Civil Aviation Authority

CAP 716

AVIATION MAINTENANCE HUMAN FACTORS (JAA JAR145)

Guidance material to support JAR 145 requirements concerning human factors

Important Note

The CAA is currently making many of the documents that it publishes available electronically (in addition to traditional printed format). Where practical, the opportunity is being taken to incorporate a clearer revised appearance to the documents. Any significant changes to the content of this document will be shown in the Explanatory Note. If no such changes are indicated the material contained in this document, although different in appearance to the previously printed version, is unchanged. Further information about these changes and the latest version of documents can be found at www.srg.caa.co.uk/pub/pub_home.asp.

Civil Aviation Authority

CAP 716

AVIATION MAINTENANCE HUMAN FACTORS (JAA JAR145)

Guidance material to support JAR 145 requirements concerning human factors

Important Note

The CAA is currently making many of the documents that it publishes available electronically (in addition to traditional printed format). Where practical, the opportunity is being taken to incorporate a clearer revised appearance to the documents. Any significant changes to the content of this document will be shown in the Explanatory Note. If no such changes are indicated the material contained in this document, although different in appearance to the previously printed version, is unchanged. Further information about these changes and the latest version of documents can be found at www.srg.caa.co.uk/pub/pub_home.asp.

7 January 2002

ISBN 0 86039 832 3

First edition 7 January 2002

Enquiries regarding the content of this publication should be addressed to:

Human Factors, Operating Standards Division, Safety Regulation Group, Civil Aviation Authority, Aviation House, Gatwick Airport South, West Sussex, RH6 0YR

Printed and distributed by: Documedia Solutions Ltd, 37 Windsor Street, Cheltenham, Glos., GL52 2DG

List of Effective Pages

Chapter	Page	Date				Chapter	Page	Date
	iii	7 January 2002	Chapter 12	1	7 January 2002	Appendix K	4	7 January 2002
	iv	7 January 2002	Chapter 12	2	7 January 2002	Appendix K	5	7 January 2002
	v	7 January 2002	Chapter 12	3	7 January 2002	Appendix K	6	7 January 2002
	vi	7 January 2002	Appendix A	1	7 January 2002	Appendix K	7	7 January 2002
	vii	7 January 2002	Appendix A	2	7 January 2002	Appendix K	8	7 January 2002
	viii	7 January 2002	Appendix A	3	7 January 2002	Appendix K	9	7 January 2002
	ix	7 January 2002	Appendix A	4	7 January 2002	Appendix K	10	7 January 2002
	x	7 January 2002	Appendix A	5	7 January 2002	Appendix K	11	7 January 2002
	xi	7 January 2002	Appendix B	1	7 January 2002	Appendix K	12	7 January 2002
	xii	7 January 2002	Appendix B	2	7 January 2002	Appendix L	1	7 January 2002
	xiii	7 January 2002	Appendix B	3	7 January 2002	Appendix L	2	7 January 2002
	xiv	7 January 2002	Appendix B	4	7 January 2002	Appendix L	3	7 January 2002
Chapter 1	1	7 January 2002	Appendix C	1	7 January 2002	Appendix L	4	7 January 2002
Chapter 1	2	7 January 2002	Appendix C	2	7 January 2002	Appendix L	5	7 January 2002
Chapter 2	1	7 January 2002	Appendix C	3	7 January 2002	Appendix L	6	7 January 2002
Chapter 2	2	7 January 2002	Appendix D	1	7 January 2002	Appendix L	7	7 January 2002
Chapter 2	3	7 January 2002	Appendix E	1	7 January 2002	Appendix M	1	7 January 2002
Chapter 2	4	7 January 2002	Appendix E	2	7 January 2002	Appendix M	2	7 January 2002
Chapter 3	1	7 January 2002	Appendix F	1	7 January 2002	Appendix M	3	7 January 2002
Chapter 3	2	7 January 2002	Appendix F	2	7 January 2002	Appendix M	4	7 January 2002
Chapter 3	3	7 January 2002	Appendix F	3	7 January 2002	Appendix M	5	7 January 2002
Chapter 4	1	7 January 2002	Appendix F	4	7 January 2002	Appendix M	6	7 January 2002
Chapter 4	2	7 January 2002	Appendix G	1	7 January 2002	Appendix M	7	7 January 2002
Chapter 4	3	7 January 2002	Appendix G	2	7 January 2002	Appendix M	8	7 January 2002
Chapter 5	1	7 January 2002	Appendix G	3	7 January 2002	Appendix M	9	7 January 2002
Chapter 5	2	7 January 2002	Appendix G	4	7 January 2002	Appendix M	10	7 January 2002
Chapter 6	1	7 January 2002	Appendix H	1	7 January 2002	Appendix M	11	7 January 2002
Chapter 6	2	7 January 2002	Appendix H	2	7 January 2002	Appendix M	12	7 January 2002
Chapter 6	3	7 January 2002	Appendix H	3	7 January 2002	Appendix M	13	7 January 2002
Chapter 7	1	7 January 2002	Appendix H	4	7 January 2002	Appendix N	1	7 January 2002
Chapter 7	2	7 January 2002	Appendix H	5	7 January 2002	Appendix N	2	7 January 2002
Chapter 7	3	7 January 2002	Appendix I	1	7 January 2002	Appendix N	3	7 January 2002
Chapter 7	4	7 January 2002	Appendix I	2	7 January 2002	Appendix N	4	7 January 2002
Chapter 8	1	7 January 2002	Appendix I	3	7 January 2002	Appendix O	1	7 January 2002
Chapter 8	2	7 January 2002	Appendix I	4	7 January 2002	Appendix O	2	7 January 2002
Chapter 9	1	7 January 2002	Appendix I	5	7 January 2002	Appendix O	3	7 January 2002
Chapter 9	2	7 January 2002	Appendix I	6	7 January 2002	Appendix P	1	7 January 2002
Chapter 10	1	7 January 2002	Appendix J	1	7 January 2002	Appendix Q	1	7 January 2002
Chapter 10	2	7 January 2002	Appendix J	2	7 January 2002	Appendix Q	2	7 January 2002
Chapter 11	1	7 January 2002	Appendix J	3	7 January 2002	Appendix Q	3	7 January 2002
Chapter 11	2	7 January 2002	Appendix J	4	7 January 2002	Appendix Q	4	7 January 2002
Chapter 11	3	7 January 2002	Appendix K	1	7 January 2002	Appendix R	1	7 January 2002
Chapter 11	4	7 January 2002	Appendix K	2	7 January 2002	Appendix R	2	7 January 2002
Chapter 11	5	7 January 2002	Appendix K	3	7 January 2002	Appendix R	3	7 January 2002

Appendix S	1	7 January 2002
Appendix S	2	7 January 2002
Appendix S	3	7 January 2002
Appendix S	4	7 January 2002
Appendix T	1	7 January 2002
Appendix T	2	7 January 2002
Appendix T	3	7 January 2002
Appendix T	4	7 January 2002
Appendix T	5	7 January 2002
Appendix T	6	7 January 2002
Appendix T	7	7 January 2002
Appendix T	8	7 January 2002
Appendix T	9	7 January 2002
Appendix T	10	7 January 2002
Appendix T	11	7 January 2002
Appendix T	12	7 January 2002
Appendix T	13	7 January 2002
Appendix T	14	7 January 2002
Appendix T	15	7 January 2002
Appendix T	16	7 January 2002
Appendix T	17	7 January 2002
Appendix U	1	7 January 2002
Appendix U	2	7 January 2002
Appendix V	1	7 January 2002
Appendix V	2	7 January 2002
Appendix V	3	7 January 2002
Appendix V	4	7 January 2002
Appendix V	5	7 January 2002
Appendix V	6	7 January 2002
Appendix V	7	7 January 2002
Appendix W	1	7 January 2002
Appendix W	2	7 January 2002
Appendix W	3	7 January 2002
Appendix W	4	7 January 2002
Appendix X	1	7 January 2002
Appendix X	2	7 January 2002
Appendix X	3	7 January 2002
Appendix X	4	7 January 2002
Appendix Y	1	7 January 2002
Appendix Y	2	7 January 2002
Appendix Y	3	7 January 2002

Contents

	List of Effective Pages	
	Explanatory Note	
	Acknowledgements	
	Amendment Record	
	Foreword	
	Glossary of Terms	
Chapter 1	**Introduction**	
Chapter 2	**Safety Culture**	
	Safety Culture	1
	Maintenance Organisation Safety Policy	2
Chapter 3	**An Integrated Approach to Human Factors and Safety**	
	Integrated Approach	1
	Elements of a Human Factors Programme	2
Chapter 4	**Factors Associated with the Individual**	
	Factors Associated with the individual	1
	Fitness for Work	2
	Shiftwork and Fatigue	2
	Competence, Knowledge, Experience and Recency	3
Chapter 5	**Errors, Violations and Non-compliance with Procedures**	
	Errors and Violations	1
	Non-compliance with Procedures	2
Chapter 6	**Procedures, Documentation and Maintenance Data**	
	Maintenance Data	1
	Procedures and Work Instructions	2

Chapter 7 Error capturing

Functional Checks 1
Duplicate Inspections 1
Pilot Pre-flight Checks 3
Design for Error Resistance 4

Chapter 8 Planning and Preparation

Chapter 9 Teamwork, Communication, Handovers and Sign-offs

Task and Shift Handovers 1
Sign-offs 2

Chapter 10 Environmental Factors, Tooling and Ergonomic Audits

Environmental Factors. 1

Chapter 11 Occurrence Reporting and Management

Occurrence reporting and management 1
Key Elements for the Establishment of an Internal Occurrence Management Scheme (OMS) 2

Chapter 12 Human Factors Training for Personnel Involved in Maintenance

Human Factors Training 1
Initial and Recurrent Training 1

Appendix A Definition of Human Factors

Appendix B ICAO Standards for Human Factors in Maintenance

Appendix C Example Safety Policy

Appendix D Safety Accountabilities

Appendix E Example Disciplinary Policy

Appendix F Incidents/ Accidents Where Maintenance Error was a Factor

Appendix G Incident and Accident Analysis Statistics

Appendix H The "Dirty Dozen"

Appendix I Shiftwork and Fatigue

Appendix J Visual Inspection and NDI

Appendix K **Environmental Factors & Tooling**

Appendix L **A Methodology for Evaluating the Visual Environment in Inspection**

Appendix M **Communication, Handovers and Teamwork**

Appendix N **Procedures and Work Instructions**

Appendix O **Guidelines for Writing Procedures**

Appendix P **Aircraft Maintenance Procedure Optimisation System (AMPOS)**

Appendix Q **CAA Airworthiness Notice 71: Maintenance Error Management Systems**

Appendix R **Safety Management Systems and (Human) Risk Assessment**

Appendix S **Human Factors Training Recommendations (from JAA MHFWG Report)**

Appendix T **Human Factors Training Syllabus (JAR145)**

Appendix U **Human Factors Knowledge Syllabus (JAR66-9)**

Appendix V **Council Directive 93/104/EC, 23/11/93; Aspects of the Organisation of Working Time**

Appendix W **Maintenance Error Decision Aid (MEDA) Concepts**

Appendix X **Maintenance Error Decision Aid (MEDA) Form**

Appendix Y **Sources of Further Information**

Explanatory Note

1 Introduction

1.1 This document is aimed primarily at JAR145 organisations, to help them meet the JAR145 requirements concerning human factors. It contains guidance material which, if applied appropriately to your organisation, should help reduce the risks associated with human error and human factors.

1.2 This is a living document and will be revised at intervals to take into account changes in regulations, feedback from industry, and recognised best practice. Updates will be notified via the CAA website, and will be free to download. If you have any comments concerning this document, please pass them back to the editor via your CAA regional office or direct to Maintenance Requirements and Policy Section, Gatwick Head Office, the address of which can be found on the CAA website.

Acknowledgements

1.1 Acknowledgments are given to all those from the UK CAA and industry who have contributed to this document, either in terms of writing chapters, helping to review sections, or contributing to the work of the JAA Maintenance Human Factors Group on whose work this CAP is heavily based (the JAA MHFWG report can be found on www.jaa.nl/maintenance/documents/humanfactors_frame.html). In particular, acknowledgment is given to the authors of all the documents referenced, most of which can be found on http://hfskyway.faa.gov. Last but not least, acknowledgement is given to all those reading and applying the information contained in this document.

Amendment Record

Amendment Number	Amendment Date	Incorporated by	Incorporated on
Edition 1	7 January 2002		

Foreword

1.1 CAP716 provides guidance material for JAR145 organisations on how to apply human factors 'best practice' in organisational processes and procedures.

1.2 A separate document CAP715, written primarily from the perspective of the individual engineer, addresses human performance and limitations, and is based on the JAR66 Module 9 syllabus.

1.3 The human factors training syllabus referred to in CAP716 Chapter 12 and Appendix T incorporates the JAR66 Module 9 syllabus items but expands considerably to include mainly organisational issues. The emphasis is intended to be on training all staff to understand and apply the principles described in CAP716; if these principles are not applied within the organisation, the training will be of limited value.

1.4 It is recognised that small organisations may find it burdensome to apply some of the guidance contained within this document, therefore would stress that there is a need to tailor this guidance to the size of organisation and the nature of their business.

Glossary of Terms

AAIB	Air Accidents Investigation Branch
AANC	(US) Ageing Aircraft Inspection Validation Centre
AD	Airworthiness Directive
ADAMS	(Human Factors) in Aircraft Dispatch and Maintenance
AMC	Acceptable Means of Compliance (for JARs)
AME	Aircraft Maintenance Engineer
AMT	Aircraft Maintenance Technician
AMPOS	Aircraft Maintenance Procedure Optimisation System
AOG	Aircraft On the Ground
ATA	Air Transport Association of America
ATC	Air Traffic Control
AWN	Airworthiness Notice
BASIS	British Airways Safety Information System
BASIS MEI	BASIS Maintenance Error Investigation
BCAR	British Civil Airworthiness Requirements
CAA	(UK) Civil Aviation Authority
CAMC	Canadian Aviation Maintenance Council
CARMAN	Consensus Based Approach to Risk Management
CASA	(Australian) Civil Aviation Safety Agency
CBT	Computer Based Training
cd	candela
CEO	Chief Executive Officer
CFS	Chronic Fatigue Syndrome
CMI	Computer Managed Instruction
CRM	Crew Resource Management
DDA	Document Design Aid
DOE	Department of Energy (USA)
ERNAP	Ergonomics Audit Programme
FAA	Federal Aviation Administration
FEMA	Failure Modes and Effects Analysis
fL	footLambert
FODCOM	Flight Operations Department Communication

GAIN	Global Aviation Information Network
HAZOP	Hazard and Operability study/ assessment
HF	Human Factors
HFRG	(UK) Human Factors in Reliability Group
HRA	Human Reliability Assessment
HSE	(UK) Health and Safety Executive
IBT	Internet Based Training
ICAO	International Civil Aviation Organization
IEM	Interpretative/ Explanatory material (for JARs)
IES	(US) Illuminating Engineering Society
IFA	International Federation of Airworthiness
IMIS	Integrated Maintenance Information System
JAR	Joint Aviation Requirement
LAE	Licensed Aircraft Engineer
lm	lumen
LOFT	Line Oriented Flying Training
lux	lumens/m^2
MARSS	Maintenance and Ramp Safety Society
MEDA	Maintenance Engineering Decision Aid
MEMS	Maintenance Error Management System
MEMS FMS	Maintenance Error Management System Free MEDA Software
MESH	Maintenance Engineering Safety Health
MHFWG	JAA Maintenance Human factors Working Group
MM	Maintenance Manual
MOE	Maintenance Organisation Exposition
MOR	(UK) Mandatory Occurrence Report
MRM	Maintenance Resource Management
NAA	National Aviation Authority
NASA	(US) National Aeronautics and Space Administration
NASA TLX	NASA Task Loading Index
NDI	Non-Destructive Inspection
NDT	Non-Destructive Testing
NPA	Notice of Proposed Amendment (for JARs)
NTSB	(US) National Transportation Safety Board
OJT	On-the-Job Tuition

OSHA	(US) Occupational Safety and Health Administration
PC	Personal Computer
PRA	Probablistic Risk Assessment
PSA	Probablistic Safety Assessment
REM	Random Eye Movement
ROI	Return on Investment
SA	Situational Awareness
SB	Service Bulletin
SHEL Model	Software, Hardware, Environment, Liveware
SMM	Shift Maintenance Manager
SMS	Safety Management Systems
STAMINA	(Human Factors) Safety Training for the Aircraft Maintenance Industry
SWAT	Subjective Workload Assessment Technique
TC holder	Aircraft Type Certificate holder
TGL	Temporary Guidance Leaflet (for JARs)
TQM	Total Quality Management
TQM	Total Quality Management
TWA	Time Weighted Average sound level
UK HFCAG	UK Human Factors Combined Action Group
UK OTG	UK Operators' Technical Group
UK RAF SAM	UK Royal Air Force School of Aviation Medicine
VIRP	(US) Visual Inspection Research Programme

Chapter 1 Introduction

1.1 This document is aimed primarily at JAR145 organisations, to help them meet the JAR145 requirements concerning human factors. At the time of writing this document, these were described in (i) JAR145, (ii) NPA 145-10, (iii) NPA 145-12, (iv) the JAA Maintenance Human Factors Working Group (MHFWG) report[1] (in support of NPA12), and (v) JAR66.

JAR145. NPA145-10. NPA 145-12. MHFWG report. JAR66.

1.2 This UK Civil Aviation Publication (CAP) is **not** designed as study material for JAR66-9, although there are some areas common to both JAR145 and JAR66. CAP715, "An Introduction to Aircraft Maintenance Engineering Human Factors for JAR66", was in preparation at the time of writing this document, and should now be available.

1.3 References are provided to relevant sections of JARs and NPAs. These were correct at the time of producing this document, but may become out-of-date with subsequent changes to the JARs. The reader is therefore urged to consult the latest version of the relevant JAR and associated NPAs. The intention is to update CAP716 at intervals to maintain consistency with the JARs.

1.4 It is recommended that this CAP be read in conjunction with CAP712 "Safety Management Systems for Commercial Air Transport Operations", since human factors should be regarded as part of a Safety Management System for an organisation, and not as a separate, self-contained initiative. There are some common areas, in particular safety culture and safety data reporting, investigation, analysis and action.

1.5 This CAP is divided into two parts: (i) a succinct outline of the human factors requirements in JAR145 and how to meet them, and (ii) appendices containing further guidance, background and reference information, should this be required.

1.6 The emphasis is upon practical guidance material for real-world situations, acknowledging (but not condoning) the fact that sometimes people fail to comply with procedures, albeit often with the best of intentions. It recognises that organisations operate within a competitive commercial environment, and concentrates upon risk and error management rather than risk and error elimination.

1.7 An organisation can minimise its vulnerability to human error and reduce its risks by implementing the best human factors practice described within the document. This will help enable the JAR145 Accountable Manager to meet his responsibilities to "establish and promote a ... safety policy" within the organisation and to make sure that this policy, and its implementation, are effective in addressing the potentially high risk area of human factors.

NPA145-12, 145.30 (b).

1.8 It should be stressed that this CAP concentrates upon the potential implications of human factors or failures upon aviation safety and not on how human factors affects the individual's efficiency or well-being or individual health and safety. However, if good human factors principles are applied within maintenance and engineering in order to improve safety, there should also be associated benefits that can be realised for the individual. It should also be stressed that this document addresses aviation safety, rather than the safety of the individual at work, although it is often the case

1. www.jaa.nl/maintenance/documents/humanfactors_frame.html

that good practices for aviation safety will also be good practices for health and safety, and vice versa. Note: there is separate guidance material published by the UK Health and Safety Executive which addresses human factors from a health and safety perspective[1].

1.9 All the principles described in this CAP are applicable to all JAR145 organisations (and certain sections are also applicable to JAROPS, JAR21 and JAR147 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 the size and nature of the organisation.

1. HSG65 (1997) Successful Health and Safety Management. HSE Books.

Chapter 2 Safety Culture

1 Safety Culture

1.1 An organisation with a good safety culture is one which has managed to successfully institutionalise safety as a fundamental value of the organisation, with personnel at every level in the organisation sharing a commitment to safety.

1.2 One of the key elements is effective support from the top levels of the organisation, for safety. It is necessary for senior management to demonstrate their commitment to safety in practical terms, not just verbally or only as long as safety is a no-cost item. It is all very well for an organisation to commit to putting in place, say, a safety reporting and investigation scheme but if such a scheme is not resourced properly, or if safety recommendations are not acted upon, it will be ineffective. It is also important that such commitment to safety is long-term, and that safety initiatives are not the first items to be cut in terms of financial support when the organisation is looking for cost savings. Safety management within an organisation should be addressed with as much commitment as financial management tends to be. CAP 712[1] describes the elements of a Safety Management System which should, if implemented properly and supported, lead to a good safety culture.

Table 1 Key Elements Contributing Towards a Good Safety Culture

- Support from the top
- A formal safety policy statement
- Awareness of the safety policy statements and buy-in from all levels within the organisation
- Practical support to enable the workforce to do their jobs safely, e.g. in terms of training, planning, resources, workable procedures, etc.
- A just culture and open reporting
- A learning culture and willingness to change when necessary
- Corporate and personal integrity in supporting the safety policy principles in the face or potentially conflicting commercial demands

1.3 A good safety culture needs to be nurtured, and is not something which can be put in place overnight, or with a training course alone. It can be improved in the short term by putting staff through a training course dealing with the elements of safety culture. However, the improvement will only be sustained if the types of behaviours conducive to safety are rewarded and poor safety behaviour is not condoned, or even punished (in the extreme cases). This relies on staff at all levels within the organisation, especially middle management and supervisory levels, (i) recognising what good and bad safety behaviour is, (ii) good safety behaviour being encouraged, and (iii) poor safety behaviour being discouraged. Sometimes the opposite is true in that staff are rewarded for cutting corners in order to meet commercial deadlines and, in a few cases, punished for complying with procedures (e.g. refusing to sign off work which they have not had the opportunity to check[2]). A good safety culture is based on what actually goes on within an organisation on a day-to-day basis, and not on rhetoric or superficial, short term safety initiatives.

1. CAP 712 (June 2001) Safety Management Systems for Commercial Air Transport Operations.
2. CHIRP reports

1.4 It is possible to measure the safety culture of your organisation by using a safety culture questionnaire survey[1]. Care should be taken with the timing of such a survey, in that it may be positively or negatively affected by specific recent events such as industrial action, training courses, etc. It is important to be sure that you are measuring behaviour, attitudes and fundamental beliefs, rather than morale. More detailed elements which contribute towards a good safety culture can be found in Annex G of CAP 712.

2 Maintenance Organisation Safety Policy

2.1 A company should establish a safety policy. This should be part of the Maintenance Organisation Exposition (MOE), and signed by the Accountable Manager. The safety policy should define the senior management's intentions in terms of commitment to ensuring that aircraft are returned to service after maintenance in a safe condition. An example safety policy can be found in Appendix C.

NPA145-12, 145.65(a).

2.2 An organisation should list (ideally in the MOE) the processes which contribute towards safety, including (i) quality processes, (ii) reporting scheme(s) for defects, safety concerns, occurrences, quality discrepancies, quality feedback, maintenance errors, poor maintenance data, poor procedures, poor work instructions, (iii) appropriate training (including human factors training), (iv) shift/task handover procedures (see Table 1). The organisation should state how it addresses, or plans to address, these issues.

2.3 The accountable manager should be responsible for establishing and promoting the company safety policy. This safety policy should include a commitment to addressing the human factors elements within the organisation. In addition to defining top level responsibility, specific roles and responsibilities at other senior and middle management levels within the company should be clearly defined, with individuals being clear as to their roles in implementing the company safety policy. It is not realistic to place sole responsibility for safety on an individual, since safety is affected by many factors, some of which may be outside their control. However, it *is* realistic to place responsibility upon the accountable manager to ensure that the organisation has in place the training, processes, tools, etc. which will promote safety. If the accountable manager, and other staff to whom he has devolved responsibility for action, find themselves in a situation where commercial and safety priorities potentially conflict, they should remind themselves of the content of the organisation's safety policy which they have committed to support.

NPA-12, 145.30(b). NPA-12, 145.65(a). AMC145.65(a).

1. (1997) Health and safety climate survey tool. HSE books. ISBN 0 7176 1462 X

Table 2 Examples of items which should be listed in the MOE

Safety Policy
Manpower resources
Control of man-hour planning versus scheduled maintenance work
Procedures to detect and rectify maintenance errors
Shift/task handover procedures
Procedures for notification of maintenance data inaccuracies and ambiguities to the type certificate holder
Human factors training procedure

NPA145-12, Section 2, Appendix 2.

2.4 The wording of the safety and quality policy is important. The actual wording will probably vary between organisations. As a minimum, the policy should commit to:

- recognising safety as a prime consideration at all times
- applying human factors principles
- encouraging personnel to report maintenance related errors/ incidents without fear of automatic punitive action

2.5 In addition, it should include the need for all personnel to comply with procedures, quality standards, safety standards and regulations. An example Safety Policy can be found in Appendix C.

2.6 It is all very well having a policy which states all the right things, but all staff (senior management, certifying staff, mechanics, planners, stores staff, contractors, etc.) have to actually subscribe to it and put it into practice in order to achieve the aims of having such a policy in the first place. Evidence[1] indicates that actual practice does not always reflect policies and procedures. Ultimately it is the responsibility of the accountable manager to see that practice, procedures and policies do not conflict. Double standards, where senior or middle management claim to require strict adherence to procedures by staff on the one hand, whilst 'turning a blind eye' or even unofficially condoning 'work-arounds'[2] (involving some form of procedural violation) on the other hand, are unacceptable. If the procedures are good, then staff should work to them and receive management support to do so; if the procedures are poor then it is the responsibility of management to try to improve them.

2.7 Senior management should also look closely at the performance indicators which they set, and which are set for them, and highlight any potential conflicts between these performance indicators and safety objectives. Performance indicators on which bonuses or penalties are set are more often commercially based than safety based, and may result in safety being compromised in order to meet performance targets.

1. ADAMS Consortium (1999) Aircraft Dispatch and Maintenance Safety (ADAMS) study. Published on the Trinity College Dublin website (www.tcd.ie.aprg)
2. "Work around" is the term used for situations where procedures are not followed to the letter; this will often (but not always) involved procedural violations.

CAP 712 (Safety Management Systems) states:

> "The safety policies of a company define the senior management's intentions in safety matters. These policies document the fundamental approach to be taken by staff and contractors towards safety. The policies should be based on a clear and genuine Board-level commitment that, for the company, the management of aviation safety is paramount. To this is added a commitment to best practice and compliance with aviation regulations. The achievement of the policies can be implemented through suitable organisational arrangements and management systems. These provide the focus for all staff to enact their management's policies. The administrative arrangements that are in place for Quality Management should be used to provide the audit and follow-up processes required by safety management."

Further reading

a) CAP 712 (June 2001) Safety Management Systems for Commercial Air Transport Operations.

b) Eiff, G. (2001) Safety Cultures: Missing the Mark. 15th Symposium on Human Factors and Maintenance.

c) ADAMS report (contact Trinity College Dublin for details)

Chapter 3 An Integrated Approach to Human Factors and Safety

1 Integrated Approach

1.1 Human factors initiatives will be more effective if they are integrated within existing company processes, and not treated as something additional or separate or short-term. Human factors initiatives have sometimes failed in the past because they have been marginalised and regarded as a temporary ‘fashion’. Much of human factors, in the context of maintenance organisations and JAR145 requirements, is common sense, professionalism, quality management, safety management – i.e. what organisations should already have been doing all along.

1.2 The “human factors” initiatives in the context of JAR145 are really “safety and airworthiness” initiatives, the aim being to ensure that maintenance is conducted in a way that ensures that aircraft are released to service in a safe condition. The organisation should have a safety management system in place, many of the elements of which will need to take into account human factors in order to be effective.

1.3 Ideally, human factors best practice should be seamlessly and invisibly integrated within existing company processes, such as training, quality management, occurrence reporting and investigation, etc. Sometimes it is a good idea to re-invent an initiative under a new name if it has failed in the past, but you should be cautious about unnecessarily duplicating functions which may already exist (e.g. occurrence reporting schemes / quality discrepancy reporting/ etc.). It may only be necessary to slightly modify existing processes to meet the JAR145 human factors requirements.

1.4 Human factors training is probably an exception to the advice given above, in that it is usually so new and different to any existing training that it warrants being treated as a separate entity, at least for initial training. Recurrent training, however, is probably better integrated within existing recurrent training. Human factors initial and recurrent training are discussed in Chapter 12.

1.5 Having stated that it doesn’t matter what you call the initiatives, as long as they are done, this report will go on to refer to a “human factors programme” only in as far as it is a useful term to cover the elements which need to be established within an organisation to address human factors issues. The majority of these elements are addressed by JAR145 or the JAA MHFWG report.

2 Elements of a Human Factors Programme

2.1 Figure 1 (adapted from ATA Specification 113: Maintenance Human Factors Program Guidelines) shows how the various elements of a human factors programme should interact:

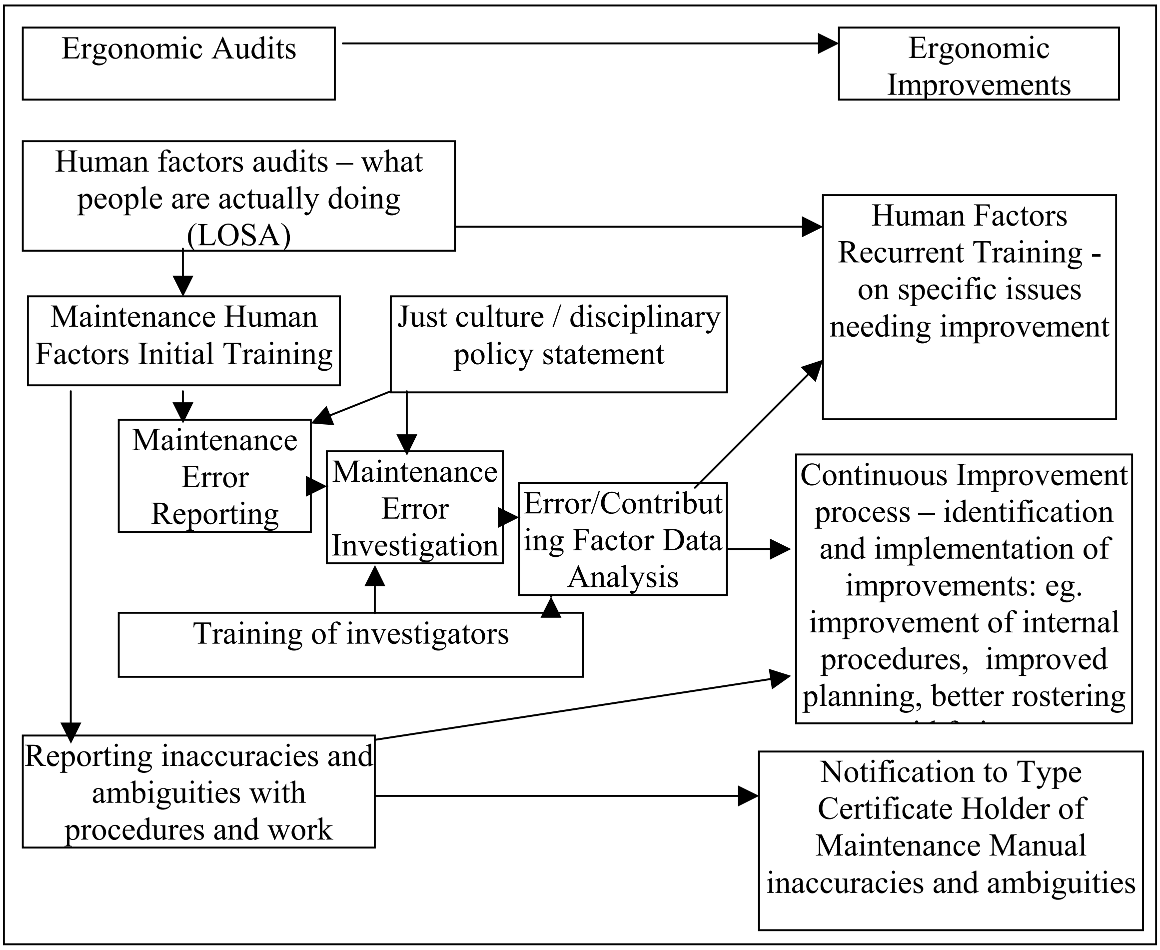

Figure 1 Adapted from ATA Specification 113 for Maintenance Human Factors Program Guidelines (1999) Air Transport Association.

2.2 The key elements of a human factors programme are:

a) Top level commitment to safety and human factors.

b) A company policy on human factors.

c) Human factors training (of all appropriate personnel, including managers - not just certifying staff).

NPA145-12, AMC145.30(e)5.

d) Reporting, investigation and analysis scheme(s) which will allow reporting of errors, actual & potential safety risks, inaccuracies and ambiguities with Maintenance Manuals, procedures or job cards (not just those which have to be reported as Mandatory Occurrence Reporting (MOR)s).

NPA 145-10, JAR145.60(b). NPA145-12, 145.45(c).

e) A clear disciplinary policy stressing that genuine errors will not result in punishment.

MHFWG report.

f) Human factors and ergonomics audits / Line Operations Safety Audits (LOSA) (of workplaces, lighting, noise, tooling, adequacy of procedures, actual compliance with procedures, manpower, adequacy of planning, etc.).

g) The resources and willingness to act upon the findings arising from occurrence reports and audits, and to provided fixes where appropriate.

h) A mechanism for reporting problems to the Type Certificate Holder.

NPA145-12, 145.45(c).

i) A mechanism for ensuring that internal procedures and work instructions are well designed and follow best practice.

NPA145-12, 145.65(b)6, 7 & 8. MHFWG report.

j) A means of providing feedback to staff on problems and fixes.

MHFWG report.

k) Abolition of any 'double standards' concerning procedural violations.

l) A policy for management of fatigue.

m) Motivation of staff to support the initiatives.

2.3 Health and safety would normally be considered separate to human factors, at least in the UK, although there are areas of overlap.

Chapter 4 Factors Associated with the Individual

1 Factors Associated with the individual

1.1 Basic competence and knowledge levels are addressed by JAR145 and JAR66, and not covered further here. The next few chapters and associated appendices concentrate on human performance and limitations, especially human error.

JAR145.30. JAR66.

1.2 It is useful to distinguish between errors and violations when considering the performance of individuals, and why they might make errors, mistakes or violations. The reader may wish to read the chapter on error and violations (Chapter 5) before proceeding further.

1.3 Generally when we talk about factors associated with the individual, we are talking about influences which may lead to a person making errors or mistakes. These factors include things such as physical fitness, fatigue, stressors, noise, distraction, etc. There are also factors which may possibly be associated with violations, such as personality type, assertiveness, etc., but these are not addressed in any great detail in this document.

1.4 Factors influencing performance include:

a) Physical fitness.

b) Physiological characteristics such as visual acuity, colour vision, hearing, etc.

c) Personality.

d) Attitude, professional integrity, motivation.

e) Arousal level, low arousal (boredom), excessively high arousal (stress), stressors.

f) Alertness, fatigue, tiredness, shiftwork, sleep, circadian rhythms.

g) Distractability, attention span, concentration, multi-tasking ability, situation awareness.

h) Information processing capability, memory, perception, intelligence.

i) Knowledge level, awareness of knowledge level, experience, recency.

j) Cultural influences, company culture, national culture, norms.

1.5 Since the majority of these topics are JAR66 issues rather than JAR145 issues, they are not discussed in detail in the main body of this text. Further information concerning most of these factors may be found in Appendix I and in basic textbooks on human factors and psychology. However, a couple of the topics are discussed in greater detail below (and in the associated appendices).

2 Fitness for Work

2.1 Certifying staff working on a JAR66 license "must not exercise the privileges of their certification authorisation if they know or suspect that their physical or mental condition renders them unfit to exercise such privileges". This includes blood-alcohol level, drugs & medication, eyesight, colour vision and psychological integrity. This CAP provides some guidance on these issues (see Appendix I), but more comprehensive information can be found in CAP715 and AN47.

JAR66. JAR66.50, AMC 66.50. JAR66.65 (b)(7).

2.2 Worth of particular mention is that, on 19 March 2001, the UK Government announced proposals to conduct drink and drugs tests and to introduce a blood/alcohol limit for anyone performing a safety critical role in UK civil aviation. The limit proposed for commercial aircrew, air traffic controllers and aircraft maintenance engineers is 20 milligrams of alcohol per 100 millilitres of blood. In addition, it is proposed that the police be given new powers to test for drink or drugs where there is reasonable cause.

3 Shiftwork and Fatigue

3.1 Fatigue has been reported as one of the factors contributing towards maintenance errors. There are no limitations on duty hours specified for maintenance personnel (at the time of writing this CAP). The EU Working Time Directive provides some guidelines (see Appendix V), but transport industries were originally excluded from the Directive. The reader is referred to the latest situation regarding applicability of the EU Working Time Directive to maintenance. A few organisations impose a voluntary limitation in terms of a maximum number of hours technicians may work. JAR145 does not (currently) address working time limitations.

3.2 JAR145 requires planners to take into account human performance limitations when organising shifts (and planning rosters). Appendix I provides general guidance on shiftwork, fatigue, circadian rhythms, sleep, etc. in relation to realistic maintenance contexts. A separate CAA sponsored study provides detailed guidance material concerning best practice for shiftwork[1].

NPA145-12, 145.47(b). AMC145.47(b). MHFWG report.

3.3 The JAA MHFWG report provides some guidelines for minimising fatigue and its impact. Further guidance is also provided in Appendix I, and in CAP715.

3.4 There is a great deal of research on shiftwork and what are good and bad shifts from the purely scientific perspective. However, one must take into account the whole context when considering shift patterns, including what is acceptable to the staff and management within an organisation, the trade-off between length of shift and number of handovers, the pattern of work to be done, etc. There is no single ideal shift system. Organisations must select whatever shift system is most appropriate to the company and staff, but should take into account the scientific advice which is available

1. Folkard, S - currently in preparation

.

Table 3 Fatigue management. Source: MHFWG report

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 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

3.5 More formal recommendations will await the publication of the report on the CAA sponsored project on shiftwork and fatigue, and will be included in a future revision of this CAP.

4 Competence, Knowledge, Experience and Recency

4.1 JAR66 and, to a certain extent, JAR145, address in some detail knowledge and experience requirements for maintenance personnel.

4.2 There is no formal restriction on the number of aircraft types which an engineer may have on his license, although large organisations tend to restrict authorisations to two or three complex aircraft types (indeed, some NAAs have this as a legal restriction).

4.3 JAR145 recognises that technicians must remain reasonably current on the aircraft types for which they hold authorisations, therefore require that "all aircraft release certifying staff are involved in a least 6 months of actual aircraft maintenance experience in any 2 year period" and also have appropriate continuation/ refresher training.

JAR145.35(b).

Chapter 5 Errors, Violations and Non-compliance with Procedures

1 Errors and Violations

1.1 A working definition of "human error" (including violations) is "those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some chance agency"[1]

1.2 It is useful to distinguish, right from the outset, the difference between "human error" and "system error". Whilst it is always a human being who commits the error, there are two approaches to looking at error: (i) from the point of view of the individual and (ii) from the point of view of the whole system, of which the individual technician is only one part. The concept of "maintenance error" is sometimes equated to "system error".

1.3 Another useful way of looking at error (and violations) is in terms of system component failure, where human actions are part of the system and need to be engineered such that they are resistant to error and, in the case of failure, error detection and alerting mechanisms built into the system.

1.4 People often think of "human error" as an erroneous action made by the last person to touch the aircraft before it went wrong! It may well be the case that there was an erroneous action on the part of a maintenance technician, but it is important to look at this in the context of the whole system and organisational factors which may have contributed to that error.

1.5 The reader is encouraged to read CAP 715 which contains a succinct description of types of errors and violations, or to Professor James Reason's book "Human Error" for a more detailed description and discussion of the subject. A good understanding of the causes of errors and violations is necessary in order to address them. All to often, the 'blame and train' approach is used inappropriately to address error.

1.6 It is important to understand the root causes behind errors and violations, and whether an error is a 'one off' or a more systemic problem which may re-occur, and whether it is a problem with an individual technician or with the system.

1.7 Human Factors training will help individual recognise the factors which may lead to errors and violations and to avoid error provoking situations and behaviour as far as possible. However, this can only have limited effectiveness without the whole maintenance system being designed to be error resistant, e.g. well-written procedures, good planning, mechanisms for detecting and highlighting errors when they do occur, etc.

1.8 Human error is inevitable and can never be totally eliminated. The emphasis within a maintenance organisation should be upon pro-active error management. The processes and mechanisms described within the CAP should help an organisation to better manage its errors, violations and error potential. For further guidance on error capturing and error management, see chapters 5 and 7.

1. Reason, J. (1990) Human Error. Cambridge University Press.

2 Non-compliance with Procedures

2.1 Evidence indicates that maintenance personnel often fail to comply with procedures. JAR145 necessarily requires, and assumes, compliance with procedures, but also addresses some of the issues which lead to non-compliance (e.g. poorly written procedures, unavailability of appropriate maintenance data or tooling, time pressure, etc.).

NPA12, AMC145.65(a). NPA20-6, ACJXX(8)(c)(viii). NPA12, AMC145.65(b)6,7,8.

2.2 There have been several studies looking at why people do not follow procedures. The results of one of these studies are summarised in Table 4.

Table 4 Why people don't follow procedures. Source: Human Reliability Associates Ltd. (Author, Date, Title, Publisher please.)

"Procedures are not used because...		**% agreeing**
Accuracy	..they are inaccurate	21
	..they are out-of-date	45
Practicality	..they are unworkable in practice	40
	..they make it more difficult to do the work	42
	..they are too restrictive	48
	..they are too time consuming	44
	..if they were followed 'to the letter' the job couldn't be done in time	62
Optimisation	..people usually find a better way of doing the job	42
	..they do not describe the best way to carry out the work	48
Presentation	..it is difficult to know which is the right procedure	32
	..they are too complex and difficult to use	42
	..it is difficult to find the information you need within the procedure	48
Accessibility	..it is difficult to locate the right procedure	50
	..people are not aware that a procedure exists for the job they are doing	57
Policy	..people do not understand why they are necessary	40
	..no clear policy on when they should be used	37
Usage	..experienced people don't need them	19
	..people resent being told how to do their job	34
	..people prefer to rely on their own skills and experience	72
	..people assume they know what is in the procedure	70

2.3 One of the reasons for procedural non-compliance identified in a recent European study[1] is that there are better or quicker ways of doing the job. Some of these methods may be safe; others may not. It is important to determine and document the best procedures, and to establish a situation whereby the best, quickest and safest way of doing the job is to follow the established procedures, abolishing the 'need' to work around procedures in order to get the job done.

2.4 Many procedural non-compliances are due to problems with the procedures themselves. These issues are addressed in Chapter 6.

1. Adams Consortium (1999) Aircraft Dispatch and Maintenance Safety (ADAMS) study. Published on the Trinity College Dublin website (www.tcd.ie.aprg)

Chapter 6 Procedures, Documentation and Maintenance Data

Procedures fall into two categories: those produced by the manufacturer and those produced by, and within the control of, the maintenance organisation or aircraft operator. The former will be referred to as Maintenance Data; the latter will be referred to as procedures and work instructions. This CAP provides guidance on the design and presentation of procedures, and how to identify procedures where there is scope for improvement. This guidance is aimed at JAR145 companies, but would also apply to JAR21 and JAROPS organisations.

1 Maintenance Data

1.1 Access and Availability

JAR145 requires that maintenance data is readily available for use, available in close proximity to the aircraft being maintained, and that there should be an adequate number of computer terminals, microfilm/ microfiche readers, and printers.

AMC145.45(f)(g)2,3.

1.2 Inaccuracies, ambiguities and gaps

1.2.1 It is recognised that some maintenance manuals provided by the manufacturers often offer scope for improvement. Ideally, maintenance manuals should be validated when first written, for each new aircraft type and variant, but this is a task which is rarely carried out as thoroughly as it might be, if at all. Accordingly, it tends to be left to operational experience to pick up the inaccuracies, ambiguities or missing information in maintenance manuals. In addition, the information in the maintenance manual is not necessarily always in an appropriate form to be used in a maintenance environment, and some translation may be required to make this data more usable.

1.2.2 Maintenance organisations must have in place a procedure whereby such inaccuracies, ambiguities[1] or missing information are recorded and reported to the type certificate holder. Staff should be encouraged to report such problems, but it should be borne in mind that they will only continue to do so if they believe that the problems are being addressed. Type certificate holders should act upon reported defects, and update the manuals quickly. There is currently no requirement for TC holders to validate Maintenance Manuals or to ensure that they are 'user friendly'.

NPA12, AMC145.45(c).

1.2.3 It is good human factors practice for manufacturers to ensure that maintenance manuals are correct, complete, unambiguous and 'user friendly', both from the outset and on a continuing basis.

1.2.4 Further information on reporting systems can be found in Chapter 11.

1. Note: CAP562 (CAAIP leaflet 11-22 Appendix 4-1) highlights the problem of ambiguities in maintenance data, and asks technicians to report these to the organisation responsible for publishing the information.

2 Procedures and Work Instructions

2.1 A work instruction is what you should do, whereas a procedure is how you should do it. Job cards are usually work instructions; procedures generally originate from the Maintenance Manual.

2.2 Writing procedures and work instructions

2.2.1 As well as maintenance data and procedures provided by the manufacturer having scope for improvement, there is also often a better way of writing or presenting technical procedures and work instructions which are produced by, and used within, a maintenance organisation. Obviously the fundamental elements of the procedures should not deviate from the manufacturer's requirement, but there is often scope for presenting that information in such a way that it is more easily understandable and usable. Guidance material is provided in Appendix O to help ensure that procedures and work instructions are written well. The main points are summarised in Table 5.

JAR145.45(c). NPA12, AMC145.65(b)7,8.

Table 5 Guidelines for designing procedures.

- Procedure design and changes should involve maintenance personnel who have a good working knowledge of the tasks.
- All procedures, and changes to those procedures, should be verified and validated before use where practicable
- Ensure procedures are accurate, appropriate and usable, and reflect best practice
- 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
- Take account of the environment in which they are to be used
- Ensure that all key information is included without the procedure being unnecessarily complex
- Where appropriate, explain the reason for the procedure
- 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.
- Ensure consistency in the design of procedures and use of terminology, abbreviations, references, etc.
- Provide training on the use of technology to access and print procedures and maintenance data.
- Ensure that printing and copy quality is good, and that there are enough printers, copiers, etc.

2.2.2 Organisations should advise the type certificate holder of any improvements which they have implemented regarding maintenance manuals.

2.3 Reporting discrepancies

2.3.1 In addition, there should be an internal occurrence/discrepancy reporting system whereby staff can report inaccuracies or ambiguities in procedures, or, indeed, suggest better ways of doing particular tasks, such that procedures can be frequently updated and improved. This system must result in actions and improvements to the procedures, otherwise it will not be used by the workforce. AMPOS is an example of such a system (see Appendix P).

NPA12, AMC145.65(b)6.

2.4 Consistency

2.4.1 Consistency is important, and whilst it is beyond the scope for JAR145 to require greater consistency between Manufacturers' Manuals (e.g. Airbus and Boeing), there is plenty of scope within a JAR145 maintenance organisation to provide consistency in its documentation. Indeed, JAR145 requires organisations to provide a common workcard or worksheet system for use throughout relevant parts of the organisation.

JAR145.45(e)

Chapter 7 Error capturing

Error capturing forms an important part of the safety net. There are many types of error capturing mechanisms, including functional checks, leak checks, inspection of tasks before signing for work done by others, independent Duplicate Inspections (DIs), pilot pre-flight checks, etc. JAR145 offers duplicate inspections as one means of detecting errors, and lists likely criteria for applying such inspections.

AMC145.65(b)4. NPA12, AMC145.65(b)4(b)&(c). NPA12, Section2, Appendix 2, 2.24.

1 Functional Checks

1.1 Functional checks are error capturing mechanisms in some instances since they will detect, if properly actioned, if something is not installed, secured properly, adjusted correctly or meets specified criteria in the manuals. This is true for most systems and is an inherent part of the maintenance process. It is, in the majority of cases, impossible to carry out a duplicate inspection on a flying control without a functions check since the range of movement, control stop clearances, control system friction or loading checks cannot be determined otherwise.

1.2 The problem is that since they are regarded as an inherent part of the system, it is only when the function checks or ground runs are not carried out and an incident occurs, (e.g. the well publicised double engine oil loss on a 737-400 at Daventry, UK[1]) that their benefit in error prevention or error capture is properly realised.

2 Duplicate Inspections

2.1 Duplicate Inspections are inspections where the task or process is performed by one person, a first check carried out by that person (if qualified to self-certify) or by a supervising certifying engineer, and then independent checks carried out by a second suitably qualified person. Both the first and second checks should be thorough and, in the case of control systems, ensure that they include functional checks for freedom and full range of movement.

2.2 There is no universally agreed list of tasks or points against which duplicate inspections should be carried out. Some National Authorities have requirements for duplicate inspections or required inspection items; others do not. This reflects the different perception of the value of duplicate inspections or simply a cultural belief, whether right or wrong, that the normal inspection process cannot fail. The tasks and criteria in Table 6 should help determine which tasks might warrant duplicate inspections.

2.3 It is important to consider (i) the criticality of the task and consequences of failure, (ii) the vulnerability of the task to human error (which might be determined by previous incidents, a risk assessment, etc.) and (iii) the presence or absence of other checks (e.g. functional checks). However, one should not assume that just because other checks are present in the procedures or aircraft systems, that they will be effective. It is generally better to have several mechanisms for detecting error and not to rely on just one, or to relax checks (e.g. duplicate inspections) on the assumption that a

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

problem will be detected by one of the other error detection mechanism (e.g. pre-flight checks by pilots).

Table 6 Tasks which may warrant Duplicate Inspections[1].

• Installation, rigging and adjustments of flight controls • Installation of aircraft engines, propellers and rotors • Overhaul, calibration or rigging of components such as engines, propellers, transmissions and gearboxes Note: this list is merely guidance and is by no means a comprehensive listing of all tasks which may benefit from a DI.

1. Source: JAR145 NPA-12. AMC-145.65(b)(4)(b)

NPA12, AMC145.65(b)4(b).

2.4 Avoid overuse of duplicate inspections. Overuse, combined with inadequate manpower, can result in checks being skimped and reduce the effectiveness of the duplicate inspection as an error capturing mechanism. It is easy to be lulled into a false sense of security simply because DIs have not found a mistake on a particular system or an individual has not previously made an error.

2.5 The UK CAA requirements concerning duplicate inspections are found in:

a) BCAR A6-2 (A5-3 for vital points) and

b) CAAIP part 2, IL 2-13 Control Systems.

2.6 The latter describes best practice when carrying out duplicate inspections, and contains detailed information. The major points are summarised in Table 7.

Table 7 Duplicate Inspection 'best practice'

• Both parts of the duplicate inspection must be carried out by suitably qualified persons • The second part of the duplicate inspection should be carried out by a person not involved in the original task • Inspection and checks should be carried out thoroughly, and not influenced by any knowledge concerning the competence of the original technician who did the work of the certifying technician who carried out the first check. Thoroughness of inspection should not be interpreted as a lack of trust in the accuracy of the original work. • It should take place as soon as possible after the task has been completed and the original inspection has taken place, with the dates and times of both inspections recorded. • For control systems, the duplicate inspection should cover checks for full and free movement (freedom and range of movement). • Measurements should be taken, e.g. range of movement, clearances, tensions, operating performance, etc., compared against required figures (maintenance manual limits) and recorded. • Avoid just recording "complied" or "satis" as results of checks; record the nature and extent of the movement or result of the inspection observed during each step of the check.

2.7 In many respects the onus of responsibility for determining what work requires a duplicate inspection rests with the certifying engineer. For aircraft manufactured more recently it has been a requirement that the manufacturer identify vital points in the aircraft and its systems. Such vital points are points or areas in the design where it has not been entirely possible to eliminate through design the possibility of failure by a single item or incorrect assembly. The philosophy is identified in BCAR A5-3 and whilst not specified it is felt appropriate that such vital points are the subject of independent inspections as if duplicate inspections were applicable.

2.8 The effectiveness (or otherwise) of duplicate inspections has been debated at length. There have been several incidents where DIs have been ineffective and incidents or accidents have resulted. On the other hand, there is a great deal of evidence from communications with maintenance personnel[1] to indicate that DIs are effective in most cases. The evidence tends only to be anecdotal because occasions where problems have been picked up by a second independent inspection have invariably been rectified and therefore not resulted in an incident or formal report.

2.9 Concerns which have been expressed as to why DIs might not be effective are that (i) the technician may do the task less diligently if he thinks that someone else will check it and pick up any errors, (ii) over-use of DIs may result in the independent inspections being carried out less thoroughly, and (iii) the lack of finding errors or faults can introduce complacency. The results of the informal survey carried out by the JAA MHFWG during 2000 indicated that the first concern was not generally supported by industry experience or opinion and that, far from being *less* diligent, a technician was likely to be even *more* diligent if he knew that his work would be inspected.

2.10 In summary, an independent inspection is likely to be more effective than a second inspection carried out by the person doing the task. Duplicate Inspections are considered to be an effective mechanism for trapping errors, but should not be relied upon as the only mechanism since they are not always 100% successful.

3 Pilot Pre-flight Checks

Whilst not specifically intended as a mechanism for capturing maintenance errors, nevertheless pilot pre-flight checks should act as another barrier to prevent such an error from resulting in an accident. A well publicised incident involving an Airbus 320[2] at Gatwick where the spoilers were left in maintenance mode, might have been prevented had the pilots noticed that the flight controls were not responding correctly during the pre-flight checks.

1. An informal survey was carried out by the JAA MHFWG during 2000.
2. AAIB/AAR 2/95, Excalibur Airways, A320-212, G-KMAM, Gatwick, August 1993. Published January 1995.

4 Design for Error Resistance

4.1 This CAP will not go into detail concerning design for error resistance, since the document is not intended for designers and manufacturers. However, it is useful for maintenance personnel to be aware of where design improvements might be made, such that, if they have an opportunity to highlight poor design or areas where design might be improved, they should be encouraged to do so. An example of such an opportunity might be during an incident investigation, where there is scope for identifying design issues which contributed towards the incident or error, and/or potential design solutions.Examples where design might be improved include[1]:

- designing out cross-connectability, e.g. by having parts which cannot physically fit incorrectly, colour coded parts, part numbers well labelled, staggered position of similar parts, leads that are too short to fit to the wrong connector, etc.
- cockpit warning lights for unlatched cowlings
- paint finishes and colours that aid in crack and flaw detection
- accessible inspection panels
- design such that it is obvious whether something is open or closed
- good use of placards
- guarding of moving parts or areas where snagging or chafing might occur

4.2 There are often known areas on certain aircraft where design provision for maintenance activities is not ideal. These need to be made known to technicians, both via training and by publishing warning notices in the procedures or information used by technicians on the job. It would be beneficial to share such information between maintenance organisations.

4.3 It is important to feedback knowledge concerning poor design to the manufacturer in order that problems can be rectified or, if not feasible or economical, they can be highlighted in Maintenance Manuals and avoided in future designs.

1. Courteney, H. (2000) Human Centred Design for Maintenance. In: 15th HFIAM Symposium. Available from http://hfskyway.faa.gov

Chapter 8 Planning and Preparation

1.1 Planning is critical to human factors in that it should aim to ensure that there are adequate appropriately qualified & alert personnel, tools, equipment, material, maintenance data and facilities at the right place, at the right time, for the scheduled (and, as far as is possible, unscheduled) tasks. Indeed, JAR145 states that an organisation may only maintain an aircraft (or aircraft component) when all necessary facilities, equipment, tooling, material, maintenance data and certifying staff are available.

JAR145.80.

1.2 It is not the purpose of this CAP or of JAR145 to tell planners how to do their jobs but, rather, to highlight some of the human factors issues which they should be taking into account in the planning process, such as human performance limitations when working shifts and long hours.

1.3 Depending on the amount and complexity of work generally performed by the maintenance organisation, the planning system may range from a very simple procedure to a complex organisational set-up including a dedicated planning function in support of the production function.

1.4 The production planning function includes two complimentary elements:

- scheduling the maintenance work ahead, to ensure that it will not adversely interfere with other maintenance work as regards the availability of all necessary personnel, tools, equipment, material, maintenance data and facilities;
- during maintenance work, organising maintenance teams and shifts and provide all necessary support to ensure the completion of maintenance without undue time pressure.

1.5 When establishing the production planning procedure, consideration should be given to the following:

- logistics,
- inventory control,
- square meters of accommodation,
- hangar availability
- man-hours estimation,
- man-hours availability,
- preparation of work,
- co-ordination with internal and external suppliers, etc.
- scheduling of safety-critical tasks during periods when staff are likely to be most alert**,** and avoiding periods when alertness is likely to be very low, such as early mornings on night shifts.

NPA145-12, AMC145.47(a).

1.6 Further information concerning fatigue and shiftwork can be found in chapter 4.

1.7 JAR145 requires an organisation to have a maintenance man-hour plan showing that the organisation has sufficient staff to plan, perform, supervise, inspect and quality monitor the organisation. In addition, the organisation must have a procedure to reassess work intended to be carried out when actual staff availability is less than the planned level for any particular work shift or period.

JAR145.30(c)

1.8 It is important that planners attend human factors training, in order to better appreciate how good or bad planning can potentially affect human performance and, ultimately, safety and airworthiness.

NPA145-12, AMC145.30(e)5.

Chapter 9 Teamwork, Communication, Handovers and Sign-offs

This document does not discuss teamwork or communication in detail in the main text, although some further information is provided in Appendix M. It concentrates instead on task and shift handovers, and on written communication of information. Sign-offs are discussed within this chapter since they are particularly important when tasks are handed over from one person to another, particularly when this was unplanned and there is no formal handover.

1 Task and Shift Handovers

1.1 The primary objective of handovers is to ensure that all necessary information is communicated between the out-going and in-coming personnel. Effective task and shift handover depends on three basic elements:

- The outgoing person's ability to understand and communicate the important elements of the job or task being passed over to the incoming person.

NPA12, AMC145.47(c)1.

- The incoming person's ability to understand and assimilate the information being provided by the outgoing person.
- A formalised process for exchanging information between outgoing and incoming persons and a place and time for such exchanges to take place.

1.2 Organisations should have a recognised procedure for task and shift handovers which all staff understand and adhere to. This procedure should be listed in the MOE.

NPA12, AMC145.47(c)2.

1.3 Whilst there is no specific requirement in JAR145 for time to be specifically rostered in to allow for an overlap of 20 or 30 minutes whilst a shift handover takes place, this would be considered good human factors practice.

1.4 Further detailed information is provided in Appendix M concerning task and shift handovers, and appropriate ways of recording information for handover. Whilst all essential information (especially the detailed status of tasks) should be recorded in written form, it is also important to pass this information verbally in order to reinforce it. This is known as redundancy, or the 'belt and braces' approach.

2 Sign-offs

2.1 Research indicates that many maintenance tasks are signed off unseen. In order to prevent omissions, mis-installations, etc., every maintenance task or group of tasks should be signed-off. To ensure the task or group of tasks is completed, sign-off should only take place after completion and appropriate checks. Work by non-competent personnel (i.e. temporary staff, trainee,…) should be checked by authorised personnel before they sign-off. The grouping of tasks for the purpose of signing-off should allow critical steps to be clearly identified.

NPA12, AMC145.65(b)4(c)

NOTE: A "sign-off" is a statement by the competent person performing or supervising the work, that the task or group of tasks has been correctly performed. A sign-off relates to one step in the maintenance process and is therefore different to the release to service of the aircraft.

NPA12, AMC145.65(b)4(c)

2.2 Signing off small groups of tasks will help prevent situations where a technician is called away from one task to do another, and the person picking up the previous task has no record of what has been completed and what has not. If there are accepted break points at frequent intervals during each main task (i.e. the sign-off points), technicians should be encouraged to continue with the task up to the next break point without interruption, and only after the sign-off allow themselves to be diverted onto another task if this is required.

2.3 Sign-off points would be determined by the maintenance organisation as appropriate to the nature of their work.

2.4 Sign-offs should be considered a mechanism for helping to ensure that all steps have been carried out, and carried out correctly, and not primarily as a mechanism for identifying the responsible person in the event of something going wrong. It is understood that, in some cases, the person signing-off the task or groups of tasks will be unable to view or inspect, in detail, the work which has been carried out, but it is important that that person has a high degree of confidence that the work has been carried out correctly. If sign-offs end up as purely a paper exercise, where the person signing off the tasks has little idea whether they have been carried out correctly, the whole point of the sign-off mechanism will have been lost. It is appreciated that signing off tasks generates a certain workload, but considered that the safety benefits outweigh the disbenefits.

Chapter 10 Environmental Factors, Tooling and Ergonomic Audits

1 Environmental Factors.

1.1 Information on the following may be found in CAP715:

- noise
- fumes
- illumination
- climate and temperature
- motion and vibration
- confined spaces
- working environment.

1.2 JAR 145 makes certain provisions in terms of facilities and work environment, although guidance tends to be general rather than specific. The requirements and associated AMCs are summarised in Table 8.

Table 8 Facility requirements Source: JAR145

Hangars	should be available for base maintenance; optional for line maintenance, but hangar availability during inclement weather is recommended. Hangars should be large enough to accommodate aircraft on planned base maintenance.
Protection against contaminants	minimised to below visible level.
Temperature	adequate for personnel to carry out work without undue discomfort
Lighting	adequate to ensure each inspection and maintenance task to be carried out
Noise	below distraction level, where possible; otherwise below distraction level with ear plugs/ ear muffs.
Equipment/ tools	all equipment, tools and material should be made available when needed.

AMC145.25(a), (b), (c). AMC145.40(c)

1.3 There has been a great deal of research carried out in North America[1] concerning environmental factors such as temperature, noise, lighting, etc. and a detailed ergonomic audit tool (ERNAP[2]) developed appropriate for aviation maintenance, which can assist in the evaluation of work environments, tooling and documentation.

1.4 It is appreciated that aircraft maintenance takes place in many different locations and environments, and that it is not always possible to carry out maintenance in a hangar

1. for details, see http://hfskyway.faa.gov
2. Meghashyan, G. (1996) Electronic Ergonomic Audit System for Maintenance and Inspection. (Galaxy Scientific Corporation, Atlanta, Georgia) Proceedings of the Tenth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection (1996). Available from: http://hfskyway.faa.gov

maintained at a comfortable temperature, with adequate lighting and noise levels, etc. However, it should be recognised that environmental factors can contribute towards errors and efforts made to ensure that the environment is as 'work-friendly' as reasonably possible, e.g. putting an aircraft into a hangar, if space is available, rather than carrying out the work on the apron, where appropriate, even though this may take slightly longer to arrange a tow.

1.5 Further details concerning environmental factors, tooling and ERNAP are given in Appendix K.

Chapter 11 Occurrence Reporting and Management

1 Occurrence reporting and management

1.1 A key element of a human factors programme is a system whereby problems, or potential problems, can be reported and dealt with. Many organisations already have some form of reporting system for technical issues or discrepancies, but this may need to be expanded, or additional system(s) put in place, to allow for the reporting of human errors, ambiguities with procedures, mismatches between required and actual practice, etc.

1.2 A Mandatory Occurrence Reporting (MOR) scheme already exists within the UK, whereby organisations and individuals are required to report occurrences meeting the MOR criteria, to the CAA[1]. Also, there is a national confidential occurrence reporting scheme (CHIRP) to which individuals can report.

JAR145.60

1.3 This chapter refers to *internal* company reporting schemes which may or may not already exist, in order to ensure that there is a mechanism for all safety related concerns to be reported, recorded, analysed and appropriate action taken.

1.4 The JAR145 requirement is for an organisation to have in place an internal occurrence reporting scheme to enable the collation of occurrence reports, including the assessment and extraction of relevant information in order to identify adverse trends or to address deficiencies in the interests of safety. This system should include evaluation of known, relevant information relating to occurrences and promulgation of such related information.

NPA145-10, JAR145.60(a)

1.5 The type certificate holder is required, via JAR21, to have a system for the collection, investigation and analysis of data (expanded in NPA21-24 to include reports of, and information relating to, faults, malfunctions, defects or other occurrences which cause, or might cause, adverse effects on continuing airworthiness). Unfortunately, at the time of writing this document there was no requirement at present for the TC holder to rectify problems such as maintenance manual ambiguities (unless directed to do so by the NAA). The reader is referred to JAR21 and NPA21-24 for further details.

JAR21.3(a). NPA21-24, JAR21.3(a)

1. CAP381, UK Civil Aviation Authority.

2 Key Elements for the Establishment of an Internal Occurrence Management Scheme (OMS)

2.1 An Occurrence Management Scheme should contain the following elements:

- Clearly identified aims and objectives
- Demonstrable corporate commitment with responsibilities for the Occurrence Management Scheme 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
- Occurrence Management Scheme 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 Occurrence Management Scheme, 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 The following elements of an Occurrence Management Scheme are covered in more detail later in this chapter:

- 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.
- A mechanism for reporting such occurrences should be available.
- A mechanism for recording such occurrences should be available.
- Significant occurrences should be investigated in order to determine causal and contributory factors, i.e. why the incident occurred.
- 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.
- 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.
- Feedback to reportees, both on an individual and more general basis, is important to ensure their continued support for the scheme.
- The process should enable data sharing, whilst ensuring confidentiality of sensitive information.

2.4 Just culture code of practice

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

2.4.2 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.

2.4.3 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. An example of such a code of practice is given in Appendix E.

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

2.5 Processes for reporting occurrences

2.5.1 Incidents, occurrences, errors and potential safety hazards may be identified as a result of an event (an incident, air turnback, rework, etc.) or by a report submitted by a staff member (e.g. reporting an error made by themselves or a colleague which was detected and did not result in an event).

2.5.2 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 (e.g. 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.

2.5.3 It is likely that a reporting mechanism will already be prescribed, partially or wholly, by the existing mandatory reporting requirements or by an existing company reporting scheme. A company may wish to utilise this for all reporting, or may wish to have a separate reporting scheme for maintenance errors.

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

2.5.5 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[1].

2.6 Processes for recording occurrences

2.6.1 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

1. www.gainweb.org

specific categories and keywords, with all the data being classified according to a rigid structure.

2.6.2 Existing schemes for general occurrence data recording include: ICAO's ADREP, ECCAIRS, UK CAA's MORS, USA's ASRS, UK's CHIRP, etc.

2.6.3 A commonly used taxonomy for recording and investigation of maintenance-related occurrences is the Maintenance Error Decision Aid (MEDA). The MEDA form is included in Appendix X.

2.6.4 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 (e.g. 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, e.g. health and safety monitoring, Quality Assurance, etc.

f) existing products/ tools, and their cost.

2.6.5 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.

2.7 Investigation of occurrences

2.7.1 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 should set certain criteria, usually related to the significance of the incident, to determine which occurrences are investigated, e.g. rework costing more than £500, air turnbacks, delays more than 60 minutes, etc.

2.7.2 Investigation processes can vary considerably in depth and nature. Aircraft maintenance 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 may be obtained from http://hfskyway.faa.gov, and a copy of the MEDA form is included in Appendix X. For those maintaining components, the principles of MEDA still apply but some of the details may need to be adapted.

2.8 Data analysis

2.8.1 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.

2.9 Managing identified hazards

2.9.1 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 (e.g. 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 jeopardise flight safety. Actions which are inappropriate to the cause of the problem (e.g. 'blame and train') may result in the occurrence reporting system losing credibility among staff. The occurrence management process should be closed-loop in order to ensure that actions are identified and carried out.

2.9.2 An Occurrence management System 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.

2.10 Feedback

2.10.1 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.

2.11 Sharing of results

2.11.1 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.

2.11.2 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.

2.11.3 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).

2.11.4 Further information concerning data exchange can be obtained from Global Aviation Information Network (GAIN)[1], and from the UK Confidential Human Factors Incident Reporting (CHIRP) office.

2.12 Applicability according to size of organisation

2.12.1 Whilst all the principles described above are applicable to all JAR-145 approved organisations, 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.

1. www.gainweb.org

Chapter 12 Human Factors Training for Personnel Involved in Maintenance

1 Human Factors Training

1.1 Human Factors Training is not a new concept; indeed it has been in place for flight deck crew, in the form of Crew Resource Management (CRM) training, for many years now. Some maintenance organisations have already adopted human factors training prior to any requirement to do so. Some of these initiatives have been successful; others have not.

1.2 There has been research carried out into how human factors training might best be implemented within an organisation to be successful. Much of this research took place in North America, with some research, notably the ADAMS and STAMINA projects, having been carried out in Europe. It is considered that we now know enough to provide some useful guidelines concerning human factors training, which are detailed in this Chapter and in Appendix U.

1.3 One of the key elements of a good human factors or safety management programme is appropriate training in issues associated with safety and airworthiness, both from a technical and non-technical perspective. The non-technical safety training (aside from health and safety training) tends to be referred to as "Human Factors" training but really addresses how to ensure that work is carried out professionally such that an aircraft is released to service in an airworthy condition.

1.4 The aims of Human Factors training should be to (i) impart knowledge on human factors, (ii) to develop skills, where appropriate, (iii) to influence people's attitudes and (iv) to influence behaviour (all in support of improved safety). Training will not be successful in the long term unless what it teaches is supported within the organisation on a day-to-day basis. The human factors training requirement within JAR145 should not be considered in isolation but, rather, as a part of the total package of measures.

1.5 JAR 66 already includes a requirement to demonstrate knowledge of Human Factors elements which are included in Module 9 of the syllabus. However, this only applies to certifying staff and is not a requirement for training: it is only tested by means of examination. A good 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 in isolation cannot really assess certain aspects such like "skill" and above all "attitude", which are two of the training objectives discussed above. Training in human factors is, therefore, important in order not only to help people understand what the issues are, but how to adopt good human factors practice in all aspects of work. Such training is appropriate for all staff who have an impact upon safety and airworthiness, not just for engineers or certifying staff.

2 Initial and Recurrent Training

2.1 JAR145 (Amendment 3) required only that certifying staff received continuation training in various subject, including human factors. NPA145-12 introduced a requirement for both initial and recurrent training for all relevant staff within a JAR145 organisation. The reader is referred to JAR145 and NPA145-12 for details.

JAR145.35(c). NPA145-12, JAR145.30(e). NPA145-12, AMC145.30(e)5,6,7,8.

2.2 All appropriate personnel receive both initial and recurrent human factors training. This should include:

- Post-holders, managers, supervisors
- Certifying staff, technicians, and mechanics.
- Technical support personnel such as planners, engineers, technical records staff
- 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

NPA145-12. AMC145.30(e)5.

2.3 The recommended form of initial training is a formal training course (ICAO recommends a duration of about 2 days), following a set syllabus, although recognising that the length and content of the should be tailored according to the size and type of organisation, the nature of its business and individuals' jobs. Recurrent training should be more flexible, as long as it achieves the objectives of (i) ensuring that all staff remain current in human factors, (ii) addressing topical issues where training is required and (iii) collecting feedback on human factors issues from the workforce. The lessons learned in initial training are likely to fade if not supported by recurrent training.

NPA145-12, AMC145.30(e)6. NPA145-12, AMC145.30(e)7.

2.4 A syllabus for initial training is provided in Appendix U, along with recommendations as to who ought to be providing such training.

NPA145-12, AMC145.30(e)6, Appendix 9. MHFWG report.

2.5 JAR147 details how organisations should conduct training and associated examinations if they wish to qualify certifying staff according to JAR66. Whilst human factors training and examination is covered in that it is one of the JAR66 modules (see Appendix T), no specific details are given relating to human factors in particular. General training and examination requirements are detailed, including the experience and knowledge of instructors.

JAR147.35.

2.6 The JAA MHFWG report recommends certain criteria for instructors providing human factors training within JAR145 organisations. Human factors is not an easy subject to teach, especially since the emphasis in JAR145 is upon skills and attitudes rather than knowledge. Accordingly, it is recommended that a human factors trainer:

- has attended an acceptable Human Factors training course that covers the JAR145 initial training syllabus;
- has received additional instruction in training and facilitation techniques;
- has worked for at least 3 years for a maintenance organisation (in the case of continuation training)

MHFWG report, attachment 7, paragraph 6.

2.7 Training could be provided by either a trainer employed by the organisation or by trainer(s) 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.

2.8 In cases where organisations cannot provide their own in-house training, it is acceptable to contract out as long as the main trainer has a good background in aviation maintenance. This person does not have to have been a maintenance technician (although this would be of benefit), but must have a good, practical understanding of maintenance engineering human factors practice and theory. It is not enough simply to present a set of slides on the syllabus topics without having enough knowledge to illustrate points using practical examples, or to answer questions. The quality of the trainer is key to the success of human factors training, remembering that JAR145 human factors training is more about changing attitudes and less about imparting knowledge.

2.9 It is essential that the human factors trainer (or facilitator) believes in what they are teaching, and has enough credibility and knowledge to pass on this belief to his students. It will be possible for organisations to meet the letter, but not the spirit, of the human factors training requirement by placing their staff on the shortest, cheapest course available. However, organisations are strongly encouraged to investigate the intrinsic quality of the training courses and trainers, and not necessarily to judge by cost, duration or course content. A good human factors trainer should be able to positively influence his trainees' safety behaviour which, ultimately, should reflect positively upon the organisation's safety culture, and even its commercial profitability (the reader is referred to the Return on Investment studies, on http://hfskyway.faa.gov).

2.10 Organisations should be wary of inappropriate adaptations of CRM training being offered as a means to comply with the JAR145 human factors training requirement. Whilst some of the principles may be common to flight operations and maintenance, such courses would need major changes in order to be applicable, and it would be necessary to ensure that the trainer also has a good background in maintenance. Organisations are encouraged to develop their own human factors training, albeit possibly with the assistance or advice of professional human factors trainers.

Appendix A Definition of Human Factors

1 What is Human Factors?

1.1 Human Factors[1] 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.

1.2 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.

1.3 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.

1. ICAO Human Factors Training Manual (1998) Doc 9683-AN/950

2 Some Definitions of Human Factors

2.1 "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 as referenced in ICAO Human Factors Digest No. 1. (1989). ICAO.

2.2 "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. Available from http://hfskyway.faa.gov

2.3 "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. (1997) Opening address for the 9th International Symposium on Aviation Psychology. Ohio University, USA.

2.4 "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."

Sanders, M.S. and McCormick, J. (1993) Human Factors in Engineering and Design. McGraw-Hill.

2.5 "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

2.6 "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. HSG48

3 ICAO Definitions Relating to Human Factors

3.1 "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."

ICAO Annex 6, part 1.

3.2 "Human performance: Human capabilities and limitations which have an impact on the safety and efficiency of aeronautical operations."

ICAO Annex 6, part 1, Definitions.

3.3 "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, paragraph 1.4.2.

3.4 "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, paragraph 1.4.3.

3.5 "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, paragraph 1.4.4.

3.6 "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, paragraph 1.4.6.

4 Models Describing Human Factors

4.1 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[1], is the SHEL model, the name being derived from the initial letters of its components: Software (e.g. maintenance procedures & documentation), Hardware (e.g. design for maintenance), Environment (e.g. lighting) and Liveware (i.e. the person or people, including maintenance technicians & mechanics, supervisors, planners, managers, etc.).

4.2 The model shows the interfaces between the human (the 'L' in the centre box) and the other elements of the SHEL model[2], e.g.: 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 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.

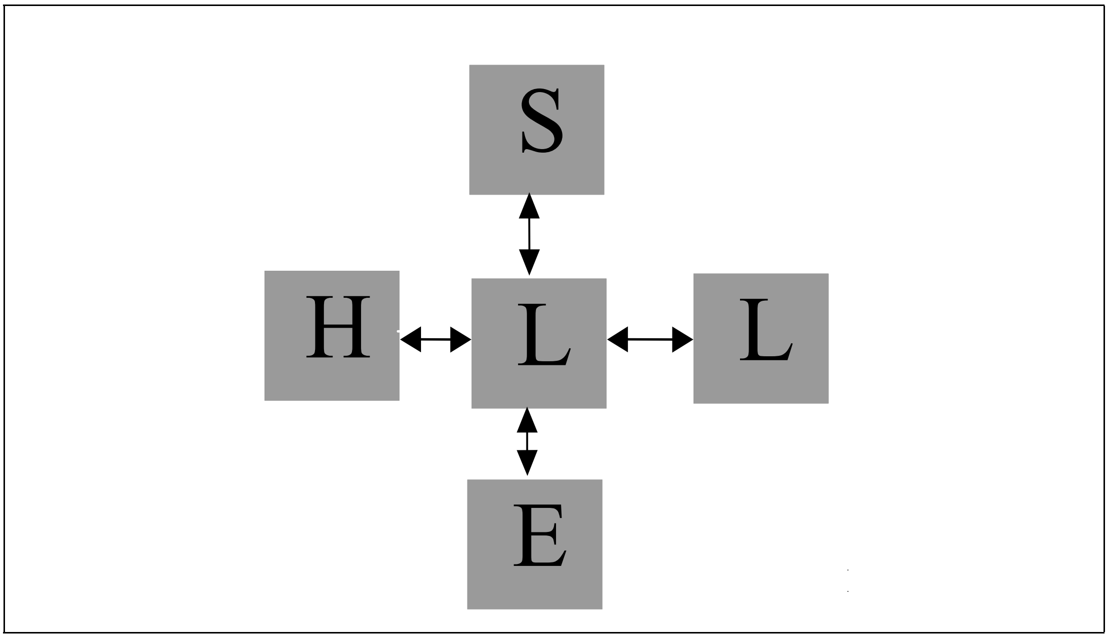

Figure 2 SHEL Model. Source: Edwards, 1972, modified by Hawkins, 1975. As referenced in ICAO Human Factors Digest No. 1; circular 216 (1989). ICAO.

1. ICAO (1989) Circular 216; Fundamental Human Factors Concepts; Human Factors Digest No.1. ICAO.
2. Hawkins, F.H. (1993) Human Factors in Flight. Gower

4.3 Many people use variants of the SHEL model, e.g. British Airways PEEP model (see Figure 3), the emphasis being upon the interfaces and integration between the technician and the aspects which affect his performance.

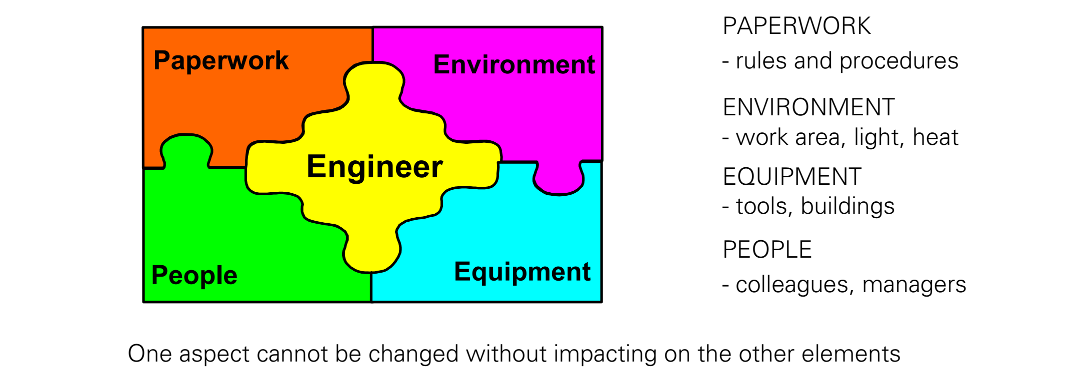

Figure 3 BA's PEEP model: an integrated approach

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

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

4.5 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 and regulators, to apply good human factors practices and principles within their own spheres of licence.

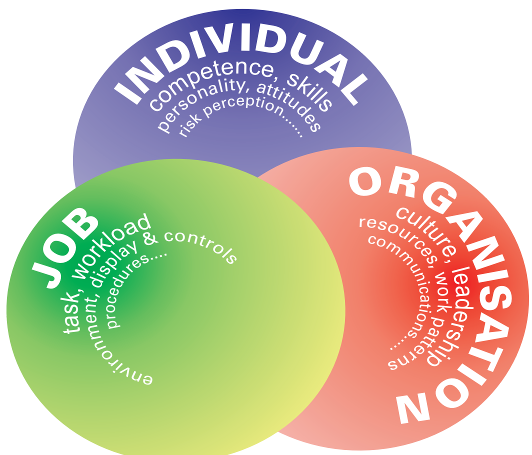

Figure 4 Factors influencing behaviour in the workplace. Source: HSE, HSG48 (1999) HSE Books.

Appendix B ICAO Standards for Human Factors in Maintenance

1.1 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:

1.2 "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."

1.3 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 9, 10 and 11 (correct as on May 1 2001). 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 9 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: Human performance and limitations e) Human performance and limitations relevant to the duties of an aircraft maintenance licence holder 4.2.1.4 Training Recommendation - the applicant should have completed a course of training appropriate to the privileges to be granted.

1.4 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.

1.5 The ICAO Annex 6 standards are the main 'requirements' from an organisational perspective.

Table 10 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.

Table 11 Annex 6 (Operations), part 3 SARPS

6.2.4.....The design and application of the maintenance manual shall observe Human Factors principles.
6.3.....The training programme established by an operator for maintenance personnel shall include training in knowledge and skills related to human performance, including co-ordination with other maintenance personnel and flight crew.
9.2....Maintenance Manual A maintenance manual provided in accordance with 6.2 shall contain the following information in respect of the helicopters used: a) procedures for servicing and maintenance: b) the frequency of each check, overhaul or inspection; c) the responsibilities of the various classes of skilled maintenance personnel; d) the servicing and maintenance methods which may be prescribed by, or which require the prior approval of, the State of Registry; and e) the procedure for preparing the maintenance release, the circumstances under which this release is to be issued and the personnel required to sign it.

NOTE: at the time of writing this CAP, an amendment was in progress to align the Annex 6, part 3 SARPS with Annex 6, part 1.

1.6 ICAO has published guidance material to assist organisations to implement the Annex I and Annex 6 SARPS.

Table 12 ICAO guidance material on human factors

Guidance material on the application of Human Factors principles can be found in: • ICAO. Human Factors Digest No. 1. Fundamental Human Factors Concepts (ICAO Circular 216) • ICAO. Human Factors Digest No. 6. Ergonomics. 1992 • ICAO. Human Factors Digest No. 12: Human Factors in Aircraft Maintenance and Inspection. 1995 Guidance material to design training programmes to develop knowledge and skills in human performance can be found in: • ICAO. Human Factors Digest No. 1. Fundamental Human Factors Concepts (ICAO Circular 216) • 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. 1992 • ICAO. Human Factors Digest No. 12: Human Factors in Aircraft Maintenance and Inspection. 1995

NOTE: These ICAO documents are being phased out of print, and replaced by the ICAO Human Factors Training Manual which includes the main elements from these documents. However, CAA versions of the digests were in preparation at the time of writing this document and should eventually be available for free download from the CAA internet site (see Appendix Y for details).

1.7 At the time of writing this document ICAO was also working on the production of two further initiatives likely to be of influence in maintenance:

- Publication of an ICAO document "Human Factors Guidelines for Aircraft Maintenance" - draft in preparation during 2001.
- Line Operations Safety Audit (LOSA) - an approach to collecting information on every day good and bad practice, as opposed to the more traditional emphasis upon basing remedial actions upon accident or incident data.

1.8 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 C Example Safety Policy

1.1 A safety 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.

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

1.3 The policy should be applied within the company.

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

Table 13 Example Safety Policy 1

It is our policy:

- to set our safety standards at or above the level required by the National Authority, JAA 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
- establish, and publish, management safety accountabilities

1.5 Further information on Safety Management Systems can be found in Appendix R.

1.6 Further information on disciplinary policy can be found in Appendices Q and E.

1.7 Further information on management safety accountabilities can be found in Appendix D.

Table 14 Example Safety Policy 2 (from the GAIN Operator's Flight Safety Handbook (2000) Issue 1. Available from www.gainweb.org)

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

Table 14 Example Safety Policy 2 (from the GAIN Operator's Flight Safety Handbook (2000) Issue 1. Available from www.gainweb.org)

Auditing & Measuring for Improvement

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

1.1 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.

1.2 Example wording is given below, for guidance:

Table 15 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 E Example Disciplinary Policy

1.1 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.

1.2 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 (suspended) 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 punitive 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.

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

1.4 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 tat the individual is fully aware of the implications of their actions, etc. Only in the worst case would dismissal be considered as appropriate action.

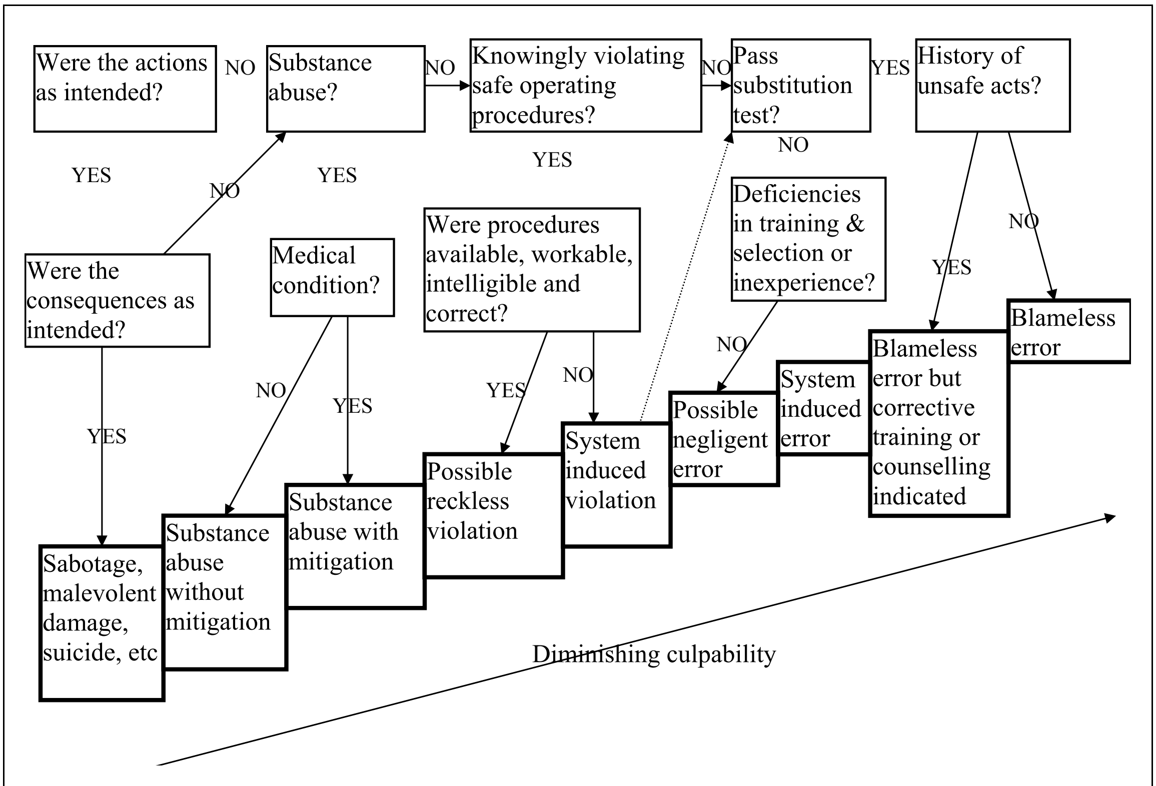

Figure 5 A decision tree for determining the culpability of unsafe acts. Reason (1990)

1.5 An organisation may wish to use Figure 5 as a guide when drawing up a disciplinary policy, whilst remembering what they are trying to achieve by ascertaining the degree of culpability - i.e., to prevent a re-occurrence of that incident, not to establish blame or to mete out punishment for its own sake.

1.6 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

a) Johnston, N. (Spring 1995) *Do blame and punishment have a role in organisational risk management?"*. Flight Deck. pp. 33-6.

b) Marx, D. "The link between employee mishap culpability and commercial aviation safety." http://hfskyway.faa.gov

c) Marx D. (1998) Discipline and the "blame-free" culture. Proceedings of the Twelfth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection.

Appendix F Incidents/ Accidents Where Maintenance Error was a Factor

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.aaib.gov.uk). Several of the major incidents and accidents where maintenance Human Factors have been a significant factor are summarised below:

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

1.1.1 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.

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

1.2.1 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.

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

1.3.1 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.

1.3.2 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.

1.3.3 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"[1], by Maurino et al.

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

1.4.1 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.

1.4.2 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.

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

1.5.1 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.

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

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

1.6.1 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[3] findings included:

a) "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".

b) "The 'OK to close' inspection of the pylon area was hampered by inadequate lighting and perceived dangers of the scaffolding".

1. Reason, D., Maurino, D., Johnston, N., Lee, R. Chapter 4: The BAC1-11 windscreen accident, *in* Beyond Aviation Human Factors. (1995) Avebury
2. AAIB report No: 2/95 - Airbus A320-212, at London Gatwick Airport, on 26 August 1993. Published in January 1995.
3. NTSB Special Investigation Report 94/02. Northwest Airlines, B747, N637US, New Tokyo International Airport, Narita, Japan, 1 March 1994.

c) "The CITEXT used by [the airline] was inadequate".

d) "The work environment for the heavy maintenance of the airplane was inadequate and contributed to an error-producing situation for the workers".

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

1.7.1 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.

1.7.2 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.

1.7.3 The full text of the investigation can be found in AAIB report 3/96[1] and in the AAIB website[2]. A detailed discussion of the incident can be found in Professor James Reason's book "Managing the Risks of Organizational Accidents"[3].

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

1.8.1 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.

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

1.9.1 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.

1.10 Lufthansa A320 incident, 20 March 2001[4]

1.10.1 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.

1. AAIB report No: 3/96 - Boeing 737-400, Near Daventry, on 23 February 1995. Published in July 1996.
2. www.open.gov.uk/aaib/aaibhome
3. Reason, J. (1997) Managing the Risks of Organisational Accidents. Ashgate.
4. Flight International Magazine, May 22-28 2001, p.14.

Further Reading:

a) ICAO Human Factors Training Manual. (1998) Doc 9683-AN/950. Chapter 6. (or ICAO Digest No.12.)

b) Reason, J. (Year) Managing the Risks of Organisational Accidents. Ashgate.

c) Maurino, D., Reason, J., Johnston, N., & Lee, R. (1995). Beyond Aviation Human Factors. Ashgate.

d) King, D. (March 1998) 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.

e) NTSB. (1989) Aircraft Accident Report--Aloha Airlines, Flight 243, Boeing 737-200, N73711, near Maui, Hawaii, April 28, 1988. NTSB 89/03

f) AAIB Report (1992) BAC 1-11 GBJRT Accident report 1/92

g) Reason, J. (Year) The BAC 1-11 windscreen accident, Chapter 4 in Maurino, D., Reason, J., Johnston, N., Lee, R. (1995) "Beyond Aviation Human Factors". (Publisher)

h) AAIB Report (1995) A320 GKMAM Accident report 2/95

i) AAIB Report (1996) B737 GOBMM Accident report 3/96

j) Lloyds Register Engineering Services (November 1995) Study into the potential for Human Error in the Maintenance of Large Civil Transport Aircraft. Report no R50003.1-2.

k) Trotte, B. (NTSB) (1989) Maintenance and inspection issues in aircraft accidents/ incidents, part I. Proceedings of the First Meeting on Human Factors Issues in Aircraft Maintenance and Inspection.

l) Danaher, J. (NTSB) (1989) Maintenance and inspection issues in aircraft accidents/ incidents, part II. Proceedings of the First Meeting on Human Factors Issues in Aircraft Maintenance and Inspection.

m) NTSB accident reports relating to maintenance. Available from http:// hfskyway.faa.gov

Appendix G Incident and Accident Analysis 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.

1 Proportion of accidents/ incidents related to maintenance:

1.1 Sears (1986)

1.1.1 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 16

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[1] 1986

1.2 Boeing study of commercial jet aircraft accidents (1982 –1991)[2]

1.2.1 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:

1. 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)
2. Boeing (1993). Accident Prevention Strategies: Commercial Jet Aircraft Accidents World Wide Operations 1982-1991.

- 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.

1.2.2 20% of the 232 accidents contained maintenance or inspection action as one of the prevention strategies.

1.3 Recent NTSB figures – (unpublished)

1.3.1 More recently (2000), it has been stated[1] that of the last 14 NTSB investigated large aircraft accidents, 7 of these have had maintenance as a major contributory factor (i.e. 50%), either 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.

2 Contributory factors in maintenance related accidents/ incidents

2.1 UK CAA maintenance MORs analysis (1992)[2]

2.1.1 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:

- 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

2.2 Boeing study (1993)[3]

2.2.1 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%)

1. Goglia, J. Unpublished statement at the 14th Human Factors in Aviation Maintenance Symposium. Vancouver, 2000, and Advances in Aviation Safety Conference, Daytona Beach, 2000.
2. UKCAA. Maintenance Error. Asia Pacific Air Safety. September 1992.
3. 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)

2.2.2 Professor James Reason[1] 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%)

2.3 Boeing study (1995) Graeber and Marx

2.3.1 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 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%).

2.4 AAIB paper[2] (1998)

2.4.1 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:

- 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

1. Reason, J. (1997) Managing the Risks of Organisational Accidents.
2. King, D. (March 1998) 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.

Further Reading:

a) ICAO Human Factors Training Manual. (1998) Doc 9683-AN/950. Chapter 6. (or ICAO Digest No.12.)

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

c) Marx, D.A. and Graeber, C. (Year) *Human Error in Aircraft Maintenance* (Publisher); Chapter 5 in Johnston, N., McDonald, N., Fuller, R. (Year) Aviation Psychology in Practice. (Publisher)

d) King, D. (March 1998) 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.

e) Trotter, B. (NTSB) (1989) Maintenance and inspection issues in aircraft accidents/ incidents, part I. Proceedings of the First Meeting on Human Factors Issues in Aircraft Maintenance and Inspection.

f) Danaher, J. (NTSB) (1989) Maintenance and inspection issues in aircraft accidents/ incidents, part II. Proceedings of the First Meeting on Human Factors Issues in Aircraft Maintenance and Inspection.

g) UK CAA (1991) *Flight Safety Occurrence Document, 92/D/12, 9 June 1992.* Cited in Hobbs, A. (March 1995) Human Factors in Airline Maintenance, Asia-Pacific Air Safety, Issue 8.

Appendix H The “Dirty Dozen”

The Maintenance and Ramp Safety Society refer to the major adverse influences on performance as “the dirty dozen” (see Table 17). (Posters depicting the “dirty dozen” may be obtained from www.marss.org).

Table 17 The “Dirty Dozen”

1. Lack of communication
2. Complacency
3. Lack of knowledge
4. Distraction
5. Lack of teamwork
6. Fatigue
7. Lack of parts
8. Pressure
9. Lack of assertiveness
10. Stress
11. Lack of awareness
12. Norms

The "dirty dozen" are encapsulated in a set of 12 posters, depicting cartoon scenarios showing what you should avoid and how to avoid it. These are as follows:

1 Lack of Communication

1.1 Lack of communication can be in the form of verbal or written or a combination of the two. The poster depicts leaving a panel undone and surmising that day shift can finish the job.

1.2 The safety nets:

a) Use logbooks, worksheets, etc. to communicate and remove doubt.

b) Discuss work to be done or what has been completed.

c) Never assume anything.

2 Complacency

2.1 Complacency is an insidious cause which with the constant repetition of many maintenance inspections can cause or contribute to an error in judgment. The poster depicts a maintenance person walking away from an aircraft which has a frayed cable behind a multi-screwed panel. He has signed the inspection sheet and is saying to himself "I've looked back there 1,000 times and never found anything wrong."

2.2 The safety nets are:

a) Train yourself to expect to find a fault.

b) NEVER sign for anything you didn't do.

3 Lack of Knowledge

3.1 In this ever changing world, Lack of Knowledge is not that uncommon a cause of an error in judgment. When coupled with the "Can-Do" attitude of most maintenance personnel, it becomes even more probable. The poster depicts a helicopter technician with a bent part in his hand saying, "This is the third one to bend! What's going on?"

3.2 The safety nets offered are:

a) Get training on type.

b) Use up to date manuals.

c) Ask a Tech. Rep. or someone who knows.

4 Distraction

4.1 This cause is thought to be responsible for about 15% of all maintenance errors. One leaves a task (both physically and/or mentally) for any reason and returns thinking that he/she is further along with the task then they are. The poster depicts a maintainer being called away from a job to answer a phone call from his wife.

4.2 The safety nets listed are:

a) Always finish the job or unfasten the connection.

b) Mark the uncompleted work.

c) Lockwire where possible or Torqueseal.

d) When you return to the job always go back three steps.

e) Use a detailed check sheet.

5 Lack of Teamwork

5.1 This cause is often tied in with lack of communication but can be responsible for major errors. With maintenance often involving a multitude of workers, good teamwork becomes essential. The poster depicts two persons guiding an aircraft in, in opposing directions. The caption says "I thought you wanted him to turn left right here!"

5.2 The safety nets call for:

a) Discuss what, who and how a job is to be done.

b) Be sure that everyone understands and agrees.

6 Fatigue

6.1 Fatigue is a very insidious cause because, until it becomes extreme, the person is usually unaware that he/she is fatigued. They are even less aware of what the effects of fatigue are. The poster depicts a person walking off the end of a horizontal stabilizer commenting that he is glad the double shift is over.

6.2 The fatigue safety nets call for:

a) Be aware of the symptoms and look for them in yourself and others.

b) Plan to avoid complex tasks at the bottom of your circadian rhythm.

c) Sleep and exercise regularly.

d) Ask others to check your work.

7 Lack of Resources

7.1 No matter who the maintainer works for, there are times when there is a lack of resources and a decision must be made between ground the aircraft or let it go. The average maintainer is a "Can-Do" type of person and takes great personal pride in repairing aircraft. Thus the decision to be made can be difficult. The poster depicts a maintainer standing in front of a helicopter with a skid on the right side and a float on the left. The caption says "We have nil stock of left skids so I guess this will have to do."

7.2 The safety nets are:

a) Check suspect areas at the beginning of the inspection and AOG the required parts.

b) Order and stock anticipated parts before they are required.

c) Know all available parts sources and arrange for pooling or loaning.

d) Maintain a standard and if in doubt ground the aircraft.

8 Pressure

8.1 Few industries have more constant pressure to see a task completed. The secret is the ability to recognize when this pressure becomes excessive or unrealistic. The poster depicts a captain looking at his watch as a maintainer rushes to close up a panel, with a line sticking out of it. The caption says "Hurry up or we're going to be late again!"

8.2 The safety nets to counteract this are:

a) Be sure the pressure isn't self-induced.

b) Communicate your concerns.

c) Ask for extra help.

d) Just say No.

9 Lack of Assertiveness

9.1 The average AME/AMT is not an assertive person and most of the time his job does not require him/her to be. However there may come a time when something is not right and he/she will have to be assertive in order to ensure the problem is not overlooked. The poster depicts a float plane leaking oil into the water and the aircraft owner telling the maintainer that he owns the aircraft and he says it's NOT a bad leak.

9.2 The counteracting safety nets offer:

a) If it's not critical, record it in the journey log book and only sign for what is serviceable.

b) Refuse to compromise your standards.

10 Stress

10.1 Stress is a normal part of every day life until it becomes excessive. The secret is to be able to recognize when it is becoming excessive. The poster depicts a maintainer pulling his tool rollaway, toward the propeller of a running engine. The caption says: "We lost our best aircraft! How are they going to pay my wages? What if I'm sued?"

10.2 Stress safety nets call for:

a) Be aware of how stress can effect your work.

b) Stop and look rationally at the problem.

c) Determine a rational course of action and follow it.

d) Take time off or at least have a short break.

e) Discuss it with someone.

f) Ask fellow workers to monitor your work.

g) Exercise your body.

11 Lack of Awareness

11.1 This often occurs to very experienced maintenance personnel who fail to think fully about the possible consequences of work they are doing. Manuals do not cover the failure and after the fact one will often hear that common sense should have told you that. The poster depicts a passenger flying forward in his seat and striking a bulkhead mounted fire extinguisher with his head. The caption says: "All the regulation said was, 'Install Where it is Easily Accessible."

11.2 The safety nets are:

a) Think of what may occur in the event of an accident.

b) Check to see if your work will conflict with an existing modification or repair.

c) Ask others if they can see any problem with the work done.

12 Norms

12.1 This last cause is a powerful one. Most people want to be considered one of the crowd and norms develop within such a group which dictates how they behave. The poster depicts an jet engine being installed with its pylon to the underwing of an aircraft. This is being done using a forklift and the caption says: "Never mind the Maintenance Manual. Its quicker the way we do it here."

12.2 The safety nets offered are:

a) Always work as per the instructions or have the instructions changed.

b) Be aware that "norms" don't make it right.

Appendix I Shiftwork and Fatigue

1 Shiftwork

1.1 The central problem in aviation maintenance is that many, perhaps most, routine tasks are performed during night-time hours, when people are more prone to errors, so that the aircraft can fly and produce revenue during the daytime. In addition, maintenance tasks often span more than one shift, requiring information to be passed from one shift to the next. Shift handover is the source of many errors.

1.2 The length of each work period also affects the error-producing effects of fatigue. In some industries, work periods are longer than in others. For example, workers in nuclear power plants are commonly scheduled to work 12-hour shifts. Whilst longer shifts may result in greater fatigue, the disadvantages may be offset by the fact that fewer shift changeovers are required (i.e. only 2 handovers with 2 twelve hour shifts, as opposed to 3 handovers with 3 eight hour shifts). However, if personnel rotate between shifts, shorter shifts may allow for greater flexibility in shift rotation, than longer shifts.

1.3 The EU Working Time Directive states:

> "...research has shown that the human body is more sensitive at night to environmental disturbances and also to certain burdensome forms of work organization and that long periods of night work can be detrimental to the health of workers and can endanger safety at the workplace."

NOTE: the reader is referred to the latest status of EU Directive 93/104/EC (see Appendix Y for the full wording of the original Directive). Although the EU legislation concerning working times currently exempts aviation, some European countries have anticipated the imminent expiry of this exemption and have provided working time restrictions through their National legislation. At the time of writing this document, the UK was not one of these countries.

1.4 The connections among shiftwork, morale, productivity and safety are not simple. The shift patterns which would appear to be the best 'scientifically', may be unpopular among workers and the poor morale which may arise if these are implemented may outweigh the benefits to the individual in terms of physiological adaptation. However, safety should always be the overriding factor when choosing shift patterns and rosters, taking into account all possible factors which may affect vulnerability to error. It is important that organisations and shift workers fully appreciate this.

1.5 From a human factors perspective, we are especially interested in shift- and schedule-related problems that are reflected in degraded maintenance performance. Listed below are some of the most common issues and problems which may occur. It is stressed that these issues and problems are neither necessarily nor entirely caused by shiftwork or scheduling. Many work-related and personal factors can contribute to most of the items described below.

- Higher Absentee Rate

  Particular shifts and schedules can cause workers to be away from work more often than people who work on more "normal" schedules. There are several factors that contribute to higher absenteeism. Shift workers tend to have more health problems than non-shift workers. A fairly innocuous cold, when coupled with the increased fatigue due to night work, can cause increased use of sick leave. Family-related issues, such as childcare and companionship, can cause workers to take short periods of time off. More serious incidents, such as an extended sickness in the family, can force shiftworkers to juggle their personal and work lives.

- Higher Error Rate

  Elevated error rates are directly associated with mental and physical fatigue. Shiftwork and shift schedules can contribute to fatigue by disrupting normal wake-sleep cycles, forcing extended working hours, and increasing personal and family-related stress. The first abilities to be compromised by fatigue are those related to cognitive processing, decision making, and judgement. Unfortunately, these are the very abilities that come into play when making safety-related maintenance decisions.

  In addition, the fact that aviation maintenance organisations tend to be 24-hour operations means that some tasks are inevitably distributed across multiple shifts. Poor shift turnover procedures, especially the communication aspect of shift turnover, has been implicated in a number of serious aviation accidents. The fatigue that accompanies working on the night shift causes shift handover procedures to assume added importance.

  The unavoidable fact is that most aviation maintenance occurs during night-time hours, which we know to be especially conducive to human error. There is nothing we can do to fundamentally alter human physical and psychological responses to night work, at least in the long term. We should expect, therefore, to experience many human errors and must tailor our procedures to provide ample opportunities to catch and fix these errors before they affect our workers or the flying public.

- Physical and Psychological Problems

  There are many studies linking shiftwork, especially rotating shiftwork and especially working at night, to a variety of physical, emotional, and psychological problems. Because aviation maintenance workers tend to be permanently assigned to a specific shift, it is reasonable to be concerned about the long-term effects of night work. Unfortunately, we have very few answers in this regard. We can't even say with certainty that working on the night shift causes the problems with which it is statistically associated.

  About the best we can do to address this issue is to provide coping processes that allow night-time workers to maintain a semblance of normal sleeping patterns and then closely monitor their physical and psychological conditions.

- Increased Injuries

  Most athletes understand that their risk of injury increases when they are tired or not paying attention. This is also true for industrial workers. Just as cognitive (thinking) errors increase with increased fatigue, so do physical errors, which result in personal injuries. All of the elements that we described above, such as loss of judgement, contribute to the increased likelihood that a worker will be injured.

- Dissatisfaction and Poor Morale

  The combination of long hours, disrupted wake-sleep cycles, increased instances of domestic conflict, and higher workloads is an obvious source of poor morale and dissatisfaction among shift workers. As a performance shaping factor, emotional issues are potent causes of poor job performance.

- Lower Productivity

  One of the primary reasons for working on shifts and longer hours on each shift is to utilise human and capital resources more efficiently. For example, expensive hangar and maintenance equipment isn't earning a return if it is idle. Also, working slightly longer shifts reduces the amount of non-productive time at the beginning and end of each shift. It is somewhat ironic that engaging in a practice that can increase productivity when used sparingly can actually decrease productivity when used excessively. To use an extreme example, people cannot produce twice as much output if they work 24 instead of 12 hours. Planning and production managers should take this into account.

- Higher Attrition Rate

  Humans can only take so much physical and mental stress. Many workers may opt to simply go elsewhere rather than endure a shift schedule that causes constant fatigue and family stress. It is costly and wasteful to lose skilled aviation maintenance workers.

  It is intended that this Appendix will be expanded at a later date with more detailed information. Until that time, readers are recommended to read the Chapter on shiftwork in Salvendy, G. Handbook of Human Factors and Ergonomics. A useful table has been extracted from this chapter, but should be used for guidance concerning the general principles only (see Table 18 below):

Table 18 Key issues regarding the design of a shift system

Number of consecutive night shifts • permanent night shifts can be hazardous and require special consideration and limitation • although open to debate, current research seems to point in favour of fewer (2-4) consecutive night shifts worked.
The scheduling of work • the length of a work shift should be dependent on the type of tasks being performed and workload on the job • excessive numbers of consecutive workdays (more than 8) should be scheduled with caution, and screening workers for physical and mental stress may be necessary. • There is no firm evidence supporting either direction; however, there seems to be some advantage to rotating schedules in a forward direction.
The scheduling of off-time • the purpose of off-time is to allow workers to recover from the fatiguing effects of work, to sleep and to socialise. Off-time ideally should be scheduled to allow all three activities to occur. • The amount of off-time should increase as does the number of consecutive workdays and the length of the work shifts increase. • A shift system should aim to maximise the amount of off-time between work shifts. • Travel time to and from work must be considered when scheduling off-time between work shifts. • For social reasons, shift systems should aim to include some weekend off-time for all workers.
Considerations for time of day • do not treat all hours of the day the same way. Acceptable daytime work shifts may prove to be excessive during the night. • Maximise the opportunity for workers to sleep during the night, Early morning shifts, for example, tend to lead to reductions in sleep length. • Consideration of psychosocial variables • keep the rotations schedules as regular as possible. It is ideal that a worker need not check the4 schedule each day to figure out whether he or she must work. • Whenever possible, allow for flexibility. This may include organisational designs such as flex time or simply allowing workers to exchange shifts with co-workers. • Minimise changes in shift schedules.

2 Fatigue

2.1 The term ‘fatigue’ has many meanings[1] and can include physical fatigue (e.g. muscle soreness, oxygen debt, or extreme tiredness caused by sleep deprivation, illness or poor nutrition), mental fatigue (e.g. associated with tasks demanding intense concentration, rapid or complex information processing and other high level cognitive skills) or emotional fatigue (the wearying effect of working under trying conditions or performing psychologically disagreeable tasks). There is often no clear distinction

1. Stokes, A., Kite, K. (1994) Flight Stress: Stress, Fatigue and Performance in Aviation. (Publisher)

between these types of fatigue, and it is probably more useful to look at fatigue in terms of the various criteria by which it is recognised.

2.2 The concept of fatigue is more easily understood through common experiences than through quantitative research. It is not possible to measure fatigue directly, as one might measure blood pressure or the length of a person's hand. Fatigue is indirectly measurable through its effects. For example, you can measure the number of errors committed per unit time on a particular task. If the person doing that task continues without rest long enough, the number of errors he or she commits increases. At some point, you would conclude that the person is fatigued. Working long hours, working during normal sleep hours, and working on rotating shift schedules all produce fatigue-like effects, although the mechanisms are different for each situation.

2.3 Symptoms of fatigue (in no particular order) may include:

- a lack of awareness
- diminished motor skills
- diminished vision
- slow reactions
- short-term memory problems
- channelled concentration - fixation on a single possibly unimportant issue, to the neglect of others and failing to maintain an overview
- easily distracted by unimportant matters, or, in the other extreme, impossible to distract
- increased mistakes
- poor judgement
- poor decisions, or no decisions at all
- abnormal moods - erratic changes in mood, depressed, periodically elated and energetic
- diminished standards

2.4 AWN 47 provides the following advice concerning fatigue:

> "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. …Individuals should be fully aware of the dangers of impaired performance due to these factors and of their personal responsibilities."

2.5 The best cure for acute fatigue is sleep - and this means restful sleep, not disturbed by the effects of alcohol or caffeine. Chronic long-term fatigue may take longer to eliminate, and may require professional advice.

2.6 At the time of writing this CAP, a CAA sponsored study, carried out by Professor Simon Folkard of University of Wales, Swansea, was looking into the issue of fatigue and shiftwork. One of the outcomes of that study is guidelines on shiftwork and fatigue. The reader is encouraged to read this report once issued.

3 Fatigue and Shiftwork Models

3.1 A few models have been developed, based on sound scientific principles and research, which attempt to highlight when workers are likely to reach unacceptable levels of fatigue. They generally require, as an input, roster details. The model developed by the Centre for Sleep Research (University of Southern Australia) is currently being trialled at Qantas maintenance. Further details can be obtained from www.unisa.edu.au/sleep and a demonstration copy of the fatigue model can be downloaded from www.interdyne.com.au

Further Reading:

a) AWN 47

b) ICAO Human Factors Training Manual (1998) Doc 9683-AN/950.

c) Maddox, M. (Ed) (1998) Personal And Job-Related Factors. Chapter 4. Human Factors Guide for Aviation Maintenance 3.0 (Publisher)

d) Ribak, J., Rayman, R.B., Froom, P. (1995) Occupational Health in Aviation: Maintenance and Support personnel. Chapter 5 (Publisher)

e) Smith, A.P., Jones, D.M. (Year) Handbook of Human Vol III Chapter 7. (Publisher)

f) Morgan, D. (1996) Sleep Secrets for shift workers and people with off-beat schedules. Whole Person Associates

g) Reed, A.T. (March 1993) Shift Wise: a shiftworker's guide to good health. Transport Canada. TP11658E.

h) CSR. Learning from others [shiftwork case studies]. University of South Australia. Centre for Sleep Research. Available from www.unisa.edu.au/sleep

i) CSR. Living with Shiftwork. University of South Australia. Centre for Sleep Research. Available from www.unisa.edu.au/sleep

j) CSR. Understanding Shiftwork. University of South Australia. Centre for Sleep Research. Available from www.unisa.edu.au/sleep

k) Fatigue management model – free demonstration version. Available from www.interdyne.com.au

l) Anon. Better Shift Systems? article in the Chemical Engineer, 11 September 1997, based on the work of Ronnie Lardner (Keil centre) and Bob Miles (HSE)

m) Caldwell, J.L. (1999) Managing Sleep for Night Shifts requires Personal Strategies. Flight Safety Foundation, Human Factors and Aviation Medicine, v46, No.2.

Appendix J Visual Inspection and NDI

1.1 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."

1.2 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 behaviours as listening, feeling, smelling, shaking, twisting, etc."

1.3 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[1], of New York State University at Buffalo[2], and others. The UK have also carried out research on both visual inspection and NDT, both the Cranfield[34] work and that carried out by AEA technology[5] concentrating upon the human factors aspects of inspection. A comparison[6] has been made of the US and UK research, the conclusion being that there is much common ground in the results obtained.

1.4 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 findings below featured in the accident report:

a) "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."

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

1. 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.
2. 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.
3. CAA (1985) Paper 85013. Reliability on In-Service Inspection of Transport Aircraft Structures. IUK Civil Aviation Authority.
4. Lock, M., Strutt, J. (1990) Inspection reliability for transport aircraft structures. CAA Paper 90003.
5. Murgatroyd, R., Worrall, G., Waites, C. (July 1994) A Study of the Human Factors Influencing the Reliability of Aircraft Inspection. AEA Report AEA/TSD/0173. (Summarised in CAA Paper 96010).
6. Murgatroyd, R., Worrall, G., Drury, C., Spencer, F. (Year) Comparison and Further Analysis of CAA and FAA Inspection Reliability Experiments. CAA Paper 96010.

1.5 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)[1] - see Table 19

Table 19 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 (i.e. AWN47) and NDT visual requirements (i.e. Jaeger No.1 and colour vision).

1.6 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, e.g. torch, mirror, penknife, hand lens, coin

1.7 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.

1.8 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 20).

1.9 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

1. The draft European Standard for the Qualification and Approval of Personnel involved in NDT (1994) prEN 4179

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 20 Potential strategies for improving aircraft inspection (visual and NDI). Source: FAA Phase I Progress report, 1991

	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

1.10 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

1.11 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, e.g. 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.

1.12 Feed-forward improves performance as it primes the inspector of known and potential defects in the inspection area.

1.13 Repetitive tasks, e.g. 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, e.g. on a new aircraft. Motivation and arousal are low without the reward of a defect.

1.14 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, e.g. a particular frame, lap joint, etc.

1.15 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.

1.16 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[1]. Training and experience may enable inspectors to improve performance in some areas, e.g. visual search strategy, and 'visual lobe size', i.e. 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 (http://hfskyway.faa.gov).

1.17 There is an excellent report which provides detailed and practical human factors related to penetrant dye techniques: *Human Factors Good Practices in Fluorescent 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:

a) Drury, C. (August 1999) Human Factors Good Practices in Fluorescent Penetrant Inspection. FAA. FAA (1992) Human Reliability in Aircraft Inspection. FAA/AAM (1992) Human Factors in Aviation Maintenance and Inspection Research Phase II Report, Chapter Five.

b) Drury, C. (1995) 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 available from http://hfskyway.faa.gov

c) Drury, C. (1996) Support of inspection research at the FAA Technical Centre and Sandia National Laboratories. FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase VI Report, Chapter 10.

d) Drury, C. (1992) Inspection Performance. In: Salvendy, G. (1997) Handbook of Industrial Engineering, 88. John Wiley and Sons.

e) NTSB. (1989) Aircraft Accident Report--Aloha Airlines, Flight 243, Boeing 737-200, N73711, near Maui, Hawaii, April 28, 1988. NTSB 89/03

1. 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 K Environmental Factors & Tooling

1 General

1.1 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.

1.2 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, e.g. undercarriage bays and engines.

1.3 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

2.1 The Joint Aviation Requirements (at the time of the production of this document) have attempted to address some of the environmental factors affecting performance.

> "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"

JAR 145.25 (c)

2.2 AMC 145.25(c) expands upon this as follows:

a) 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.

b) Temperatures should be maintained such that personnel can carry out required tasks without undue discomfort.

c) 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.

d) Lighting should be such as to ensure each inspection and maintenance task can be carried out.

e) 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.

f) 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.

g) 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.

h) 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.

2.3 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 JAR145 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:

a) Maddox M, Ed. (1998) Human Factors Guide for Aviation Maintenance 3.0. Chapter 5: Facility design.

b) Meghashyam, G. (1996) Electronic Ergonomic Audit System for Maintenance and Inspection. Proceedings of the Tenth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection.

c) Koli, S., Drury, C., Cuneo, J., Lofgren, J. (1995) Ergonomic audit for visual inspection of aircraft. Chapter 4, FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase IV Progress Report (1995). Available from http://hfskyway.faa.gov

d) Workley, F. (Manager Maintenance Operations, National Air Transportation Association) (1993) Environmental requirements of maintenance organisations. 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:

Meghashyam, G. (1996) Electronic Ergonomic Audit System for Maintenance and Inspection. (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 are available from 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.

3.1 Introduction to ERNAP

3.1.1 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.

3.2 The audit program

3.2.1 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.

3.2.2 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.

Table 21 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	

3.2.3 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

4.1 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.

4.2 Environmental conditions outside the comfort zones can affect performance directly (e.g. limiting manual dexterity in cold conditions, affecting concentration, etc.), or indirectly (e.g. 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.

4.3 There is little degradation 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.

4.4 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.

4.5 The UK legislation[1] 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".

1. HSC L24. Workplace (Health, safety and Welfare) Regulations, 1992. HMSO

Further Reading:

a) Health and Safety Commission. Workplace Health, Safety and Welfare; Approved Code of Practice. (1992) London HMSO. ISBN 0 111 886333 9

b) Health and Safety Commission Approved Code of Practice and Guidance L24.

c) Sanders, M., McCormick, E. (1993) Human Factors in Engineering and Design. Chapter 5.

d) Maddox M, Ed. (1998) Human Factors Guide for Aviation Maintenance 3.0. Chapter 3: Workplace Safety.

e) Salvendy, G. (1997) Handbook of Human Factors and Ergonomics. Chapter 28.

f) Smith, A.P., Jones, D.M. (1992) Handbook of Human Performance (Vol I - Physical environment - Chapters 4 and 5).

5 Noise

5.1 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.

5.2 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.

5.3 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, i.e. multiple riveting action during structural repair. Noise cannot be eliminated altogether.

5.4 Many studies have been carried out looking at what types of tasks are affected by noise, and what types of errors occur. One study[1], 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

5.5 Noise can affect motivation, reduce tolerance for frustration and reduce levels of aspiration. It can lead to the choice of certain strategies (e.g. 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

1. Levy-Leboyer, A and Moser, G. (1983) Noise effects on two industrial tasks. In: Proceedings of the 3rd International Congress on Noise as a Public Health Problem.

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!"?

5.6 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.

5.7 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.

5.8 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[1].

5.9 If noise levels are (likely to be) too high, the best remedial action is to mask the noise source (e.g. cover with noise proofing insulation) or move the noise source further away, preferably outside the hangar (see Table 22).

Table 22 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
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

5.10 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

1. Stranks, J. (2000) The Handbook of Health and Safety Practice, Edition 5. Pearson Education Ltd.

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:

a) JAR145.25(c) and AMC145.25 (c)

b) Maddox M, Ed. (1998) Human Factors Guide for Aviation Maintenance 3.0. Chapter 5: Facility design.

c) Smith, A. P., Jones, D. M. (1992) Handbook of Human Performance (Vol I - Physical environment - Chapter 1).

d) Salvendy, G. (1997) Handbook of Human Factors and Ergonomics. Chapter 24.

e) Sanders, M., McCormick, E. (1993) Human Factors in Engineering and Design. Chapter 18.

6 Illumination.

6.1 According to Drury et al[1], 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.

6.2 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/m^2 = 1 lux; 1 lumen/ ft^2 = 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/m^2 (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/m^2.

6.3 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 http://hfskyway.faa.gov) for further information. A methodology for evaluating the visual environment in inspection, extracted from the FAA Human Factors Guide, is contained in Appendix B.

6.4 The Illuminating Engineering Society recommends illumination levels for area and task lighting for different types of work and situations, e.g. 200 to 500 lux for task

1. 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) Available from http://hfskyway.faa.gov

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.

6.5 The UK Health and Safety Executive (HSE) publish guidance on lighting levels (see Table 23). Whilst this guidance is not specifically for aviation maintenance environments, parallels can be drawn with similar work environments.

Table 23 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 components, textile production	500	200

6.6 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 24 offers suggestions concerning ways to control the effects of glare sources.

Table 24 Techniques for Controlling Glare. Source: Adapted from Rogers, 1987

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.

6.7 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.

6.8 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.

6.9 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:

a) Kaufman, J.E., Haynes, H. Eds. (1981) IES Handbook Application Volume. Chapter 9. Illuminating Engineering Society of North America.

b) HSE (1997) Lighting at Work (HSG38). ISBN 0 7176 1232 5.

c) CIBSE Lighting Guide; the Industrial Environment (LG01) (1989) ISBN 0 900 953 38 1.

d) CIBSE Lighting Guide; the Outdoor Environment (LG06) (1992) ISBN 0 900 953 53 5.

e) Parker, J. (1991) The Work Environment in Aviation Maintenance. Human Factors Issues in Aircraft Maintenance and Inspection Meeting 5. Available from http://hfskyway.faa.gov

f) Maddox, M. Ed. (1998) Human Factors Guide for Aviation Maintenance 3.0. Chapter 5: Facility design available from http://hfskyway.faa.gov

g) Salvendy, G. (1997) Handbook of Human Factors and Ergonomics. Chapter 26. (Wiley Interscience)

h) Sanders, M., McCormick, E. (1993) Human Factors in Engineering and Design. Chapter 16. (McGraw-Hill)

i) Smith, A. P., Jones, D. M. (1992) Handbook of Human Performance (Vol I - Physical environment - Chapter 11). (Publisher)

j) Reynolds, J., Gramopadhye, A., Drury, C. (State University of New York at Buffalo, Department of Industrial Engineering) (1992) Design of the aircraft inspection/maintenance visual environment. Proceedings of the Seventh Meeting on Human Factors Issues in Aircraft Maintenance and Inspection.

Appendix L 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. Available from http://hfskyway.faa.gov

1 Introduction

1.1 The following information is extracted from a study by Drury et al[1], and represents guidance to develop a methodology which allows adequate lighting equipment to be selected in order to provide an improved visual environment.

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

1.3 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.

1.4 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.

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

2 Light Characteristics/Lighting System Design

2.1 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.

2.2 **Light Level**

2.2.1 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) (now at edition 9). Vision can be improved 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.

1. 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. Available from http://hfskyway.faa.gov

2.2.2 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.

2.2.3 Table 25 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 25 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

3 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 26 presents some of the commonly used lighting sources and their characteristics (adapted from Eastman Kodak, 1983).

Table 26 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.

4 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.

5 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 27 presents recommended surface reflective values to assist in obtaining an adequately uniform visual environment.

Table 27 Recommended Diffuse Reflective Values (Adapted from IES, 1987)

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

6 Specialised Lighting

6.1 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.

6.2 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.

7 Design Requirements For Lighting

7.1 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).

7.2 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.

7.3 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.

8 Guide for Visual Environment Evaluation

8.1 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.

a) 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.

Table 28 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 Power source	Weight/ size Accessories 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

b) 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 28). Requirements are given for both personal and portable lighting.

c) 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.

d) 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 29). The assessment of these considerations should result in additional improvements in the overall visual environment.

Table 29 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

8.2 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

a) Drury, C.G. and Fox, J.G. (Eds.) (1975) Human reliability in quality control. London: Taylor and Francis.

b) Drury, C.G., Prabhu, P.V. and Gramopadhye, A.K. (1990) Task analysis of aircraft inspection activities: Methods and findings. Proceedings of the Human Factors Society 34th Annual Meeting, 1181-1185.

c) Eastman Kodak (1983) Ergonomic design for people at work (Vol. I). Beshmart, CA: Lifetime Learning Publications.

d) Illuminating Engineering Society (1987) IES lighting handbook, application volume. New York: Illuminating Engineering Society.

e) Illuminating Engineering Society (1984) IES lighting handbook, reference volume. New York: Illuminating Engineering Society.

f) 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. Available from http://hfskyway.faa.gov

g) FAA/AANC Visual Inspection Research Program (VIRP). Drury, C. (1995) Chapter 9, FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase V Progress Report. Available from http://hfskyway.faa.gov

h) Reynolds, J., Gramopadhye, A., Drury, C. (State University of New York at Buffalo, Department of Industrial Engineering) (1992) Design of the aircraft inspection/maintenance visual environment. Proceedings of the Seventh Meeting on Human Factors Issues in Aircraft Maintenance and Inspection.

i) Koli, S., Drury, C., Cuneo, J., Lofgren, J. (1995) Ergonomic audit for visual inspection of aircraft. Chaper 4, FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase IV Progress Report. Available from http://hfskyway.faa.gov

j) Drury, C. (University at Buffalo) (1989) The Information Environment in Inspection. Proceedings of the Second Meeting on Human Factors Issues in Aircraft Maintenance and Inspection.

Appendix M 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

1.1 ‘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”.

1.2 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.

1.3 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.

1.4 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:

a) Maddox, M. Ed. (1998) Human Factors Guide for Aviation Maintenance 3.0. Chapter 13: Communication.

b) 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).

c) 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

2.1 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[1] 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".

2.2 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".

2.3 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.

2.4 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 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

1. AAIB report No:3/96 - Boeing 737-400, Near Daventry, on 23 February 1995.

> 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."

2.5 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".

2.6 AWN12, Appendix 53 was issued as a result of a serious incident[1] 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".

2.7 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".

2.8 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[2]. . . . . 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".

2.9 In October 1994 there was an incident[3] 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[4], in 1986), the results would have been catastrophic.

2.10 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 translation process, and that standard practices required by regulation (e.g. duplicate inspections) and control and management methods, correlate. A contributory factor in the B737 double engine oil loss incident[5] 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.

---

1. AAIB report No: 3/96 - Boeing 737-400, Near Daventry, on 23 February 1995.
2. Continental Express Flight 2574, Embrayer 120. NTSB accident report NTSB/AAR-92/04.
3. Incident, Chinook, GBWFC, Aberdeen Scotland, 25 October 1999.
4. AAIB report No: 2/88 - Accident to Boeing Vertol 234 LR, G-BWFC, off Sumburgh, Shetland Isles, 6 November 1986.
5. AAIB report No: 3/96 - Boeing 737-400, Near Daventry, on 23 February 1995.

2.11 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.

2.12 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.

2.13 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:

a) AWN3

b) AWN12, Appendix 52 and 53

c) Human Factors Digest No. 12: Human Factors in Aircraft Maintenance and Inspection. (ICAO Circular 253) (1995)

d) FAA/AAM (1993) Human Factors in Aviation Maintenance and Inspection Research Phase III Report; Chapter 7: Design of Workcards.

e) AAIB report on Incident to B737 near Daventry, 23 February 1995. AAIB report No 3/96.

3 Shift Handover

3.1 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 a Airbus A320 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.

3.2 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).

3.3 **Concepts**

3.3.1 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.

3.3.2 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.

3.3.3 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.

3.4 **Aids to effective communication at shift handover**

3.4.1 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.

3.5 **Barriers to effective communication at shift handover**

3.5.1 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:

- carefully specifying the information to be communicated e.g. by specifying the actual component, tooling or document.
- 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:

- emphasising the potential for miscommunication and its possible consequences
- developing the communication skills of people who are involved in shift handovers

3.6 **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.

3.7 **Shift Handover Meetings**

3.7.1 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.

3.7.2 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.

3.7.3 Table 30 lists the sort of topics that should be covered in the managers'/supervisors' handover meeting.

Table 30 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	ADs, SBs, etc. Company technical notices Company policy notices

3.7.4 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.

3.7.5 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.

3.8 Walkthroughs

3.8.1 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".

3.8.2 Table 31 lists the sort of topics that should be covered in the supervisors/certifying staff's walkthrough meeting.

Table 31 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

4.1 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.

4.2 Handing over a task directly to another person

4.2.1 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.

4.3 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.

4.4 Scheduled tasks

4.4.1 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.

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)	Mick Spencer	⑨ stamp
	b) With the flaps selected up, disconnect the operating link from one transmitter gearbox only.	Mick Spencer	⑨ stamp
	c) Pressurise the hydraulic system and select flaps down	Mick Spencer	⑨ stamp
	d) Make sure that the flaps start to move and then the system cuts out.	Mick Spencer	⑨ 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.		

Figure 6 Task Card

4.4.2 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. Figure 6 is an example of a Task Card.

4.4.3 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:

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).			

Figure 7 Supplementary card

4.4.4 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.

4.5 **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 JAR 145.50(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

5.1 Airworthiness Notice No. 12 Appendix No. 53 was issued as a result of a serious incident[1] 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.

5.2 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 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.

5.3 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.

5.4 This Section of the handbook describes the types of tasks that need Non-Routine Task Cards or Process Sheets, and what the goals are from a human factors perspective.

6 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.

1. AAIB report 2/95

Table 32 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

a) Maddox, M.E. (1998) FAA Human Factors Guide for Aviation Maintenance. Chapter 4 Shiftwork and Scheduling Guidelines.

b) Lardner, R. (1996) Offshore Technology Report - OTO 96 003. Effective Shift Handover - A Literature Review. Health and Safety Executive.

c) Miles, R. (UK Health And Safety Executive) (1998) Guidelines in producing an effective shift and task handover system. Proceedings of the Twelfth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection.

d) Department of Energy (1990) Conduct of operations requirements for DOE facilities, DOE 5480.19. Washington, DC.

e) Department of Energy (1993) Guide to good practices for operations turnover, DOE-STD-1038-93. Washington, DC.

f) Department of Energy (1993) Guide to good practices for shift routines and operating practices, DOE-STD-1041-93. Washington, DC.

g) 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 N Procedures and Work Instructions

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 5. 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.

1 Requirements Standards

1.1 The regulatory requirements for procedures are stated in JAR OPS 1.905, JAR 21, and in JAR 145.65.

2 Issues and Problems

2.1 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.

2.2 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.

3 Feedback Processes

3.1 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 11 discusses incident and problem area reporting and investigation systems, of which highlighting problems with procedures, manuals, etc., should be a part.

4 Guidance for the Design of Procedures

4.1 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 (e.g. 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.

4.2 Much work has been carried out concerning guidelines for good procedures design, and a list of the salient points can be found in Appendix O. 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.

5 FAA Document Design Aid (DDA).

5.1 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[1], summarises the main guidance material which exists.

1. Drury, C., Sarac, A., Driscoll, D. (1997) Documentation Design Aid Development. Chapter 4, FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase VII, Progress Report.

5.2 This project is not the first to bring together human factors research findings and good practice into codified guidelines. Simpson and Casey's[1] Developing Effective User Documentation come from the nuclear power industry, while Wright's Information Design[2] 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[3], 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[4]., and Patel, Prabhu and Drury (1992)[5] 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.

5.3 The main points from the DDA guidelines are summarised in Appendix O.

6 CARMAN

6.1 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.

7 AMPOS

7.1 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 manufacturer. This should enable problems with procedures to be identified and appropriate solutions to be implemented. Further details concerning AMPOS can be found in Appendix P.

---

1. Simpson, H. and Casey, S.M. (1988). Developing Effective User Documentation: A Human Factors Approach, New York: McGraw-Hill.
2. 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.
3. Missing reference?
4. Patel, S., Drury, C. G. and Lofgren, J. (1994). Design of workcards for aircraft inspection. Applied Ergonomics 1994, 25(5), pp. 283-293.
5. 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.

8 Conclusion

8.1 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

a) Documentation Design Aid. Available from http://hfskyway.faa.gov

b) Drury, C., Sarac, A., Driscoll, D. (1997) Documentation Design Aid Development. Chapter 4, FAA/AAM Human Factors in Aviation Maintenance and Inspection Research Phase VII, Progress Report. Available from http://hfskyway.faa.gov

c) Human Centred Management for Aircraft Maintenance. Report of the ADAMS work. 1999.

d) CAP676 (1997) Guidelines for the Presentation of Aircraft Checklists. UK Civil Aviation Authority.

e) Embrey, D. (1998) Creating a procedures culture to minimise risks using CARMAN. Proceedings of the Twelfth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection.

f) Embrey, D. (March 2000) Preventing Human Error: Developing a Consensus Led Safety Culture based on Best Practice. Proceedings of the Violations, Procedures and Human Factors conference, London.

g) (March 2000) Proceedings of the Violations, Procedures and Human Factors Conference, London.

Appendix O Guidelines for Writing Procedures

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.

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

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

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

c) Ensure procedures are accurate, appropriate and usable, and reflect best practice

d) 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.

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

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

g) Where appropriate, explain the reason for the procedure.

h) 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.

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

j) 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

k) ensure consistency in the design of procedures and use of terminology, abbreviations, references, etc.

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

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

n) 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.

o) 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.

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

q) 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.

r) 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).

s) 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.

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

u) Use emphasis (e.g. 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

v) 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

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

x) 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).

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

z) 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.

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

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

ac) Clearly link the check box with the associated step, e.g. using dotted lines.

ad) Allow enough space if information needs to be entered

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

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

ag) Provide training on the use of technology to access and print procedures and maintenance data

Further reading:

a) CAP676. (1997) Guidelines for the Design and Presentation of Emergency and Abnormal Checklists. UK Civil Aviation Authority.

Appendix P Aircraft Maintenance Procedure Optimisation System (AMPOS)

1.1 AMPOS is designed to provide a feedback loop of human factors based information to the critical personnel within the aircraft maintenance organisation and the aircraft manufacturer, interfacing with the existing communications technologies of these organisations. Continuous improvement and organisational learning will occur through the incorporation of this information into the work practices and documentation of both the maintenance organisation and the manufacturer. AMPOS is to be built on the identification of cases where the reporter identifies the possibility of some action to improve maintenance operations, procedures and processes, in relation to the goals of enhanced safety, reliability and efficiency.

1.2 However AMPOS is not simply a system for gathering information – it supports a continuous improvement process. Thus the core functionality of the system will be the transformation of the inputs into a process of change. This process should be cumulative (individual cases may often in themselves be hard to assess because of their specificities), it should provide both guidance for action and review of the effectiveness of that action. It should also provide the possibility of an overview of the 'health' or effectiveness of the system as a self-regulating optimisation process. AMPOS is an IT based system and is developing interfaces to integrate with existing technology in both the maintenance organisation and the aircraft manufacturer organisation.

1.3 Further information on AMPOS may be found on the website www.tcd.ie/aprg

Appendix Q CAA Airworthiness Notice 71: Maintenance Error Management Systems

AIRWORTHINESS NOTICE

No. 71

Issue 1

20 March 2000

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[1], 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.

1. CAP382, paragraph 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.

4.1.3 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.

4.1.4 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.

4.1.5 The CAA would expect that identified safety issues would be acted upon[1]. 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.

4.1.6 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.

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

Tel: 01293 573363
Fax: 01293 573987

1. 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.

Appendix R Safety Management Systems and (Human) Risk Assessment

1.1 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.

1.2 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.

1.3 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."

1.4 The identification of human risk areas can be difficult and time consuming. Four stages are necessary: (i) the identification of areas of potential risk (e.g. missing a crack during an inspection), (ii) identification of existing controls (e.g. duplicate inspections), and identification of (iii) probability of occurrence (e.g. likely, rare) and (iv) likely consequences (e.g. 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, including Human Reliability Assessment (HRA) 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, i.e. 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.

1.5 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.

1.6 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.

1.7 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.

1.8 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 (e.g. 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.

1.9 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.

1.10 There are several scientific techniques available which may assist with all or some of the stages of hazard identification and risk assessment, many of which were developed from the nuclear power and process control industries. These include:

a) The Technique for Human Error Rate Prediction (THERP)

b) Human Cognitive Reliability (HCR)

c) Time Reliability Correlations (TRC)

d) Human Error Assessment and Reduction Technique (HEART)

e) Success Likelihood Index Method (SLIM)

f) Influence Diagram Approach (IDA)

g) Absolute Probability Judgement (APJ)

h) Paired Comparisons (PC)

i) Technica Empirica Stima Errori Operatori (TESEO) (Empirical technique to estimate operator error)

j) Maintenance Personnel Perfomance simulator (MAPP)

k) Human Error Database (HED)

l) Tripod Delta

m) Tripod-Beta

n) REVIEW

o) Influence Diagram Methodology (IDM)

1.11 Further details about these techniques can be found in the document: HSE. Human Reliability Assessment – a Critical Overview; ACSNI Study Group on Human Factors, or in Professor Reason's book: Managing the Risks of Organisational Accidents. 1997.

1.12 Human Reliability Assessment is a logical part of the process of risk assessment, and may form part of the Safety Management process within an organisation. HRA should be carried out in a stepwise manner. Training, auditing, feedback and independent analysis can all improve the HRA process and results.

Further reading and contacts:

a) Reducing Error and Influencing Behaviour. HSG48, 2nd Edition. (1999) Chapters 3 and 5. HSE Books. ISBN 0 7176 2452 8

b) Human Reliability Assessment – a Critical Overview. (1991) ACSNI Study Group on Human Factors. HSE Books. ISBN 0 11 885695 2

c) Edwards, C. (1998) Managing Human Factors within a Safety Management System. Proceedings of the Twelfth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection.

d) Reason, J. (1997) Managing the Risks of Organisational Accidents. Ashgate.

e) UK Civil Aviation Authority (2000) 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.

1.13 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 S Human Factors Training Recommendations (from JAA MHFWG Report)

This text is taken directly from the JAA Maintenance Human Factors Working Group report, May 2001.

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. [The JAA MHFWG report] 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. [The JAA MHFWG report] 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 [the JAA MHFWG report] Guidance Material.

1.3 Finally [the JAA MHFWG report] 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

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

5.2 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.

8.2 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.

8.3 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.

8.4 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, e.g., 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, e.g., 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 (e.g. 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.

Appendix T Human Factors Training Syllabus (JAR145)

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

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
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
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 (e.g. investigation of incidents)

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
3.2		Types of errors in maintenance tasks	K: Understand the main error types (e.g. 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, e.g. 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, e.g. routine, situational, optimising. • Violation provoking situations, e.g.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, e.g. 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 (e.g. avionics, driving on airports, close visual inspection, etc), and in certain conditions (e.g. 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

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
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."
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 (e.g. 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, e.g. 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

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
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, e.g. 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
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, e.g. 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)

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
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 (e.g. 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 affecton 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 (e.g. 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 behavior 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
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

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
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, e.g. 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 ~~time management~~] skills.	• What constitutes workload; relationship between workload and stress; relationship between workload and arousal; overload and underload • Causes of high workload (e.g. 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

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
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 (e.g. noise insulation) and how protect hearing against noise (e.g. 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
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.

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
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.

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
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, e.g. 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
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.

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
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, e.g. Boeing and Airbus. • Formats of information (e.g. paper, photocopies, microfiche, computerised, etc) and their pros and cons. • Accidents/ incidents involving poor access to technical documentation, e.g. Narita 747 engine drop.
7	Communication		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 (e.g. on shift handover) to be communicated both verbally and in writing. • OJT + classroom exercises, e.g. 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, e.g. domino exercise • Accidents/ incidents involving shift handover deficiencies, e.g. 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, e.g. B737-400 oil loss incident. • Delegation, prioritisation of tasks • Leadership styles – use of authority or assertiveness

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
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.
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, (e.g. 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 (e.g. 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.

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
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
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.

No.	Topic	Subtopic	Objectives for initial Training	Examples for initial training Contents
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, e.g. 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. e.g. company magazine, feedback to individuals involved in incidents, etc

Appendix U Human Factors Knowledge Syllabus (JAR66-9)

Topic	**Subtopic**	**A**	**B1**	**B2**
GENERAL	The need to take human factors into account.	1	2	2
	Incidents attributable to human factors / human error.			
	"Murphy's law.			
HUMAN PERFORMANCE and LIMITATIONS.	Vision.	1	2	2
	Hearing.			
	Information processing.			
	Attention and perception.			
	Memory.			
	Claustrophobia and physical access.			
SOCIAL PSYCHOLOGY	Responsibility: individual and group	1	1	1
	Motivation and de-motivation			
	Peer pressure			
	Culture issues			
	Team working			
	Management, supervision and leadership			
FACTORS AFFECTING PERFORMANCE.	Fitness / health.	2	2	2
	Stress domestic and work related.			
	Time pressures and deadlines.			
	Workload overload and under load.			
	Sleep and fatigue, shift work.			
	Alcohol, medication, drug abuse.			

Topic	Subtopic	A	B1	B2
PHYSICAL ENVIRONMENT.	Noise and Fumes.	1	1	1
	Illumination.			
	Climate and temperature.			
	Motion and vibration.			
	Working environment.			
TASKS.	Physical work	1	1	1
	Repetitive tasks.			
	Visual inspection.			
	Complex Systems.			
COMMUNICATION.	Within and between teams.	2	2	2
	Work logging and recording.			
	Keeping up to date, currency.			
	Dissemination of information.			
HUMAN ERROR	Error models and theories.	1	2	2
	Types of error in maintenance tasks			
	Implications of errors (ie accidents)			
	Avoiding and managing errors			
HAZARDS in the WORKPLACE	Recognising and avoiding hazards	1	2	2
	Dealing with emergencies			

Appendix V Council Directive 93/104/EC, 23/11/93; Aspects of the Organisation of Working Time

Council Directive 93/104/EC of 23 November 1993 concerning certain aspects of the organization of working time

Official Journal L 307 , 13/12/1993 p. 0018 - 0024

Amendments:

Amended by **300L0034** (OJ L 195 01.08.2000 p.41)

Article 1

Purpose and scope

1. This Directive lays down minimum safety and health requirements for the organization of working time.

2. This Directive applies to:

(a) minimum periods of daily rest, weekly rest and annual leave, to breaks and maximum weekly working time; and

(b) certain aspects of night work, shift work and patterns of work.

3. This Directive shall apply to all sectors of activity, both public and private, within the meaning of Article 2 of Directive 89/391/EEC, without prejudice to Article 17 of this Directive, with the exception of air, rail, road, sea, inland waterway and lake transport, sea fishing, other work at sea and the activities of doctors in training;

4. The provisions of Directive 89/391/EEC are fully applicable to the matters referred to in paragraph 2, without prejudice to more stringent and/or specific provisions contained in this Directive.

Article 2

Definitions

For the purposes of this Directive, the following definitions shall apply:

1. working time shall mean any period during which the worker is working, at the employer's disposal and carrying out his activity or duties, in accordance with national laws and/or practice;

2. rest period shall mean any period which is not working time;

3. night time shall mean any period of not less than seven hours, as defined by national law, and which must include in any case the period between midnight and 5 a. m.;

4. night worker shall mean:

(a) on the one hand, any worker, who, during night time, works at least three hours of his daily working time as a normal course; and

(b) on the other hand, any worker who is likely during night time to work a certain proportion of his annual working time, as defined at the choice of the Member State concerned:

(i) by national legislation, following consultation with the two sides of industry; or

(ii) by collective agreements or agreements concluded between the two sides of industry at national or regional level;

5. shift work shall mean any method of organizing work in shifts whereby workers succeed each other at the same work stations according to a certain pattern, including a rotating pattern, and which may be continuous or discontinuous, entailing the need for workers to work at different times over a given period of days or weeks;

6. shift worker shall mean any worker whose work schedule is part of shift work.

Article 3

Daily rest

Member States shall take the measures necessary to ensure that every worker is entitled to a minimum daily rest period of 11 consecutive hours per 24-hour period.

Article 4

Breaks

Member States shall take the measures necessary to ensure that, where the working day is longer than six hours, every worker is entitled to a rest break, the details of which, including duration and the terms on which it is granted, shall be laid down in collective agreements or agreements between the two sides of industry or, failing that, by national legislation.

Article 5

Weekly rest period

Member States shall take the measures necessary to ensure that, per each seven-day period, every worker is entitled to a minimum uninterrupted rest period of 24 hours plus the 11 hours' daily rest referred to in Article 3.

The minimum rest period referred to in the first subparagraph shall in principle include Sunday.

If objective, technical or work organization conditions so justify, a minimum rest period of 24 hours may be applied.

Article 6

Maximum weekly working time

Member States shall take the measures necessary to ensure that, in keeping with the need to protect the safety and health of workers:

1. the period of weekly working time is limited by means of laws, regulations or administrative provisions or by collective agreements or agreements between the two sides of industry;

2. the average working time for each seven-day period, including overtime, does not exceed 48 hours.

Article 7

Annual leave

1. Member States shall take the measures necessary to ensure that every worker is entitled to paid annual leave of at least four weeks in accordance with the conditions for entitlement to, and granting of, such leave laid down by national legislation and/or practice.

2. The minimum period of paid annual leave may not be replaced by an allowance in lieu, except where the employment relationship is terminated.

Article 8

Length of night work

Member States shall take the measures necessary to ensure that:

1. normal hours of work for night workers do not exceed an average of eight hours in any 24-hour period;

2. night workers whose work involves special hazards or heavy physical or mental strain do not work more than eight hours in any period of 24 hours during which they perform night work.

For the purposes of the aforementioned, work involving special hazards or heavy physical or mental strain shall be defined by national legislation and/or practice or by collective agreements or agreements concluded between the two sides of industry, taking account of the specific effects and hazards of night work.

Article 9

Health assessment and transfer of night workers to day work

1. Member States shall take the measures necessary to ensure that:

(a) night workers are entitled to a free health assessment before their assignment and thereafter at regular intervals;

(b) night workers suffering from health problems recognized as being connected with the fact that they perform night work are transferred whenever possible to day work to which they are suited.

2. The free health assessment referred to in paragraph 1 (a) must comply with medical confidentiality.

3. The free health assessment referred to in paragraph 1 (a) may be conducted within the national health system.

Article 10

Guarantees for night-time working

Member States may make the work of certain categories of night workers subject to certain guarantees, under conditions laid down by national legislation and/or practice, in the case of workers who incur risks to their safety or health linked to night-time working.

Article 11

Notification of regular use of night workers

Member States shall take the measures necessary to ensure that an employer who regularly uses night workers brings this information to the attention of the competent authorities if they so request.

Article 12

Safety and health protection

Member States shall take the measures necessary to ensure that:

1. night workers and shift workers have safety and health protection appropriate to the nature of their work;

2. appropriate protection and prevention services or facilities with regard to the safety and health of night workers and shift workers are equivalent to those applicable to other workers and are available at all times.

Article 13

Pattern of work

Member States shall take the measures necessary to ensure that an employer who intends to organize work according to a certain pattern takes account of the general principle of adapting work to the worker, with a view, in particular, to alleviating monotonous work and work at a predetermined work-rate, depending on the type of activity, and of safety and health requirements, especially as regards breaks during working time.

Article 14

More specific Community provisions

The provisions of this Directive shall not apply where other Community instruments contain more specific requirements concerning certain occupations or occupational activities.

Article 15

More favourable provisions

This Directive shall not affect Member States' right to apply or introduce laws, regulations or administrative provisions more favourable to the protection of the safety and health of workers or to facilitate or permit the application of collective agreements or agreements concluded between the two sides of industry which are more favourable to the protection of the safety and health of workers.

Article 16

Reference periods

Member States may lay down:

1. for the application of Article 5 (weekly rest period), a reference period not exceeding 14 days;

2. for the application of Article 6 (maximum weekly working time), a reference period not exceeding four months.

The periods of paid annual leave, granted in accordance with Article 7, and the periods of sick leave shall not be included or shall be neutral in the calculation of the average;

3. for the application of Article 8 (length of night work), a reference period defined after consultation of the two sides of industry or by collective agreements or agreements concluded between the two sides of industry at national or regional level.

If the minimum weekly rest period of 24 hours required by Article 5 falls within that reference period, it shall not be included in the calculation of the average.

Article 17

Derogations

1. With due regard for the general principles of the protection of the safety and health of workers, Member States may derogate from Article 3, 4, 5, 6, 8 or 16 when, on account of the specific characteristics of the activity concerned, the duration of the working time is not measured and/or predetermined or can be determined by the workers themselves, and particularly in the case of:

(a) managing executives or other persons with autonomous decision-taking powers;

(b) family workers; or

(c) workers officiating at religious ceremonies in churches and religious communities.

2. Derogations may be adopted by means of laws, regulations or administrative provisions or by means of collective agreements or agreements between the two sides of industry provided that the workers concerned are afforded equivalent periods of compensatory rest or that, in exceptional cases in which it is not possible, for objective reasons, to grant such equivalent periods of compensatory rest, the workers concerned are afforded appropriate protection:

2.1. from Articles 3, 4, 5, 8 and 16:

(a) in the case of activities where the worker's place of work and his place of residence are distant from one another or where the worker's different places of work are distant from one another;

(b) in the case of security and surveillance activities requiring a permanent presence in order to protect property and persons, particularly security guards and caretakers or security firms;

(c) in the case of activities involving the need for continuity of service or production, particularly:

(i) services relating to the reception, treatment and/or care provided by hospitals or similar establishments, residential institutions and prisons;

(ii) dock or airport workers;

(iii) press, radio, television, cinematographic production, postal and telecommunications services, ambulance, fire and civil protection services;

(iv) gas, water and electricity production, transmission and distribution, household refuse collection and incineration plants;

(v) industries in which work cannot be interrupted on technical grounds;

(vi) research and development activities;

(vii) agriculture;

(d) where there is a foreseeable surge of activity, particularly in:

(i) agriculture;

(ii) tourism;

(iii) postal services;

2.2. from Articles 3, 4, 5, 8 and 16:

(a) in the circumstances described in Article 5 (4) of Directive 89/391/EEC;

(b) in cases of accident or imminent risk of accident;

2.3. from Articles 3 and 5:

(a) in the case of shift work activities, each time the worker changes shift and cannot take daily and/or weekly rest periods between the end of one shift and the start of the next one;

(b) in the case of activities involving periods of work split up over the day, particularly those of cleaning staff.

3. Derogations may be made from Articles 3, 4, 5, 8 and 16 by means of collective agreements or agreements concluded between the two sides of industry at national or regional level or, in conformity with the rules laid down by them, by means of collective agreements or agreements concluded between the two sides of industry at a lower level.

Member States in which there is no statutory system ensuring the conclusion of collective agreements or agreements concluded between the two sides of industry at national or regional level, on the matters covered by this Directive, or those Member States in which there is a specific legislative framework for this purpose and within the limits thereof, may, in accordance with national legislation and/or practice, allow derogations from Articles 3, 4, 5, 8 and 16 by way of collective agreements or agreements concluded between the two sides of industry at the appropriate collective level.

The derogations provided for in the first and second subparagraphs shall be allowed on condition that equivalent compensating rest periods are granted to the workers concerned or, in exceptional cases where it is not possible for objective reasons to grant such periods, the workers concerned are afforded appropriate protection.

Member States may lay down rules:

- for the application of this paragraph by the two sides of industry, and

- for the extension of the provisions of collective agreements or agreements concluded in conformity with this paragraph to other workers in accordance with national legislation and/or practice.

4. The option to derogate from point 2 of Article 16, provided in paragraph 2, points 2.1. and 2.2. and in paragraph 3 of this Article, may not result in the establishment of a reference period exceeding six months.

However, Member States shall have the option, subject to compliance with the general principles relating to the protection of the safety and health of workers, of allowing, for objective or technical reasons or reasons concerning the organization of work, collective agreements or agreements concluded between the two sides of industry to set reference periods in no event exceeding 12 months.

Before the expiry of a period of seven years from the date referred to in Article 18 (1) (a), the Council shall, on the basis of a Commission proposal accompanied by an appraisal report, re-examine the provisions of this paragraph and decide what action to take.

Article 18

Final provisions

1. (a) Member States shall adopt the laws, regulations and administrative provisions necessary to comply with this Directive by 23 November 1996, or shall ensure by that date that the two sides of industry establish the necessary measures by agreement, with Member States being obliged to take any necessary steps to enable them to guarantee at all times that the provisions laid down by this Directive are fulfilled.

(b) (i) However, a Member State shall have the option not to apply Article 6, while respecting the general principles of the protection of the safety and health of workers, and provided it takes the necessary measures to ensure that:

- no employer requires a worker to work more than 48 hours over a seven-day period, calculated as an average for the reference period referred to in point 2 of Article 16, unless he has first obtained the worker's agreement to perform such work,

- no worker is subjected to any detriment by his employer because he is not willing to give his agreement to perform such work,

- the employer keeps up-to-date records of all workers who carry out such work,

- the records are placed at the disposal of the competent authorities, which may, for reasons connected with the safety and/or health of workers, prohibit or restrict the possibility of exceeding the maximum weekly working hours,

- the employer provides the competent authorities at their request with information on cases in which agreement has been given by workers to perform work exceeding 48 hours over a period of seven days, calculated as an average for the reference period referred to in point 2 of Article 16.

Before the expiry of a period of seven years from the date referred to in (a), the Council shall, on the basis of a Commission proposal accompanied by an appraisal report, re-examine the provisions of this point (i) and decide on what action to take.

(ii) Similarly, Member States shall have the option, as regards the application of Article 7, of making use of a transitional period of not more than three years from the date referred to in (a), provided that during that transitional period:

- every worker receives three weeks' paid annual leave in accordance with the conditions for the entitlement to, and granting of, such leave laid down by national legislation and/or practice, and

- the three-week period of paid annual leave may not be replaced by an allowance in lieu, except where the employment relationship is terminated.

(c) Member states shall forthwith inform the Commission thereof.

2. When Member States adopt the measures referred to in paragraph 1, they shall contain a reference to this Directive or shall be accompanied by such reference on the occasion of their official publication. The methods of making such a reference shall be laid down by the Member states.

3. Without prejudice to the right of Member States to develop, in the light of changing circumstances, different legislative, regulatory or contractual provisions in the field of working time, as long as the minimum requirements provided for in this Directive are complied with, implementation of this Directive shall not constitute valid grounds for reducing the general level of protection afforded to workers.

4. Member States shall communicate to the Commission the texts of the provisions of national law already adopted or being adopted in the field governed by this Directive.

5. Member States shall report to the Commission every five years on the practical implementation of the provisions of this Directive, indicating the viewpoints of the two sides of industry.

The Commission shall inform the European Parliament, the Council, the Economic and Social Committee and the Advisory Committee on Safety, Hygiene and Health Protection at Work thereof.

6. Every five years the Commission shall submit to the European Parliament, the Council and the Economic and Social Committee a report on the application of this Directive taking into account paragraphs 1, 2, 3, 4 and 5.

Appendix W Maintenance Error Decision Aid (MEDA) Concepts

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

1 The MEDA Philosophy

1.1 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 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.

1.2 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).

1.3 **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.

1.4 **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.

1.5 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.

2 The MEDA Process

2.1 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.

2.1.1 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.

2.1.2 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.

2.1.3 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.

2.1.4 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.

2.1.5 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.

2.2 **Management Resolve**

2.2.1 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:

a) Appoint a manager in charge of MEDA and assign a focal organization.

b) Decide which events will initiate investigations.

c) Establish a plan for conducting and tracking investigations.

d) Assemble a team to decide which prevention strategies to implement.

e) Inform the maintenance and engineering workforce about MEDA before implementation.

2.2.2 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.

3 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

a) Rankin, W., Allen, J., Sargent, R. (April-June 1996) Boeing introduces MEDA: Maintenance Error Decision Aid.. Airliner.

b) Allen J., Rankin W, Sargent, B. Human Factors Process for Reducing Maintenance Errors. Available from www.boeing.com/commercial/aeromagazine/aero_03/textonly/m01txt.html

c) Marx, D. The link between employee mishap culpability and commercial aviation safety. Available from http://hfskyway.faa.gov

d) Marx, D. (1998) Discipline and the "blame-free" culture. Proceedings of the Twelfth Meeting on Human Factors Issues in Aircraft Maintenance and Inspection.

e) Marx, D. (January 1998) Learning from our mistakes: A review of Maintenance Error Investigation and Analysis Systems. On: FAA CD ROM "Human Factors in Aviation Maintenance and Inspection: Ten years of Research and Development" (1999) , and *http://hfskyway.faa.gov*

f) 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.

g) 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.

Appendix X Maintenance Error Decision Aid (MEDA) Form

Section I -- General	
Reference #: ___ ___ ___ ___ ___	Analyst Name ________________________
Airline: ____	Analyst Telephone #: ____________
Station of Error: _____________________________________	Date of Investigation: __/ __ / __
Aircraft Type: _______________________________________	Date of Event: __ __/ __ __/ __ __
Engine Type:____	Time of Event: _ _ : _ _
Reg. #: ___ ___ ___ ___ ___ ___ ___	Shift of Error :
Fleet Number: ___ ___ ___ ___ ___ ___	Type of Maintenance :
Department/ML________________________________	1. Line--IF Line, what type?
ATA #: ___ ___ ___ ___	2. Base--IF Base, what type?
Aircraft Zone: _______________________________________	
Customer Ref. #: ___ ___ ___ ___ ___	Date Changes Implemented __/__/__

Section II -- Event

A. Please select the Event

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

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

Section III -- Maintenance Error

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

1. Improper Installation	( ) **3. Improper/ Incomplete Repair** (explain below)	**6. Actions Causing Equipment Damage**
( ) a. Required equipment not installed		( ) a. Equipment used improperly
( ) b. Wrong equipment/part installed	**4. Improper Fault Isolation/Inspection/Testing**	( ) b. Defective equipment used
( ) c. Wrong orientation	( ) a. Degradation not found	( ) c. Struck by/against
( ) d. Improper location	( ) b. Access panel not closed	( ) d. Other (explain below)
( ) e. Incomplete Installation	( ) c. System or equipment not deactivated/reactivated	
( ) f. Extra parts installed	( ) d. Not properly tested	**7. Actions Causing Personal Injury**
( ) g. Access panel not closed	( ) e. Fault not properly isolated	( ) a. Muscle strain
( ) h. System/equipment not reactivated/deactivated	( ) f. Not properly inspected	( ) b. Hazard contacted
( ) i. Damaged	( ) g. Other (explain below)	( ) c. Slip/Trip/Fall
( ) j. Other (explain below)		( ) d. Hazardous substance exposure
	5. Actions Causing Foreign Object Damage	( ) e. Improper use of personal protective equipment
2. Improper Servicing	( ) a. Material left in airplane/engine	( ) f. Caught in/on/between
( ) a. Insufficient fluid	( ) b. Debris on ramp	( ) g. Other (explain below)
( ) b. Too much fluid	( ) c. Debris falling into open systems	
( ) c. Wrong fluid type	( ) d. Other (explain below)	**8. Other** (explain below)
( ) d. Required servicing not performed		
( ) e. Other (explain below)		

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

Section IV -- Contributing Factors Checklist

N/A___

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

__ a. Not understandable
__ b. Unavailable/Inaccessible
__ c. Incorrect
__ d. Too much/conflicting information
__ e. Update process is too long/complicated
__ f. Incorrectly modifying manufacturer's MM/SB
__ g. Information not used
__ h. Other (explain below)

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

N/A______

2. Equipment/Tools/Parts

__ a. Unsafe
__ b. Unreliable
__ c. Poor layout of controls or displays
__ d. Mis-calibrated
__ e. Unavailable
__ f. Inappropriate for the task
__ g Can't use in intended environment
__ h. No instructions
__ i. Too complicated
__ j. Incorrectly labeled
__ k. Not used
__ l. Other (explain below)

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

N/A__________

3. Aircraft design/configuration/ parts

__ a. Complex
__ b. Inaccessible
__ c. Aircraft configuration variability
__ d. Parts unavailable
__ e. Parts incorrectly labeled
__ f. Easy to install incorrectly
__ g. Other (explain below)

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

N/A__________

4. Job/Task

__ a. Repetitive/monotonous
__ b. Complex/confusing
__ c. New task or task change
__ e. Different from other similar tasks
__ f. Other (explain below)

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

N/A______

5. Technical Knowledge/Skills

__ a. Inadequate skills
__ b. Inadequate task knowledge
__ c. Inadequate task planning
__ d. Inadequate airline process knowledge
__ e. Inadequate aircraft system knowledge
__ f. Other (explain below)

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

N/A______

6. Factors Affecting Individual Performance.

__ a. Physical health (including hearing and sight) __ f. Body size/strength
__ b. Fatigue __ g. Personal event (e.g., family problem, car accident)
__ c. Time constraints __ h. Workplace distractions/interruptions during task performance
__ d. Peer pressure
__ e. Complacency __ j. Other (explain below)

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

N/A_________

7. Environment/Facilities

__ a. High noise levels __ f. Snow __ k. Hazardous/toxic substances
__ b. Hot __ g. Lighting __ l. Power sources
__ c. Cold __ h. Wind __ m. Inadequate ventilation
__ d. Humidity __ i. Vibrations __ n. Other (explain below)
__ e. Rain __ j. Cleanliness

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

N/A_________

8. Organisational factors

__ a. Quality of support from technical organizations (e.g., engineering, planning, technical pubs) __ d. Union action
__ e. Corporate change/ restructuring
__ b. Company policies __ f. Other (explain below)
__ c. Company work processes

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

N/A________

9. Leadership/Supervision

__ a. Poor planning/organisation of tasks __ d. Unrealistic attitude/expectations
__ b. Inadequate prioritisation of work __ e. Amount of supervision
__ c. Inadequate delegation/assignment of task __ f. Other (explain below)

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

N/A__________

10. Communication

__ a. Between departments __ e. Between lead and management
__ b. Between technicians __ f. Between flight crew and maintenance
__ c. Between shifts __ g. Other (explain below)
__ d. Between maintenance crew and lead

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

N/A_______

11. Other Contributing factors (explain below)

Describe specifically how this <u>other</u> factor contributed to the error.

Section V.a – Error Prevention Strategies

A. What current existing procedures, processes, and/or policies in your organisation were 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) ____________________

Section V.b- Immediate and Long Term corrective actions

B. List recommendations for error prevention strategies. (list each recommendation as a separate line item along with the responsible manager and a projected completion date for the corrective action)

MEDA results form revision f 7/31/98

Appendix Y Sources of Further Information

1.1 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.

1.2 Many of these documents can be found on the FAACDROM "Human Factors in Aviation Maintenance and Inspection: Ten years of Research and Development" (1999). The full contents of this CDROM and many more documents, can be found on the website http://hfskyway.faa.gov

Table 33 Key documents

Document	website reference
Human Factors Guide for Aviation Maintenance. Version 3.0 (1998). Editor. Dr. Michael Maddox.	http://hfskyway.faa.gov
ICAO Human Factors Training Manual - Doc 9683-AN/950. 1998	
ATA Specification 113 for Maintenance Human Factors Program Guidelines (1999) Air Transport Association	www.air-transport.org/ public/publications/ 57.asp
People, Practices and Procedures in Aviation Engineering and Maintenance: A Practical Guide to Human Factors in the Workplace. 1999.	www.raes-hfg.com/ xmaintsg.htm
Human-Centred Management Guide for Aircraft Maintenance: Aircraft Dispatch and Maintenance Safety (ADAMS). (2000)	www.tcd.ie
MRM Handbook.	http://hfskyway.faa.gov
GAIN. Operator's Flight Safety Handbook. Issue 1. June 2000.	www.gainweb.org
"Every Day" – video.	www.ifairworthy.org/ thevideo.htm
"Engineering Solutions to Human Problems" - videos and training package.	www.ifairworthy.org/ thevideo.htm
Human Factors Process for Reducing Maintenance Errors. Allen J., Rankin W, Sargent _B.	www.boeing.com/ commercial/ aeromagazine/aero_03/ textonly/m01txt.html
Discipline and the "blame-free" culture. Marx D.	http://hfskyway.faa.gov
Learning from our mistakes: A review of Maintenance Error Investigation and Analysis Systems. Marx D Jan 1998.	http://hfskyway.faa.gov
Documentation Design Aid.	http://hfskyway.faa.gov
Electronic Ergonomic Audit System for Maintenance and Inspection (ERNAP).	http://hfskyway.faa.gov
Improving Compliance with Safety Procedures: Reducing Industrial Violations. 1995. Health & Safety Executive.	www.hsebooks.co.uk/ homepage.html

Table 33 Key documents

Document	website reference
HSE. Reducing Error and Influencing Behaviour. HSG48, 2nd Edition, 1999. HSE Books.	www.hsebooks.co.uk/ homepage.html
HSE. Improving Maintenance: a guide to reducing human error. HFRG. 2000. HSE Books	www.hsebooks.co.uk/ homepage.html
Drury, C. Human Factors Good Practices in Flourescent Penetrant Inspection. FAA. August 1999.	http://hfskyway.faa.gov
AECMA Simplified English Guide for the Preparation of Aircraft Maintenance Documentation	
CAP455 Airworthiness Notices. AWN47. UKCAA.	
CAP455 Airworthiness Notices. AWN71. UKCAA.	
CAP712 Safety Management Systems for Commercial Air Transport Operations. 2001	
CAP676 Guidelines for the design and Presentation of Emergency and Abnormal Checklists. 1997.	
CAP 715 An Introduction to Aviation Maintenance Human Factors for JAR66. 2001	

Table 34 Key books to read

Key books to read
Reason, J. (1990) Human Error. Cambridge University Press. *ISBN 0-521-31419-4*
Reason, J. (1997) Managing the Risks of Organisational Accidents. Ashgate. *ISBN 1-84014-105-0*
Maurino, D., Reason, J., Johnston, N., & Lee, R. (1995) Beyond Aviation Human Factors. Ashgate. *ISBN 0-291-39822-7*

Table 35 Key websites (*** denotes particularly useful, at the time of writing this report)

www.air-transport.org	Air Transport Association of America
www.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.chirp.co.uk	Confidential Human Factors Incident Reporting scheme
www.faa.gov	FAA
www.gainweb.org	Global Aviation Information Network
www.galaxyscientific.com	Galaxy Scientific
http://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
www.hse.gov.uk	Health and Safety Executive
www.icao.int	ICAO
www.ifairworthy.org	International Federation of Airworthiness
www.jaa.nl	JAA – note: part 1 regulatory material only
www.jrc.it	European Joint Research Centre
www.marss.org ***	Maintenance and Ramp Safety Society – from where you can order the MARSS videos and "dirty dozen" posters.
www.ntsb.gov	National Transportation Safety Board
www.nlr.nl	Dutch National Aerospace Laboratory
www.open.gov.uk/aaib	Air Accidents Investigation Branch
www.raes.org.uk	Royal Aeronautical Society
www.raes-hfg.com	Royal Aeronautical Society Human Factors Group – with up-to-date links to maintenance human factors websites and documents
www.srg.caa.co.uk	UK CAA Safety Regulation Group
www.tcd.ie	Trinity College Dublin – for information on ADAMS, STAMINA, AMPOS, SCARF, AITRAM.
www.tc.gc.ca	Transport Canada