictable and therefore can be identified and managed", said Dr Davies. "HSE expects to see industry tackle maintenance risks in a structured and proactive way, making it part of every company's safety management system. HSE is committed to pursuing the continued reduction of accidents resulting from maintenance activities through advice and, where necessary, enforcement."

To obtain a copy:
http://www.hsebooks.co.uk
HSE Books, PO Box 1999, Sudbury, Suffolk CO10 2WA (Tel: 01787-881165/Fax: 01787-313995).
HSE priced publications are also available from all good book shops.

HSE
ISBN 0 7176 1818 8, price £16.00.

Additional References
1. *Improving compliance with safety procedures: reducing industrial violations* HSE Books 1995, ISBN 0-7176-0970-7.
2. *Reducing error and influencing behaviour* (HSG48 Revised) HSE Books 1999, ISBN 0-7176-2452- 8.

9. Human-Centred Management Guide for Aircraft Maintenance: Aircraft Dispatch and Maintenance Safety (ADAMS) (1999)

Produced by:
The ADAMS project consortium:
- Trinity College Dublin (TCD)
- Defence Evaluation Research Agency (DERA)
- Joint Research Centre (JRC)
- National Aerospace Laboratory (NLR)
- Sabena
- Scandinavian Airlines System (SAS)
- FLS Aerospace (IRL) Ltd
- Airbus Industrie

An Overview of Human-Centred Management

The safety and reliability of aircraft maintenance operations depends as much upon people as it does on the technical systems of aircraft, parts, tools and equipment. Nevertheless, incident reports continue to show that aircraft technicians sometimes make mistakes, and aircraft maintenance organisations sometimes fail to organise and monitor their work effectively, and these failures can have disastrous or near-disastrous consequences. Furthermore, even when things do not go radically wrong, the evidence suggests that on a routine day-to-day basis the systems, which should ensure that work is accomplished to the highest possible standard, are not functioning effectively. In response to new regulations, which demand consideration of the human factors of maintenance operations, many organisations are embarking on human factors programmes, typically involving training or incident investigation. Unfortunately, these programmes are not always successful in achieving better ways of doing things, for a variety of reasons.

This guide is the result of an on-going series of research programmes into the human aspects of safety and reliability in aircraft maintenance, funded by the European Commission, involving leading European aviation organisations and research institutes. It is designed to give practical guidance on how to manage the human side of aircraft maintenance. Its starting point is the responsibility of every approved maintenance organisation, under the JAA, to manage and to be accountable for the safety and reliability of their operations. Its goal is to demonstrate how organisations can consistently improve their performance through better planning of systems and operations to meet human requirements, through learning to improve operations and to prevent incidents and accidents, and through the development of competence to achieve organisational goals. This is a systematic approach to managing human factors in aircraft maintenance, which is designed to overcome the limitations of many current human factors programmes.

This first chapter covers the following topics:
- some examples of individual error and organisational failure
- common deficiencies in current safety systems
- typical limitations of current human factors practice
- an outline of human-centred management for aircraft maintenance

The following four chapters outline in more detail the main features of human centred management under the following headings:
- Goals of human centred management
- Design, planning and 'best practice'
- Organisational learning to improve safety and reliability
- Competence and training

Case studies and further guidance material to illustrate and develop the recommendations contained in these chapters are attached to the guide as a series of appendices.

for further information, contact:

APRG,
Department of Psychology
Trinity College,
College Green,
Dublin 2
Ireland

www.tcd.ie/aprg/

10. STAMINA Human Factors Project

Human factors – the training remedy

Aircraft maintenance is a training-oriented industry. As human factors have emerged as critical to safety of maintenance, a major response by the industry has been to introduce human factors training. Human factors training has been developed by airlines, manufacturers and training organisations; it has now been mandated by the JAA. The industry is committed to training as a remedy for human factors problems.
Will training deliver significant improvements in safety? Possibly, but it is likely to have only short term effects if the industry has a limited conceptualisation of training as a brief "fix-it" to a more comprehensive and sustained approach. The STAMINA project has been developing such an approach.

Training throughout the organisation.

Perhaps the most critical element of a comprehensive approach to human factors training is targeting the entire organisation, not just the technicians. To think that the problems are restricted the "hands-on" personnel and that solutions can be restricted to them is a very limited view of human factors.

Maintenance work is intimately affected by decisions and actions of supervisors, shift and contract managers, planners, technical writers, and organisational management. These are the personnel who set the context for the work of the technicians. They need human factors training which addresses their particular roles. Three critical roles are specifically targeted by STAMINA training: managers, supervisors and trainers.

While management do not have day to day contact with maintenance personnel, the organisational context that they set has a major influence. This influence encompasses both the general safety climate and the impact of specific decisions and policies – allocation of resources, policies regarding personnel involved in incidents, training, incident and accident investigation, information flow, etc.

Supervisors play a vital role in setting the immediate social context in which the work is done – at the level of the work team. As well as specific roles such as allocating tasks, the supervisor establishes the working style of the team – group or individual decision-making, openness to suggestions, problem-solving style, responses to errors, etc. The supervisor's behaviour can affect whether human factors training becomes on ongoing learning experience for a technician, or a set of naïve idealistic notions.

Addressing competence

Much of the existing training in the industry consists of discrete one- or two-day courses for maintenance personnel aimed at raising their awareness and knowledge of human factors. The assumption is that raising awareness and imparting knowledge should be sufficient to impact behaviour in the operational setting. Human factors is treated simply as a body of knowledge which technicians must know, in the same way in which they should know about aerodynamics or aircraft structure.

But bringing about effective change in operational behaviour is a much more demanding task than the mere application of knowledge. Skills need to be learned and developed – communication skills, decision making ability, etc. Attitudes and values may need to be changed – willingness to take responsibility for safety and admit mistakes, willingness to work as a team, etc. Developing skills and having a lasting impact on attitudes and values cannot be achieved in the space of a short training course. Human factors is something that not only has to be known, it has to be done.

"Human factors…
has to be done,
• not just understood"

Beyond compliance

Central to the philosophy of STAMINA is the conviction that mere compliance with regulations is inadequate and could be counterproductive. While the STAMINA core materials cover the JAR 66 and JAR145 syllabi, the focus is more on enhancing safety, reliability and efficiency.
Motivation for mere compliance will lead to the minimum investment human factors training to meet the regulatory requirements and a purely pragmatic implementation strategy. On the other hand, motivation to impact operational reality will encourage optimal investment and considered implementation of human factors training.

Addressing operational realities

Effective transfer of training requires addressing the operational realities. In particular the following need to be addressed and discussed.

- Barriers to safe performance – time pressure, confusing procedures, etc.
- Management' role. The presence of a manager at the training, who is prepared to listen, to acknowledge deficiencies and discuss relevant issues, is very useful.
- Operational double standards. For example, technicians may be put under pressure to meet deadlines but feel that they will be blamed if an incident results from cutting corners.

Training that ignores or avoids these "hot" issues of the working environment will readily be perceived as purely wishful thinking.

Progressive integration of human factors with technical training

The initial challenge of human factors is to change the existing culture of the company from one which is primarily technically oriented to one which is equally competent at managing the human aspects of the operation. The challenge for the future will be to sustain and enhance this new culture. A key element of this is training of personnel entering the company.
Initial training of technicians is explicitly about teaching them the knowledge and skills they will need to do their jobs. But there is another, more implicit, type of learning occurring. Technicians are learning the professional culture of aircraft maintenance. Trainers play a key part of this process, influencing the development of professional attitudes, values and roles.
If human factors is treated merely as another subject on the curriculum, a great opportunity will be missed to influence the formation of this professional culture in the next generation of technical personnel
Integration of technical and human factors training comprises two aspects:
Incorporation of human factors material into the instructional content of technical classes. This could take a number of forms:

- instructional material on human factors issues relevant to the particular technical topic being instructed;
- setting up model best-practice structures such as an error reporting system;

- highlighting of human factors issues which arise in the course of training.
- Practical training of human factors competence – best practice in dealing with a range of human factors-critical situations

Using human factors principles to inform the instructional context. Much learning about professional culture derives from observing role-models (instructors, supervisors, etc) and from practical experience in the work-place. If the messages from these sources contradict the explicit content of the training, that content will be wasted. Technicians will learn to do what they see done, not what is supposed to be done.

Integration of training with other human factors initiatives

STAMINA is an ambitious approach to human factors. But it is only an ambitious approach that will work because of the nature of the changes that are required. Human factors are not discrete, easily identified and readily solved problems. They are problems that are inherent in systems that have been set up to perform technical functions and are now being required to address human issues. The change has to be in the whole system.

Training is by no means the full solution to human factors problems. It needs to part of a broader strategy within the company. STAMINA can play two roles in this context:

- Training management in developing a comprehensive approach to human centred management.
- Providing training support for initiatives such as process improvement, incident investigation. FLS, for example, used STAMINA to support the pilot implementation of AMPOS[53].

Further reading

Cromie, S., (1999) A Comprehensive Approach to Human Factors Training in Aircraft Maintenance, Journal of Professional Aviation Training. 1(4)

The STAMINA partnership

- Trinity College, Dublin (TCD)
- Nationaal Lucht-en Ruimtevaartlaboratorium (NLR), Amsterdam
- FLS Aerospace (IRL)
- SAS

In collaboration with the E.U. Joint Research Centre (JRC) at Ispra

The STAMINA training has been developed with the support of the European Community within the framework of the Leonardo Da Vinci programme

For more information:

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[53] Aircraft Maintenance Procedure Optimisation System

11. International Federation of Airworthiness (IFA) www.ifairworthy.org/

Introduction

The International Federation of Airworthiness (IFA) is an organisation dedicated to improving aviation safety by increasing international communication awareness and co-operation on all aspects of airworthiness particularly Continuing Airworthiness. IFA started from the International Federation of Aircraft Technology and Engineering, founded in the mid 1960's and adopted its present title in 1975. Membership is open to corporate organisations and aviation professionals, with over 100 organisations representing:

- Airworthiness Authorities
- Aviation Insurers
- Aircraft Leasing Companies
- Aviation Consultancies
- Air Transport Operators
- Aerospace Manufacturers
- International Air Safety Organisations
- Professional Aeronautical Societies
- Service/Repair Organisations
- Colleges and Universities

Role

Promoting world-wide co-operation on airworthiness and continuing airworthiness issues including regulation and the sharing of experience to improve aviation safety.

Main Activities

- Organising Annual Technical Conferences on Aviation Safety and, where appropriate, jointly with the Flight Safety Foundation and IATA.
- Updating IFA Members on proposed changes to airworthiness requirements and procedures, by way of the IFA Information Service.
- Providing a forum for discussion on airworthiness problems with a view to solutions.
- Establishing IFA' s position on airworthiness problems with a view to initiatives or position papers.
- Supporting the efforts already being made by recognised international authorities in the field of continuing airworthiness and harmonised standards.
- Co-operating with ICAO and the Flight Safety Foundation in joint projects concerned with airworthiness issues under the guidance of its Technical Committee.
- Sponsoring a technical committee, which has members from all the main IFA interest groups to monitor technical activities and proposed initiatives.
- Liaison with the International aviation regulatory authorities on issues of interest to IFA members.
- Improving the co-ordination between maintenance & flight operations in the management of safe

The IFA was responsible for instigating the production of the video "Every Day", on maintenance human factors and safety management, and also contributing towards the production of the 4 video set "Engineering Solutions", produced by TVC.

12. “Every Day” - video

Brief description:

The Maintenance Human Factors awareness video 'Every Day' was launched at the annual IFA/FSF/IATA air safety joint seminar at Washington in 1997. This video features Professor James Reason. Many operators worldwide are using this video as an introduction to their Human Factors training programmes.

Copies may be obtained by contacting:

IFA Secretariat
14 Railway Approach
East Grinsted
W Sussex
RH19 1BPUK
tel 44 (0) 1342 301788
fax 44 (0)1342 317808
email sec@ifairworthy.org

or order online at http://www.ifairworthy.org/thevideo.htm

Price available on request

(approximately £120 for non IFA members and £60 for IFA members)

13. “Engineering Solutions to Human Problems” - videos and training package

Brief description:

In furtherance of the ICAO Annex 1 amendment No 161, concerning the mandatory requirement for all licensed engineers to have knowledge of ‘human performance and limitations relevant to the duties of an aircraft maintenance holder', the International Federation of Airworthiness (IFA) have technically and financially supported the production of a new Human Factors programme 'Engineering Solutions to Human Problems'.

This programme builds on the IFA Maintenance Human Factors awareness video 'Every Day'.

The latest programme is a Human Error management package consisting of four videos, four sets of briefing and training material, a set of case histories and Human Error study materials: there are eleven elements in all.

It has been produced by TVC Television Communications, London. in conjunction with Professor James Reason, it also features John Goglia, NTSB and David Marx, aviation consultant in human error management.

The complete package costs US$5,500 or £3300 sterling; IFA members receive a 10% discount.

Copies may be purchased by contacting:

Sales
TVC Television Communications,
15 Greek Street,
London WIV 5LF.
Tel.: +44 0207 734 6840,
Fax : +44 0207 734 2938.
E- mail: info@tvcsoho.com
www.tvcsoho.com

14. Canadian Maintenance and Ramp Safety Society (MARSS) videos and posters *www.marss.org*

In the early 1990's, the subject of Human Factors and Human Performance regarding aviation was conceived. Transport Canada and members of the aviation industry help organize the first Safety Conference, and ultimately the Maintenance and Ramp Safety Society (MARSS) was formed. MARSS consists of volunteers from all levels and fields of the aviation industry. It is a Canadian registered non- profit society whose aim is to help the industry to reduce and hopefully eliminate accidents in aviation.

MARSS issues a newsletter "Groundeffects" which features articles on human factors in maintenance, and is involved with running human factors workshops, and the production of training videos and posters (including the "Dirty Dozen" depicting human factors failures). For details, see below:

"Death of an Airline"
This video is based on an actual accident to a DC8 in Jeddah, Saudi Arabia. The "dirty dozen" are illustrated as the primary causes of the maintenance error in judgement which leads to the fatal accident.

"To kill a whopping bird"
This video depicts an accident scenario in which a Search and rescue helicopter crashes due to maintenance error. The many human factors which lead to the fatal error are well depicted.

"The anatomy of an accident"
The video uses Reason's model to illustrate how latent errors from management can lead to an active error and accident. It uses a flight accident to illustrate this point but the lesson can relate to maintenance just as well.

"Human performance in maintenance"
The video depicts an accident scenario on a military C130 Hercules aircraft in which the "dirty dozen" are illustrated as the primary causes of the maintenance error in judgement which leads to the accident. Safety nets are discussed to aid prevention.

Title	Duration	Cost (member) - Canadian $	Cost (non-member) Canadian $
Videos			
"Death of an Airline"	36 mins	250	300
"To kill a whopping bird"	19 mins	125	175
"The anatomy of an accident"	11 mins	100	150
"Human performance in maintenance"	28 mins	125	175
"Too many cooks"		poa	poa
"Danger Zone"		poa	poa
Posters			
The "Dirty Dozen"		35 each	45 each

The "Magnificent seven"		35 each	40 each

Copies can be obtained from:

MARSS
5750 Cedarbridge Way
Richmond, BC V6X 2A7
Phone: (604) 207-9100
Fax: (604) 207-9101
Email: marss@marss.org

15. The HFSkyway Website *http://hfskyway.faa.gov*

Brief description:
The Human Factors in Aviation Maintenance and Inspection (HFAMI) Web Page has been established to provide access to products of the FAA Office of Aviation Medicine's Human Factors in Aviation Maintenance and Inspection Research Program. The overall purpose is to provide a vehicle for disseminating information relative to human factors in aviation maintenance.

Information was previously circulated as a series of CDROMs, the latest (1999) entitled "Human Factors in Aviation Maintenance and Inspection; Ten years of Research and Development". Copies have been distributed by the CAA at various roadshows, and a few spares are available, on request, from osdhf@srg.caa.co.uk. However, more up-to-date information can be found on the hfskyway website.

The HFSkyway website contains all of the FAA's human factors in aviation maintenance and inspection research products between 1988 and 2002. Many examples of prototype software are also included. HFSkyway is the single source site for the most complete information on in aviation maintenance and inspection human factors. Information not native to HFSkyway can be found on one of the many HFSkyway links.

Sample of contents:

- Strategic Program Plan (1998)
- Human Factors Guide for Aviation Maintenance and Inspection 1998 Version 3.0
- Research Reports 1998 - 2002
- FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase Reports (1991-1999)
- Human Factors Issues in Aircraft Maintenance and Inspection Meeting Proceedings (1989-1998)
- Human Factors Issues in Aircraft Maintenance and Inspection Symposia Proceedings (1990 - 2001)
- National Transportation Safety Board Maintenance Accident Reports - Twenty-four accident investigation reports all having maintenance as a contributing factor in the cause of an aircraft accident.
- Bibliography of Publications 1989-1998 Published Papers on Human Factors in Aviation Maintenance and Inspection by Author

Power Point Presentations from Advances in Aviation Safety Conference and Exposition April 10, 2000 Daytona Beach Florida

- Return On Investment in Maintenance Human Factors
- Investing in Human Factors Training:Assessing the Bottom Line
- Maintenance Resource Management: Flight Safety
- Forecasting ROI for Naval Aviation Maintenance Safety Initiatives
- Maintenance Operational Risk Management
- A New Model of Return on Investment for MRM Programs
- Communication
- Human Factors in Aircraft Maintenance

- Human Factors and a Strategic Approach to Return on Investment

Job aids

- The Ergonomics Audit Program (ERNAP)
- Documentation Design Aid (DDA)
- Turbine Repair Automated Control System
- Proactive Error Reduction System

Training

- MRM computer based training
- Safe Maintenance in Aviation: Resource Training
- System for Training of Aviation Regulations
- Aircraft Maintenance Team Training
- Team Situation Awareness Training
- Leadership Training

Some of the more recent reports are:

- Use of computer based training to improve aircraft inspection performance
- Evaluating the effects of MRM in air safety
- Root cause analysis of rule violations by aviation maintenance technicians
- Shift management: the role of fatigue in human error
- Tools and techniques for evaluating the effects of MRM in air safety
- Measuring the effectiveness of error investigation and human factors training

Of particular interest to human factors trainers will be a set of powerpoint slides and notes (trainers and student) from a 1½ day presentation by Dave Hall and David Marx at the 15th HFIAM Symposium at London. These slides may be tailored to suit your own needs.

16. Boeing www.boeing.com

The Boeing website contains several useful articles on the Boeing Maintenance Error Decision Aid (MEDA), including:

Human Factors Process for Reducing Maintenance Errors
J Allen, W Rankin, B Sargent.

The following text has been extracted from these articles and website:

Maintenance Error Decision Aid (MEDA).

This tool began as an effort to collect more information about maintenance errors. It developed into a project to provide maintenance organizations with a standardized process for analysing contributing factors to errors and developing possible corrective actions (see "Boeing Introduces MEDA" in *Airliner* magazine, April-June 1996, and "Human Factors Process for Reducing Maintenance Errors" in *Aero* no. 3, October 1998). MEDA is intended to help airlines shift from blaming maintenance personnel for making errors to systematically investigating and understanding contributing causes. As with PEAT, MEDA is based on the philosophy that errors result from a series of related factors. In maintenance practices, those factors typically include misleading or incorrect information, design issues, inadequate communication, and time pressure. Boeing maintenance human factors experts worked with industry maintenance personnel to develop the MEDA process. Once developed, the process was tested with eight operators under a contract with the U.S. Federal Aviation Administration.

Since the inception of MEDA in 1996, the Boeing maintenance human factors group has provided on-site implementation support to more than 100 organizations around the world. A variety of operators have witnessed substantial safety improvements, and some have also experienced significant economic benefits because of reduced maintenance errors.

The role of Human Factors in Improving Aviation Safety
This article addresses:
- Flight deck design
- Design for maintainability and in-service support
- Error management
- Passenger cabin design

The articles described above may be downloaded from:

Human Factors Process for Reducing Maintenance Errors J Allen, W Rankin, B Sargent.
http://www.boeing.com/commercial/aeromagazine/aero_03/textonly/m01txt.html

Maintenance Error Decision Aid (MEDA).
http://www.boeing.com/commercial/aeromagazine/aero_08/human_textonly.html

17. The UK-HF/SMS CAG

The United Kingdom Human Factors Combined Action Group (UK-HFCAG) was originally created to co-ordinate UK activity on the subject of Human Factors in Engineering and Maintenance within the Aviation Industry. It has subsequently moved on to address safety management systems (and is now referred to as the UK SMS CAG), but still maintains an active role with respect to human factors

The group concentrated on providing outputs to both Industry and Regulators by pooling and focusing industry expertise and experience. The group comprised representatives of the following bodies:

- Air Accidents Investigation Branch
- Association of Licensed Aircraft Engineers
- 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 sat with the group to offer guidance and advice.

The UK-SMS CAG aims to recommend strategies and solutions to Safety Management and Human Factors issues in Engineering and Maintenance and to focus resources on providing guidelines and best practice for use within the industry.

The UK SMS CAG produced the document "People, Practices and Procedures in Aviation Engineering and Maintenance (A Practical Guide to Human Factors in the Workplace)" and the original guidance document on Safety Management Systems which was adapted and published by the CAA as CAP 712.

There are plans to set up a website for the joint work of the CAG and RAeS HFG EMSG. Readers are directed to www.raes-hfg.com in the meantime, from which a link will be set up once available.

18. **Royal Aeronautical Society Human Factors Group www.raes-hfg.com**

The RAeS HFG is a group run by volunteers, on a non-profit-making basis, for the benefit of aviation safety. This group promotes aviation human factors, and has several sub-groups addressing specific areas, one of these being the Engineering Maintenance Standing Group (EMSG).

As part of its work, the RAeS organises conferences, the proceedings of which are usually posted on the website. Two of the conferences which have been organised by the EMSG include:

- A business case for human factors
- Fatigue and working hours in aviation maintenance

There are also plans for the EMSG to work with the UK SMS CAG to provide additional guidance and advice to industry on maintenance human factors training issues, so readers are advised to consult www.raes-hfg.com for further details, once available.

19. Transport Canada - aviation safety publications and videos http://www.tc.gc.ca/civilaviation/systemsafety/pubs/menu.htm

This site lists various publications, including:

An educational package in the form of CBT, on human performance in aviation maintenance - TP13459.

The following information is taken directly from the website:

"This CD, intended for aviation maintenance personnel with technical responsibilities, promotes awareness of human performance issues. Through case studies, participants investigate what caused the error and why it happened and determine the contributing factors that interfered with performance at the critical moment. Participants also develop "safety net strategies" to prevent future errors from occurring.

This educational material also examines the factors that influence human error and the importance of error management including prevention and containment.

This CD-ROM includes:

- the facilitator's notes;
- the participant workbook;
- videos and
- a PowerPoint presentation.

Users can easily customize these materials to meet their particular needs."

Another useful product is a CD entitled "Aviation maintenance Tool Management" (TP 14123B). This contains a powerpoint presentation (with notes) on maintenance human factors, and a 10 minute video on some of the problems resulting from tools or parts having been incorrectly left in aircraft after maintenance.

For further information on how to obtain a copy:

please contract the website on

http://www.tc.gc.ca/civilaviation/systemsafety/pubs/menu.htm

20. UK Civil Aviation Authority (CAA) website

www.caa.co.uk

This site contains copies of documents published by the CAA, on the publications page. Documents of particular relevance to maintenance human factors include:

- CAP 716 - Human Factors for JAR145

- CAP 715 - Human Factors for JAR66
- CAP 718 - ICAO Digest No. 12 reprint
- CAP 712 - Safety Management Systems
- CAP 455 - Airworthiness Notices
- CAAP 2003/11
- CAAP 2003/12
- CAAP 2002/06

21. Australian Civil Aviation Safety Authority (CASA)

www.casa.gov.au

This site contains details of the extensive publications, videos and CDs produced by CASA's Aviation Safety Promotion Department on Safety Management Systems and maintenance human factors.

Documents of particular interest include:
- Safety Management Systems - an introduction
- Safety Management Systems - getting started
- Safety Management Systems - an Operator's guide
- Presentations from various roadshows and forums

22. Joint Aviation Authorities (JAA) website

www.jaa.nl

This site, at the time of publication of CAP 716 issue 2, contained current JAA requirements and a link to the newly published EASA requirements. It also contained the JAA Maintenance Human Factors Working Group report of May 2001.

23. European Aviation Safety Agency (EASA) website

www.easa.eu.int

This site contains details of the agency and the newly published EASA requirements (published in Dec 2003)

24. US Feneral Aviation Administration (FAA) websites

www.faa.gov

The majority of FAA sponsored research on maintenance human factors is on http://hfskyway.faa.gov, but readers can also access federal Aviation Regulations (FARs) via www1.faa.gov/regulations/inden.cfm.

Other websites of potential interest include:

- http://hf.tc.faa.gov/hfds
- www.hf.faa.gov

25. UK Air Accidents Investigation Branch (AAIB)

www.dft.gov.uk/aiib

This site contains copies of recent AAIB investigated accident reports and bulletins.

26. US National Transportation Safety Board (NTSB)

www.ntsb.gov

This site contains copies of recent NTSB investigated accident reports and recommendations. A selection of those which involve maintenance human factors can be found on hfskyway.

27. Canadian Transportation Safety Board (TSB)

www.tsb.gc.ca

This site contains copies of recent TSB investigated accident reports.

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28. Australian Transport Safety Bureau (ATSB)

www.atsb.gov.au

This site contains copies of recent ATSB investigated accident reports.