Safety Regulation Group

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Aircraft Maintenance Incident Analysis

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Foreword

The research reported in this Paper was funded by the Safety Regulation Group (SRG) of the UK Civil Aviation Authority (CAA), and was performed by DHAC-Avia Ltd. The original study, reported in CAA Paper 2007/04, was commissioned in response to the increasing prevalence of maintenance issues as causal or contributory factors in aircraft accidents.

This Paper comprises an updated version of CAA Paper 2007/04, extending the study period by one year to end 2006. Overall, the conclusions of the previous study are unchanged, except that an increasing trend in the total number of maintenance related MORs is now apparent.

SRG accepts the findings of the study and the recommendations are to be addressed via its Aircraft Maintenance Survey Department Human Factors Team.

Safety Regulation Group
June 2009

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Executive Summary

The objective of this study was to analyse a selection of maintenance related events on jet aircraft above 5,700kg MTOW, captured and stored under the requirements of the CAA's Mandatory Occurrence Reporting (MOR) scheme to identify trends, themes and common causes or factors.

A pilot study was conducted in 2005 with a subset of the data in order to facilitate the development of a taxonomy with which to classify these maintenance events. Three first level maintenance error types were established and the data further classified in terms of second level descriptors.

This report covers the main study where the taxonomy was applied to the 3,982 maintenance related MORs for the period January 1996 to December 2006. In the results, just over half of the occurrences analysed were attributed to incorrect maintenance actions, a quarter to ineffective maintenance control and a fifth to incomplete maintenance.

ATA Chapter headings were allocated to the data and the frequency of the top three headings concurred with an earlier CAA review and with the pilot study with the exclusion of Chapter 79 (Oil). The data showed that the vast majority of MORs were related to Chapter 25 (Equipment and Furnishings), escape slides in particular.

The study concludes that the number of maintenance related MORs as a percentage of the total number of MORs for aircraft over 5,700kg MTOW submitted to the CAA appears to decrease steadily from 1997 to 2003. This reduction may, in part, be attributable to the extensive efforts of the CAA to promote human factors awareness training, guidance and policy within the industry during this time. From 2004 the percentage has levelled at approximately the same value due to the increase in the total number of MORs being matched proportionately by an increase in the number of maintenance-related MORs. This coincides with the JAR 145 requirement for every maintenance organisation to manage maintenance errors, which may explain the increase in the number of maintenance-related MORs submitted.

Recommendations based upon the findings have been made and include improving the consistency and comprehensiveness of data captured to facilitate future trend analysis, and identification of the underlying causes of maintenance error.

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Report Aircraft Maintenance Incident Analysis

1 Introduction

1.1 The UK CAA determined to analyse the maintenance error related data, captured and stored under the requirements of the Mandatory Occurrence Reporting (MOR) scheme, with the objective of identifying common causes or factors, addressing them, and thereby reducing the associated safety risk.

1.2 A pilot study was conducted in 2005 in order to facilitate the development of a taxonomy with which to classify these maintenance events. This study was limited to 312 of the latest closed MORs featuring maintenance error on jet aircraft above 5,700kg MTOW.

1.3 This report covers the main study where a larger data set was analysed using the taxonomy devised in the pilot study. The analysis included 3,982 maintenance error MORs for jet aircraft above 5,700kg MTOW, submitted to and closed by the CAA between 1st January 1996 and 31st December 2006.

1.4 The purpose of this follow-on study was two-fold. Firstly, there was a need to test the validity of the taxonomy by establishing how well it would perform with a much larger data set. Secondly, the analysis of the MORs would identify any emergent themes or trends.

1.5 In addition, the study included a review of all high risk MORs for jet aircraft over 5,700kg MTOW, between 1st January 1996 and 31st December 2006, for any maintenance error contribution. In addition to classifying these MORs using the taxonomy, the existing AAIB investigations and reports into the events were reviewed to determine contributing factors and underlying causes that were captured by the AAIB but generally not included in the MORs.

1.6 A Microsoft Access database containing the 3,982 events, coded and classified in accordance with the taxonomy, forms a deliverable to the CAA under this project.

2 Data

2.1 The data set comprised 3,982 MORs that had been closed by the CAA from the date range 1st January 1996 to 31st December 2006. The scope of the study was deliberately restricted to larger fixed-wing jet transport aircraft in order to maintain due focus. All MORs provided by the CAA featured jet aircraft above 5,700kg MTOW and were considered by CAA to be maintenance related.

2.2 The following information was provided for each Occurrence Report:

- Aircraft type;
- Occurrence number;
- Occurrence grade classification (from April 1996);
- Occurrence date;
- Operator/maintainer;
- Registration of aircraft;
- Engine type;
- Flight phase (since January 2004);
- Event descriptor;
- Executor;
- Pretitle;
- Précis of the event and investigation;
- Location (where appropriate).

2.3 A further data set of 335 closed MORs covering all types of occurrences, classified by the CAA as high risk, were supplied by CAA for review within the date range 1st January 1996 to 31st December 2006. All maintenance-related MORs identified in the pilot study had been classified as low risk. The purpose of this exercise was to establish any maintenance error contribution to more serious occurrences that might be overlooked due to maintenance error not being regarded as the primary cause.

2.4 Reports associated with aircraft types no longer on the UK register (i.e. L1011, DC10 and MD80) and those reported as having occurred on foreign registered aircraft were excluded from both sections of the study.

3 Methodology

3.1 Background

3.1.1 The pilot study reported that a search of the human error literature identified a number of existing aircraft maintenance error taxonomies including Boeing's Maintenance Error Decision Aid (MEDA - Rankin et al, 2000), Human Factors Analysis and Classification System – Maintenance Extension (HFACS-ME - Weigmann and Shappell, 1997) and ICAO ADREP 2000. The two most commonly cited maintenance error taxonomies in the literature are Boeing's MEDA (Rankin et al, 2000) and Shappell and Wiegmann's HFACS-ME (Shappell and Wiegmann, 2001).

3.1.2 There are many similarities in terms of basic constructs and underlying causes of maintenance human error. Where they differ is in terminology and structure of data collection. While both MEDA and HFACS-ME consider errors and violations, MEDA was originally designed to investigate errors only, but was amended to include violations in 2001 in the light of experience gained and industry feedback. This amendment was never validated by Boeing and is not yet widely used by Industry, with many preferring to remain with the original MEDA process (Revision f). Furthermore, MEDA classifies violations as an organisational contributing factor (second level descriptor), and therefore does not attempt to capture the underlying cause of the procedure violation.

3.1.3 The strength of these classification methodologies lies in capturing detailed and in-depth data at the time of the incident investigation. These methodologies are less useful for retrospective application to existing data, such as the review of CAA MOR data covered in this report, where the opportunity to revisit the event is not available.

3.2 Taxonomy

3.2.1 The low level of detail in the MOR maintenance occurrence reports was instrumental in the decision to develop a new taxonomy based on a retrospective analysis of MORs. The taxonomy generated by the pilot study was based on the data sample provided. It involved reviewing all the events and associated information to determine how best they could be meaningfully categorised. Given the limited content of the MORs it was not possible to gain the depth of detail that would be possible through the application of MEDA or HFACS-ME. However, both of these taxonomies were developed to be used proactively to investigate maintenance incidents as opposed to analysing data retrospectively.

3.2.2 In addition to the information supplied by the CAA, further parameters were added to the database to identify the specific ATA Chapter associated with the area of the aircraft where the event occurred, the maintenance error type and the second level descriptor. An error code, combining the maintenance error type and the second level descriptor, was also included as a convenient reference during the analysis.

3.2.3 A number of occurrences were removed from the data set as they were considered to fall outside the scope of the study in terms of their correlation with maintenance error. In total, 698 occurrences were eliminated from the study. Component failure accounted for 207 occurrences, 5 were events involving aircraft excluded from the study (L1011, DC10 and a Sikorsky S76 helicopter), and the remaining 486 were removed as they were either non-maintenance events, no maintenance error was described in the report, or because there was insufficient information to determine whether the event was maintenance related. A list of eliminated occurrences has been passed to the CAA.

3.2.4 The resulting data set of 3,284 occurrences was analysed in accordance with the taxonomy developed during the pilot study and categorised as:

- **Maintenance Control** – An event attributed to an ineffective maintenance control system.
- **Incomplete Maintenance** – An event where the prescribed maintenance activity is prematurely terminated. In these circumstances the correct maintenance procedures appear to have been followed but something was not removed, not fitted or not set correctly towards the end of the process.
- **Incorrect Maintenance Action** – An event where the maintenance procedure was completed but did not achieve its aim through the actions or omissions of the maintainer. In these circumstances it appears that an incorrect maintenance procedure or practice was being used. This has resulted in a larger number of second level descriptors than Incomplete Maintenance, but includes the actions of not removing, not fitting or not setting something correctly by virtue of not performing the task correctly, rather than as an error of omission.

3.2.5 Further analysis of each event was conducted to determine the second level descriptors and to allocate an ATA Chapter. Definitions of the second level descriptors are contained in Appendix 2. Figure 1 below illustrates the relationship between the maintenance error type and second level descriptors.

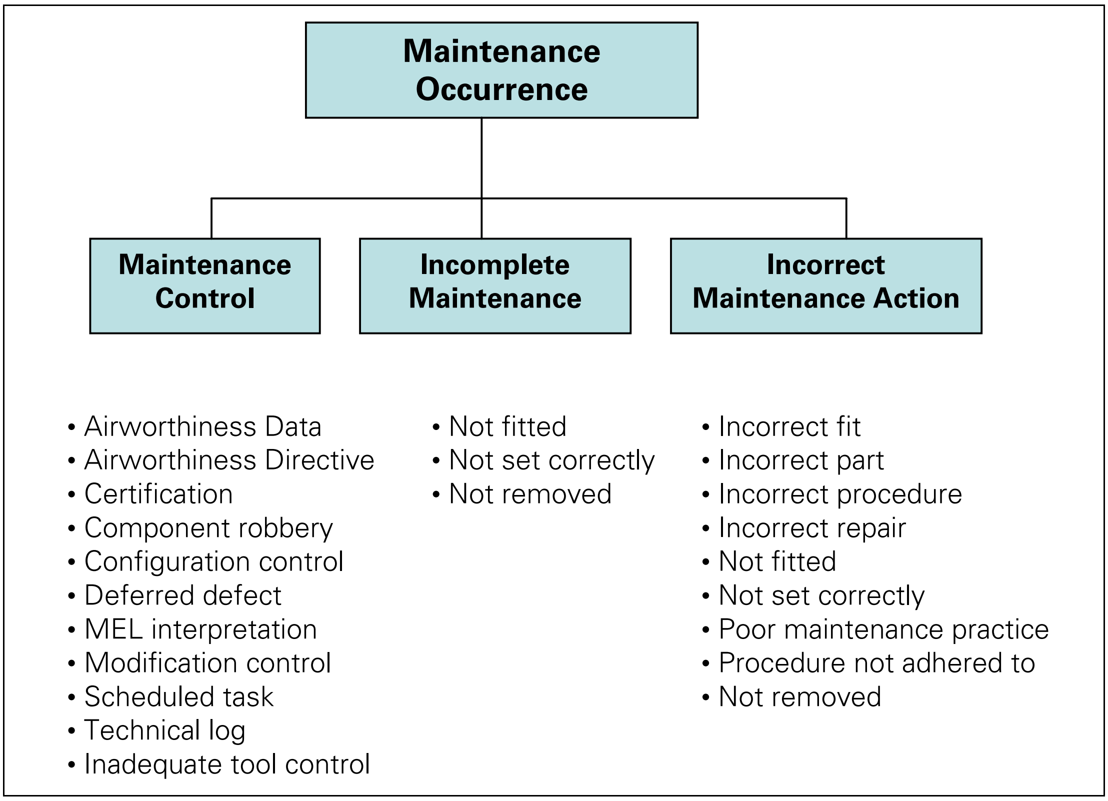

Figure 1 Maintenance Error Type and Second Level Descriptors

3.3 High Risk Occurrences

3.3.1 From the 335 high risk occurrences, only 21 were determined to have maintenance error as a contributing or causal factor.

3.3.2 All of these 21 occurrences were subjected to the same analysis as the main set of MORs. In addition, the nine that were the subject of AAIB investigations were reviewed in greater detail, and three of these were subject to the Boeing MEDA analysis.

4 Analysis of Main MOR Data Set

4.1 Maintenance Error Types

4.1.1 A review of the entire 3,982 MOR data set divided the MORs into the first level maintenance error types and identified the occurrences to be excluded as shown in Figure 2.

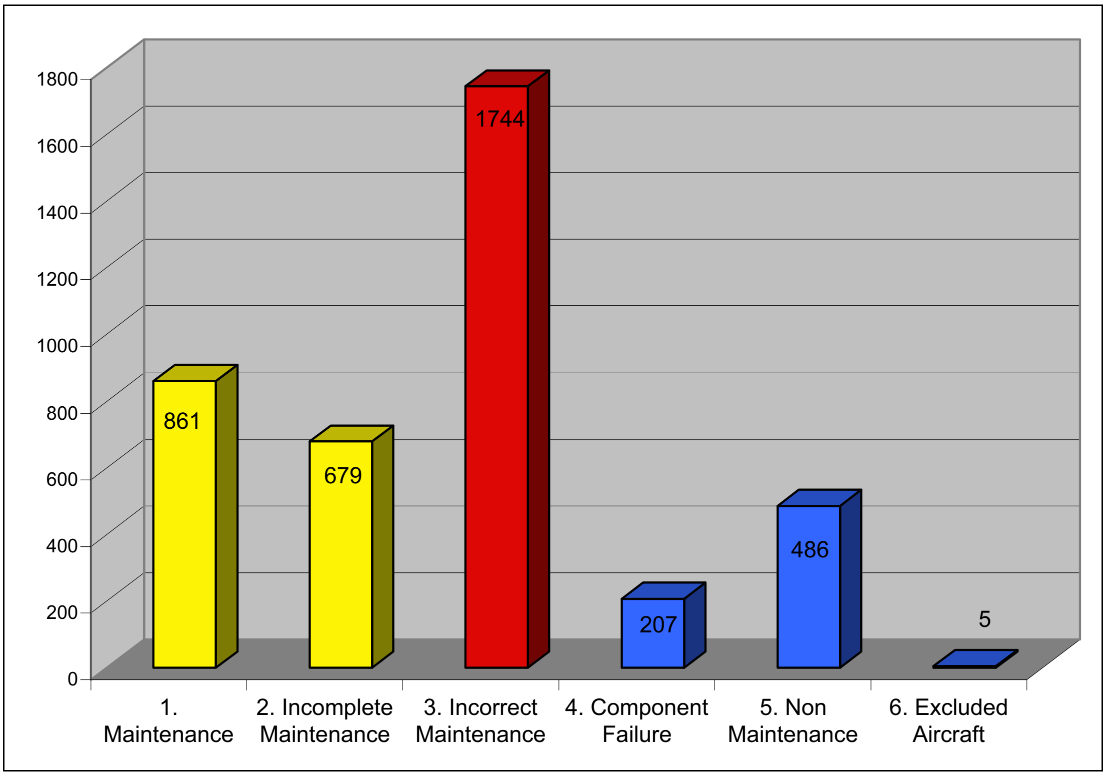

Figure 2 Breakdown of 3,982 Maintenance Error MORs

4.1.2 Having removed the 698 excluded occurrences, subsequent analysis of the remaining 3,284 occurrences provided the breakdown of second level descriptors, in terms of the number of occurrences and the percentage relative to the particular maintenance error type.

Maintenance Control:

Scheduled task	265	30·8%
Deferred defect	94	10·9%
Airworthiness data	92	10·7%
Inadequate tool control	89	10·3%
Tech log	75	8·7%
Airworthiness Directive	73	8·5%
MEL interpretation	56	6·5%
Modification control	56	6·5%
Configuration control	41	4·8%
Certification	14	1.6%
Component robbery	6	0·7%
Total	**861**	

Incomplete Maintenance:

Not fitted	308	45·4%
Not set correctly	254	37·4%
Not removed	117	17·2%
Total	**679**	

Incorrect Maintenance Action

Incorrect fit	666	38·2%
Not set correctly	493	28·3%
Incorrect part	172	9·9%
Poor maintenance practice	108	6·2%
Procedure not adhered to	90	5·2%
Not fitted	88	5·0%
Incorrect repair	72	4·1%
Incorrect procedure	30	1·7%
Not removed	25	1·4%
Total	**1744**	

4.2 ATA Chapter Headings

4.2.1 General

4.2.1.1 The data was further interrogated to provide descriptive statistics for the number of occurrences per ATA Chapter heading as shown in Figure 3.

4.2.1.2 The "none applicable" entries in Figure 3 fall into the following three categories:

- Where multiple ATA Chapter headings were involved without one obviously taking precedence;
- Where the ATA Chapter heading could not be determined;
- Where events were essentially compliance related, for example, Airworthiness Directive (AD) overruns and transposition of Tech Logs.

4.2.1.3 The analysis of data relating to ATA Chapter headings identified the top three most frequent as:

1. Equipment and Furnishings (ATA 25) 18·27%
2. Landing Gear (ATA 32) 10·6%
3. Flight Controls (ATA 27) 8·59%

4.2.1.4 It should be noted that when Chapters 71 through to 80 relating to Engines were combined, the resultant figure equated to 14·89% of the data thereby making engine maintenance second only to Equipment and Furnishings in terms of frequency.

4.2.1.5 Further analysis of each of the three most frequently recurring ATA Chapter headings revealed the breakdown shown in Figures 4 to 7.

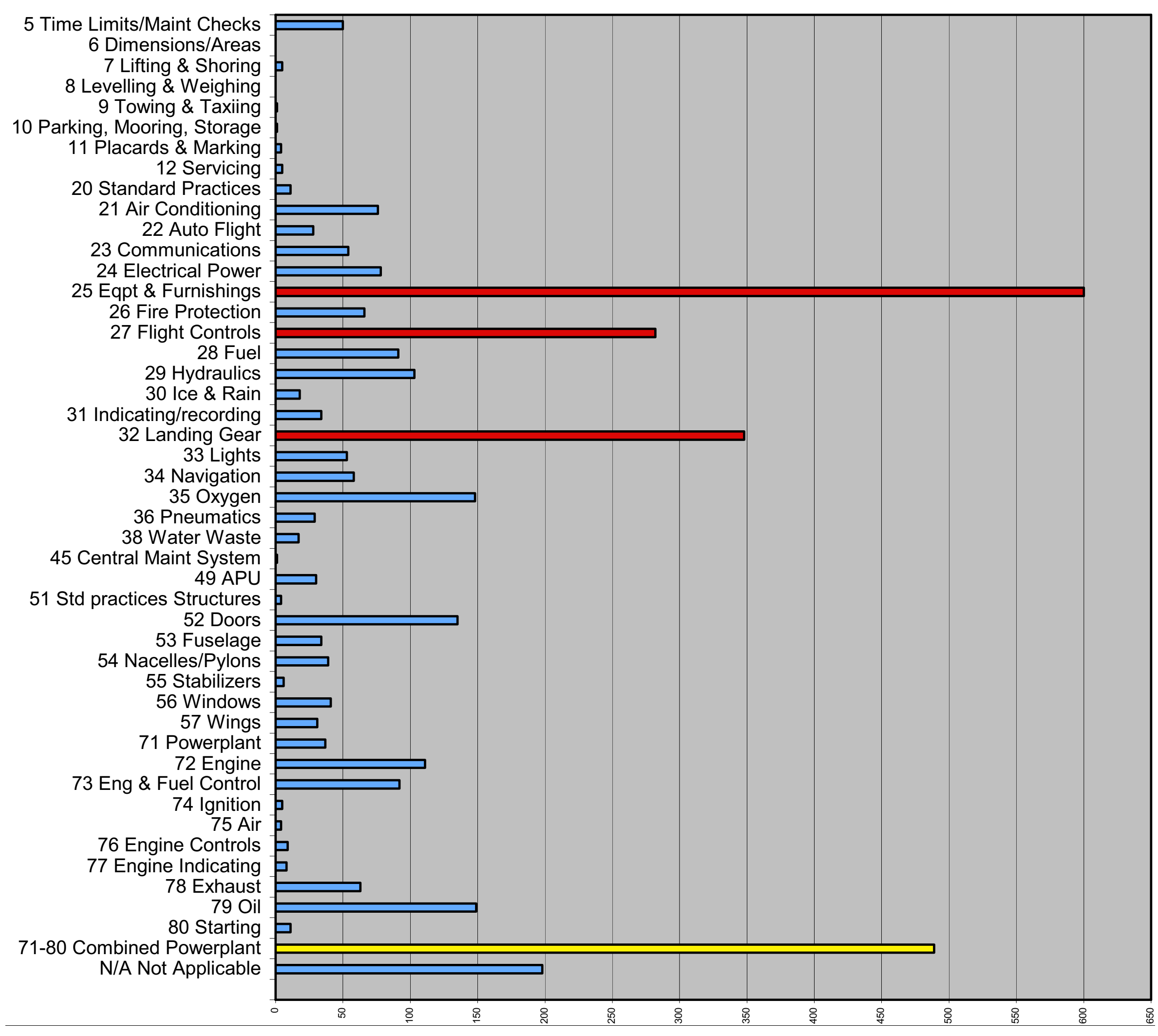

Figure 3 Breakdown of 2924 MORs by ATA Chapter

4.2.2 **ATA Chapter 25 (Equipment and Furnishings)**

4.2.2.1 A breakdown of the MORs associated with Equipment and Furnishings (ATA 25) is presented in Figure 4.

4.2.2.2 While there are a large number of different problems with Equipment and Furnishings, by far the most common problem is with Escape Slides accounting for 44% of the occurrences in ATA 25. Cabin Dividers were a particular problem that one operator had and generated 67 occurrences between 1996 and 2004. Issues relating to passenger seats were mainly associated with inadequate attachment to the aircraft structure.

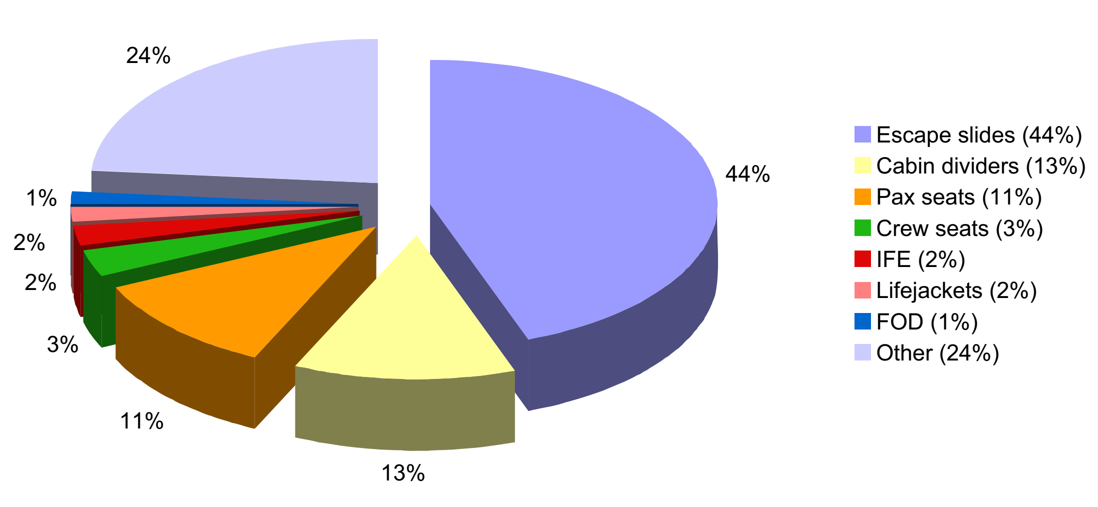

Figure 4 Breakdown of ATA 25 - Equipment and Furnishings

4.2.3 **ATA Chapter 32 (Landing Gear)**

4.2.3.1 Problems associated with ATA 32 Landing Gear were fairly evenly divided between wheels, gear and brakes as shown in Figure 5 below.

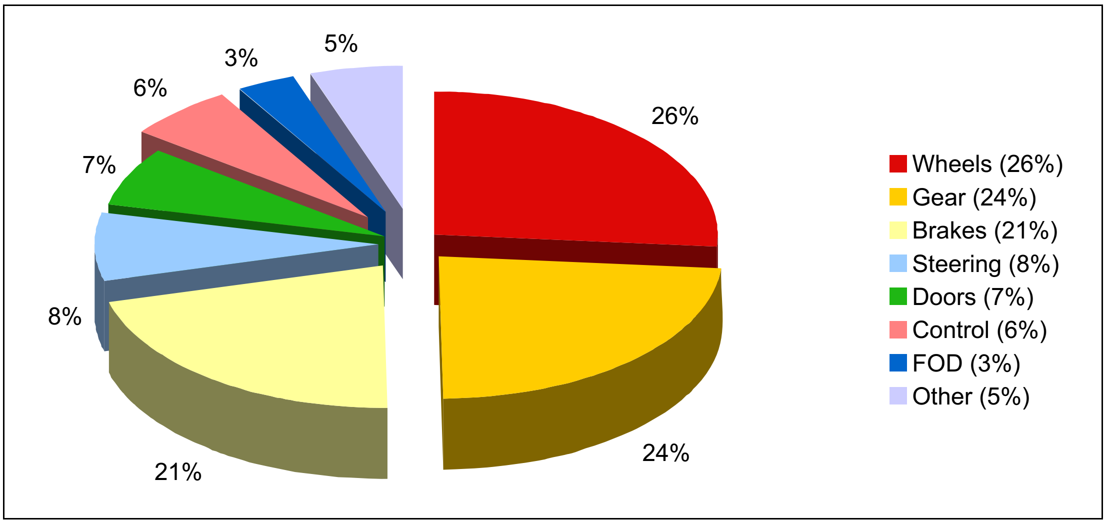

Figure 5 Breakdown of ATA 32 - Landing Gear

4.2.3.2 The most frequent problem with wheels was associated with fitting the wheel itself (36% of the wheel issues), while the most frequent issue with Landing Gear was associated with Landing Gear Safety Pins, accounting for 38% of the Landing Gear occurrences. Brake-related occurrences were varied with no specific issues dominating the data.

4.2.4 **ATA Chapter 27 (Flight Controls)**

4.2.4.1 A breakdown of the MORs associated with Flight Controls (ATA 27) is presented in Figure 6.

The most frequent Flight Control to feature in maintenance related occurrences was the Flap/Slat system. This system or its components featured in 36% of the ATA 27 related occurrences.

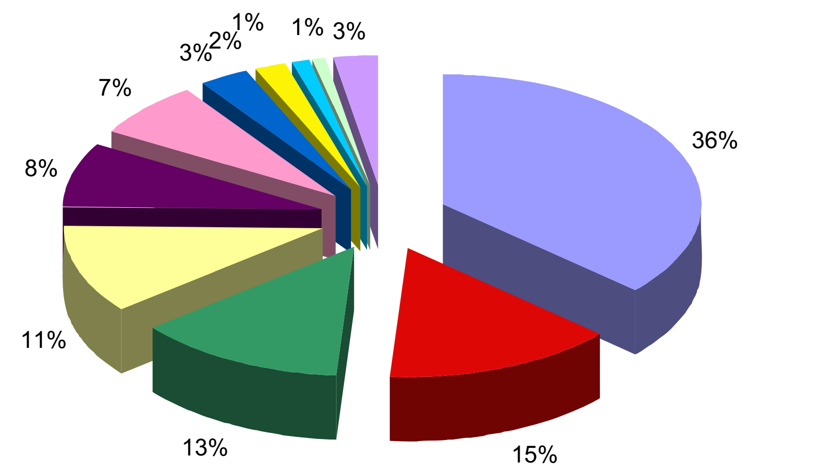

Figure 6 Breakdown of ATA 27 - Flying Controls

4.2.5 **ATA Chapters 71-80 (Combined Engine and Powerplant)**

4.2.5.1 While the combined Engine and Powerplant ATA chapter occurrences accounted for 14.89% of the data, further analysis showed little of significance. The fifteen most frequently occurring components or actions have been included in Figure 7. Oil overfilling accounted for 8%, with panels at 4%, and FOD at 3%. No patterns could be determined across the rest of the data. In combining the multiple ATA headings associated with engine maintenance, a degree of caution should be used as certain ATA Chapters do not produce certain types of errors that others do. The breakdown of errors must therefore be viewed as being applicable to the engine as a whole.

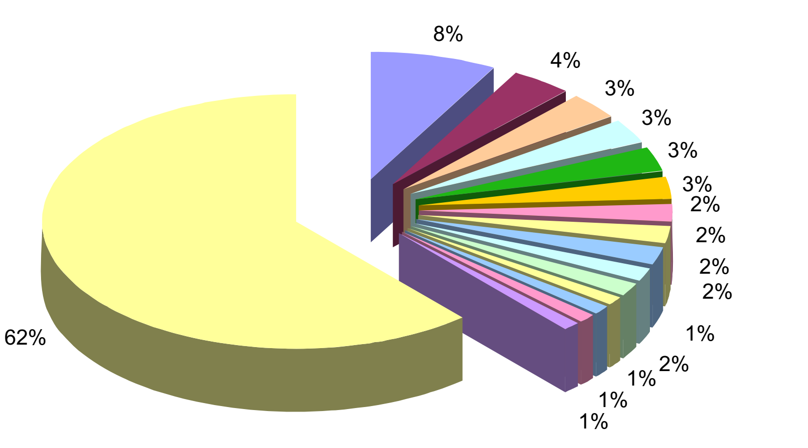

Figure 7 Breakdown of Combined ATAs 71 to 80

4.3 Maintenance Error Types by Year

The three Maintenance Error Types were plotted by year from 1996 to 2006 as shown in Figure 8 together with a plot of the total number of maintenance-related MORs.

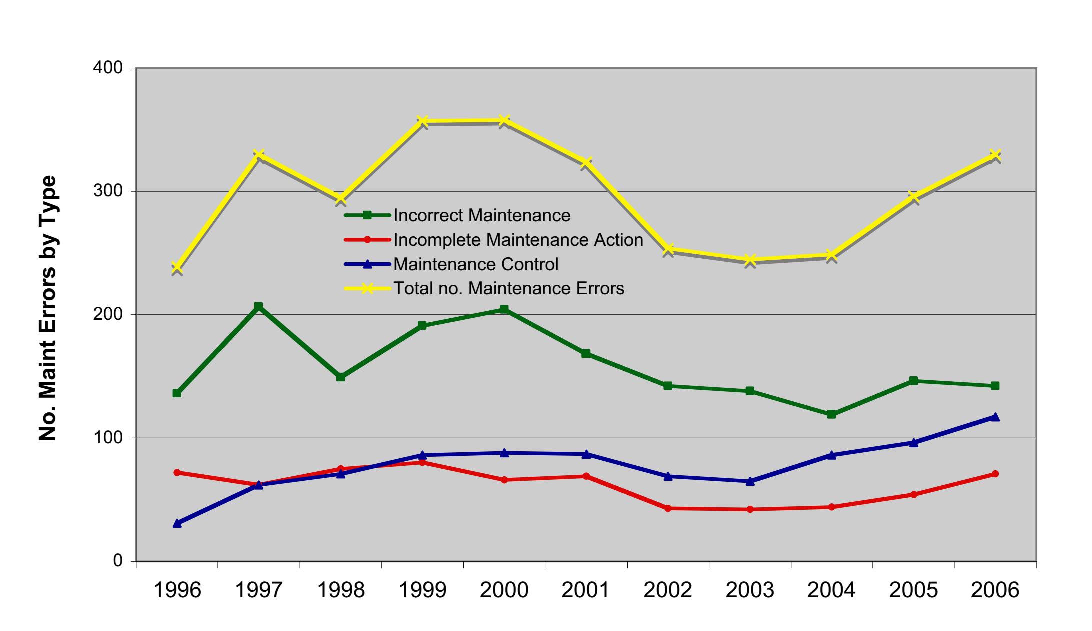

Figure 8 Number of Maintenance Error Types by Year

4.4 MORs by Year

The percentage of maintenance related MORs taken from the total number of MORs for aircraft over 5,700kg MTOW was calculated for the years 1996 to 2006 and is shown in Table 1 and Figure 9.

Table 1 Total MORs and Maintenance MORs by Year

MORs by Year	Total MORs	Maintenance MORs	Maintenance MORs as % of Total MORs
1996	1785	239	13·4%
1997	2011	330	16·4%
1998	2210	295	13·3%
1999	3081	357	11·6%
2000	3994	358	9·0%
2001	3899	324	8·3%
2002	3949	254	6·4%
2003	4173	245	5·9%
2004	4445	256	6·1%
2005	4951	296	6·0%
2006	5256	330	6·3%

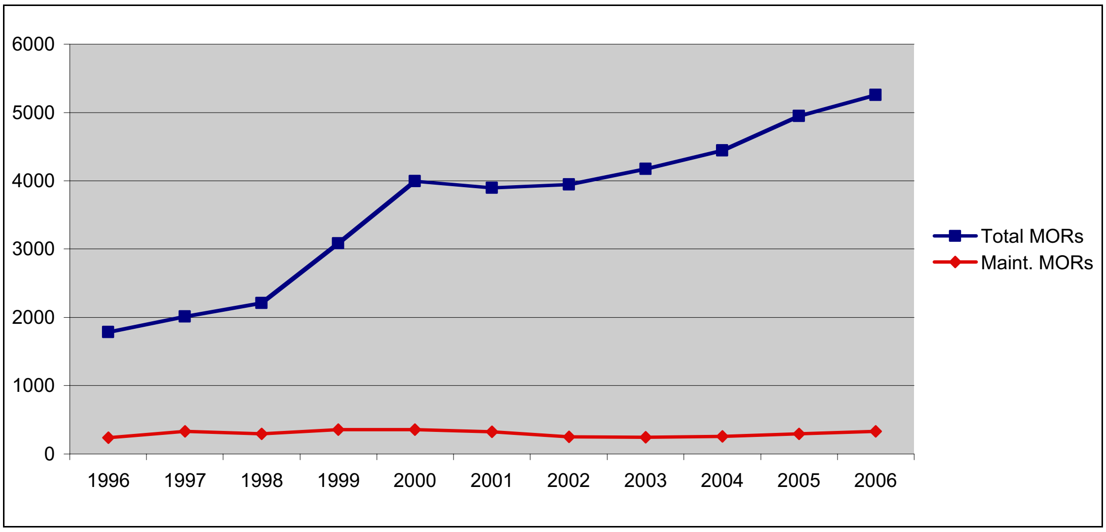

Figure 9 Total Number of MORs for aircraft over 5,700kg MTOW and Maintenance MORs by Year

4.5 Aircraft Type

The pilot study included data related to first level maintenance error types allocated by aircraft type and compared with the number of aircraft held on the UK register of aircraft. This was possible because the data set analysed was contained within a single year and, therefore, any events for that year could be attributed to aircraft currently on the UK register. When the data is taken over an extended period of time, the validity of the number of aircraft on the register is significantly degraded. If, however, subsequent MOR data were analysed year on year, this parameter would be valid and would be of interest.

5 Analysis of High Risk Incidents

5.1 General

5.1.1 Of the 335 high risk MORs, maintenance error was determined to have been a contributing or causal factor in the 21 events listed in Table 2 below.

Table 2 Maintenance Error-Related High Risk MORs

Aircraft type	Occurrence No.	Incorrect Maint Actions	Incomplete Maint	Maint Control	ATA Chapter
B737	199603331	YES			49 – APU
HS125	199603448	YES			27 – Flight Controls
A320	199603491	YES			73 – Eng Fuel
B757	199700323	YES			32 – Landing Gear
B747	199701540			YES	5 – Maint Checks
A320	199800265		YES		32 – Landing Gear
B757	199908289	YES			32 – Landing Gear
A320	199908796	YES			25 – Equip/Furnish
A320	200000263			YES	71 – Powerplant
B747	200001105		YES		27 – Flight Controls
BAE146	200006498	YES			27 – Flight Controls
BAE146	200007444	YES			32 – Landing Gear
A320	200008101			YES	72 – Engine
F100	200100433	YES			27 – Flight Controls
EMB145	200101366	YES			32 – Landing Gear

Table 2 Maintenance Error-Related High Risk MORs (Continued)

Aircraft type	Occurrence No.	Incorrect Maint Actions	Incomplete Maint	Maint Control	ATA Chapter
Learjet	200106111	YES			72 – Engine
EMB145	200106906		YES		35 – Oxygen
BAE 146	200107483	YES			29 – Hydraulics
A321	200108176		YES		72 – Engine
B737	200208116		YES		25 – Equip/Furnish
B777	200304039		YES		53 – Fuselage

5.2 Maintenance Error Types for High Risk Occurrences

5.2.1 Of the 21 high risk occurrences, twelve (57·1%) of them were due to incorrect maintenance actions being performed, six (28·6%) were due to incomplete maintenance actions and three (14·3%) were due to poor control or management of the maintenance activity.

5.2.2 Further analysis established the breakdown into the second level descriptors in terms of the number of occurrences, and the percentage of occurrences relative to the particular maintenance error type as follows.

High Risk Incidents – Maintenance Control:

Scheduled task	3	100%
Airworthiness data	0	0%
Airworthiness Directive	0	0%
Certification	0	0%
Component robbery	0	0%
Configuration control	0	0%
Deferred defect	0	0%
Inadequate tool control	0	0%
MEL interpretation	0	0%
Modification control	0	0%
Tech log	0	0%
Total	**3**	

High Risk Incidents – Incomplete Maintenance:

Not fitted	4	66%
Not set correctly	1	17%
Not removed	1	17%
Total	**6**	

High Risk Incidents – Incorrect Maintenance Action:

Incorrect fit	6	50%
Not set correctly	3	25%
Not fitted	1	8·3%
Procedure not adhered to	1	8·3%
Incorrect part	0	0%
Incorrect procedure	0	0%
Incorrect repair	1	8·3%
Poor maintenance practice	0	0%
Not removed	0	0%
Total	**12**	

5.3 ATA Chapter Headings for High Risk Occurrences

An analysis of the high risk occurrences by ATA Chapter established that the three individual ATA Chapters most frequently involved in the occurrences were Landing Gear (ATA 32), Flight Controls (ATA 27) and Engine (ATA 72), as illustrated in Figure 10 below. Taken together, the Engine related ATA Chapters (71-80) equal the frequency of ATA 32 and have been included for comparison.

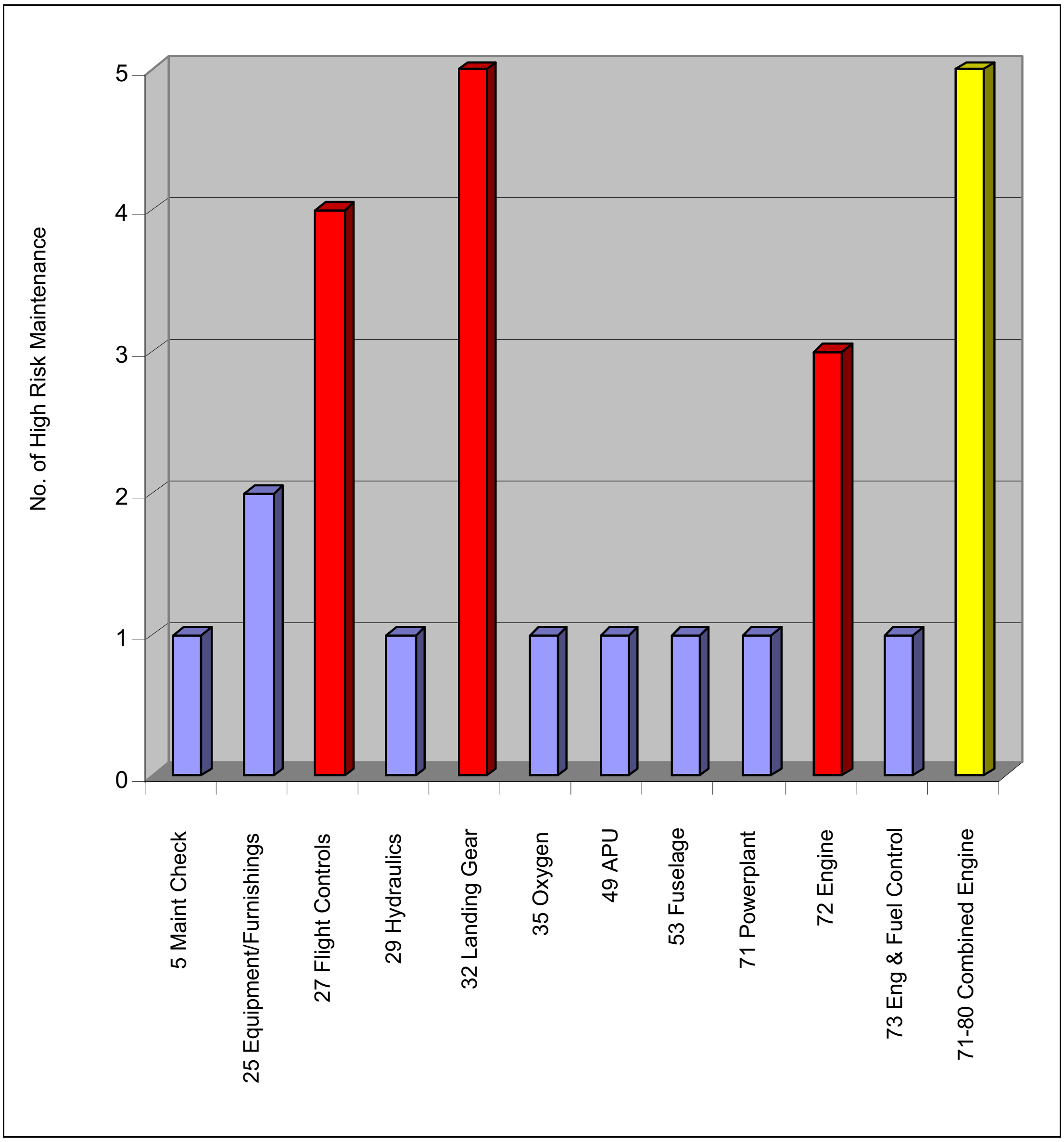

Figure 10 Breakdown of 21 High Risk MORs by ATA Chapter

5.4 High Risk MORs by Year

The distribution of high risk maintenance MORs by year over the eleven year period 1996 to 2006 is shown in Figure 11 below.

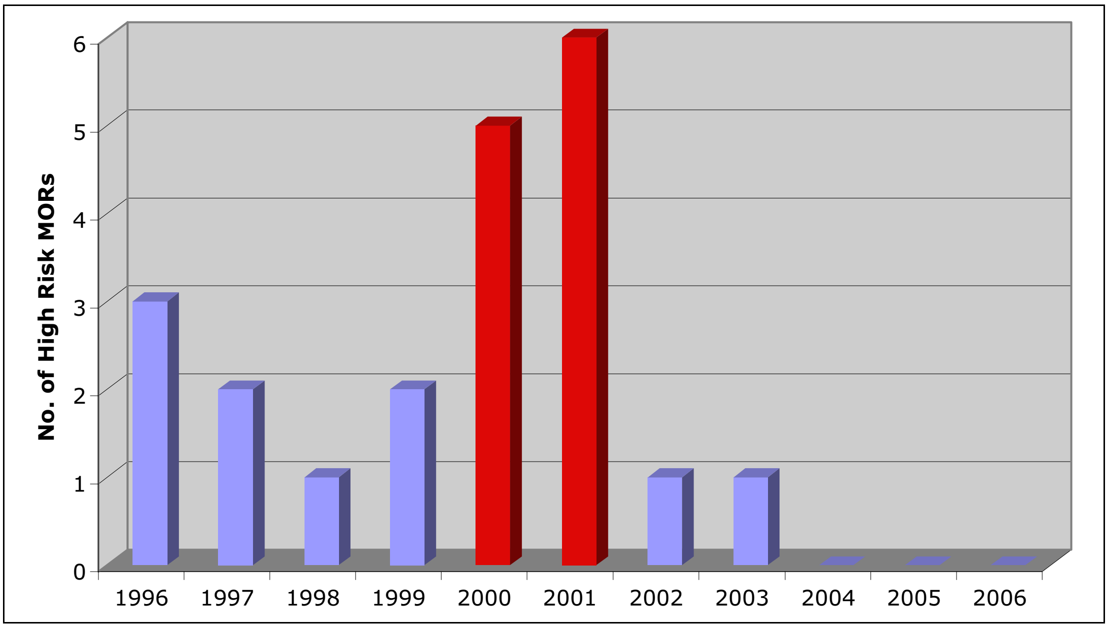

Figure 11 Breakdown of 21 High Risk MORs by Year

5.5 High Risk Occurrences with Associated AAIB Reports

5.5.1 The 21 high risk maintenance MORs subject to AAIB investigations were analysed in greater detail. The following nine occurrences had associated AAIB reports describing, in varying degrees, their investigations:

MOR 199603331 – ref AAIB Bulletin 3/97

MOR 199701540 – ref AAIB Bulletin 11/97

MOR 199700323 – ref AAIB Bulletin 4/98

MOR 199908289 – ref AAIB Bulletin 12/2000

MOR 200000263 – ref AAIB Bulletin 7/2000

MOR 200101366 – ref AAIB Bulletin 8/2002

MOR 200107483 – ref AAIB Bulletin 3/2003

MOR 200208116 – ref AAIB Bulletin 6/2004

MOR 200304039 – ref AAIB Bulletin 3/2005

5.5.2 These nine occurrences were analysed to determine if the AAIB investigation report contained different information to that included in the MORs, and whether there was sufficient detail to determine the underlying cause(s) of the maintenance error.

5.5.3 Of the nine, the six MORs listed below all suggest maintenance error as a primary causal or contributing factor. Due to the nature of the events, however, the AAIB were unable to determine who was involved or why the errors occurred.

MOR 199603331 – ref AAIB Bulletin 3/97

MOR 199701540 – ref AAIB Bulletin 11/97

MOR 199908289 – ref AAIB Bulletin 12/2000

MOR 200101366 – ref AAIB Bulletin 8/2002

MOR 200107483 – ref AAIB Bulletin 3/2003

MOR 200208116 – ref AAIB Bulletin 6/2004

5.5.4 The AAIB reports for the remaining three events listed below, however, contain a great deal of information about the circumstances surrounding the activities that led to the maintenance error.

MOR 199700323 – ref AAIB Bulletin 4/98

MOR 200000263 – ref AAIB Bulletin 7/2000

MOR 200304039 – ref AAIB Bulletin 3/2005

5.5.5 The level of detail available in these three AAIB Bulletins was sufficient for Boeing Maintenance Error Decision Aid (MEDA) reports to be compiled. The MEDA reports generated are presented in Appendix 1. While no conclusions or trends can be drawn from just three investigations, it does highlight the difference in the quality and detail of information present in AAIB reports compared with the MORs. It has proven almost impossible to determine the underlying causes of maintenance errors with any degree of certainty from MORs alone.

5.6 Underlying Causes of High Risk Occurrences

The 21 high risk, maintenance related occurrences were analysed to identify underlying causes evident from the MOR report or the AAIB report where available. Table 3 shows each occurrence and the level of information available to determine the underlying cause(s) of the error(s).

Table 3 Underlying Causes of High Risk MORs

MOR No.	A/C Type	EVENT PRECIS	AAIB Bulletin	Underlying causes/ comments
1996 03331	B737	APU turbine wheel failure.	AAIB Bulletin 3/97	Inconclusive investigation.
1996 03448	HS125	Both ailerons deflected full travel during cruise. Control cables misrigged.	MOR report only	No reason for the mis-rigging is evident in the MOR report.
1996 03491	A320	RH engine fire. HP fuel pipe leaking due chafing with P clip.	MOR report only	No reason evident from MOR report.
1997 00323	B757	Nosewheel axle broke following bearing failure and unapproved repair.	AAIB Bulletin 4/98 Ref: EW/C97/8/1	MM info not available to LAE. Lack of knowledge of the LAE's involved. Procedural violation.
1997 01540	B747	Structural damage following a heavy landing not detected.	AAIB Bulletin 11/97	Incomplete inspection performed due access difficulties at Line Station, but determined that defects would have been difficult to detect.
1998 00265	A320	Engine diffuser case attachment bolts missing after workshop repair.	MOR report only	No reason evident from MOR report.
1999 08289	B757	Damage to airframe and RH MLG inner cylinder collapsed.	AAIB Bulletin 12/2000 Ref: EW/C99/12/1	Inconclusive investigation.
1999 08796	A320	Multiple slide failure.	MOR report only	Combination of various design and maintenance errors.

Table 3 Underlying Causes of High Risk MORs (Continued)

MOR No.	A/C Type	EVENT PRECIS	AAIB Bulletin	Underlying causes/ comments
2000 00263	A320	Engine cowling departed A/C on T/O. Not latched closed after maintenance.	AAIB Bulletin 7/ 2000 Ref: EW/ C2000/1/2	Information not given to LAE. Unlocked cowling latches difficult to see during a walk-round. Unintentional procedural violation. Poor communication system for information.
2000 01105	B747	Uncommanded pitch up during descent. Pitot connections to elevator feel computer not reconnected. 1 serious injury.	NTSB report NYC00LAO85	Technical investigation only but did reveal no leak check requirement in BA manuals.
2000 06498	BAE 146	Rudder control jammed due to mis-rigging.	MOR report only	No record of system disturbance in A/C records. Reasons not established.
2000 07444	BAE 146	NLG collapsed during maintenance after emergency lowering of gear in flight.	MOR report only	Special tool not used by LAE but the reason why is not stated in MOR report.
2000 08101	A320	Nr 2 engine failure. Trend data not communicated to the Maintenance Organisation in time.	MOR report only	Lack of timely communication between trend data company and MO.
2001 00433	F100	Aileron restriction. Badly fitting panel allowing water on cables and freezing.	MOR report only	No reasons evident from MOR report.
2001 01366	EMB 145	NLG axle failed precipitated by bearing failure due to incorrect seal configuration.	AAIB Bulletin 8/ 2002 Ref: EW/ C2001/3/2	Inconclusive investigation as to the cause.
2001 06111	Learjet	Engine failure due to mis-assembly of combustor liner.	MOR report only	Technical investigation only. No reasons evident from MOR report.
2001 06906	EMB 145	Flight crew oxygen supply restricted.	MOR report only	Who installed and tested the masks during previous maintenance not determined.
2001 07483	BAE 146	Smoke in cabin after hydraulic system failure. Flex hydraulic pipe chafed due misalignment.	AAIB Bulletin 3/ 2003 Ref; EW/ G2001/10/18	No attempt to determine why the pipe was incorrectly positioned such that it chafed an adjacent pipe.
2001 08176	A321	Smoke in cabin and cargo bays. Incomplete compressor washing process.	MOR report only	No reason evident from MOR report.
2002 08116	B737	Smoke in flight deck. Braided water hose tie-rapped around electrical wire bundles and chaffed wires.	AAIB Bulletin 6/ 2004 Ref: EW/ C2002/12/03	Not investigated by AAIB but incident referenced in AAIB Bulletin as an example of wiring problems.
2003 04039	B777	ADU panel not latched closed and departs A/C on takeoff.	AAIB Bulletin 3/ 2005 Ref: EW/ C2003/06/04	Complicated work card system Complacency during walk-round inspections Normative procedural violations.

6 Discussion

6.1 Taxonomy

The taxonomy was driven by the data provided as opposed to forcing the data to fit a predetermined structure. The taxonomy was not a factor in the exclusion of any reports. The taxonomy developed in the pilot study continued to perform well with the larger data set.

6.2 Maintenance Error Types

6.2.1 Incorrect Maintenance

The results of the allocation of the occurrences included in this study to the first level maintenance error types clearly show the most common category to be incorrect maintenance actions. Examples of incorrect maintenance actions include cross connections, damage to components and non-adherence to documentation, all of which are indicative of degradation in the professional standards expected of maintenance engineers. The issues are largely focused around the incorrect installation of components, although it is not possible from the data available to determine the underlying attributable causes.

6.2.2 Maintenance Control

The focus of human factors initiatives has largely been on understanding and preventing maintenance error based upon the premise that the system, designed to support the engineers, is robust and effective. As can be shown from the data, maintenance control issues contribute just as significantly to maintenance error in terms of their effect. Errors associated with configuration control, deferred defects and control of Airworthiness Directives can impact the integrity of the aircraft in the same way as the actions of the maintenance engineer.

a) Scheduled Tasks

Failing to adequately control tasks that the system knew were required is the largest error descriptor type within Maintenance Control. 265 occurrences corresponding to 30·8% of the Maintenance Control errors were determined to be of this nature. Typically, the types of failures encountered were not calling up Maintenance Programme tasks or not calling for them in proper time.

b) Inadequate Tool Control

The second largest numbers of errors within Maintenance Control were hazards relating to inadequate tool control. A review of the data comprising Inadequate Tool Control established that there were 93 occurrences where this was the primary cause of the hazard affecting the aircraft. Of these 93 events, 45 (48%) were due to personnel inadequately controlling their own personal tools or belongings. 25 events (26%) involved tooling or consumable materials that would have been issued to the person to use during a task, but with no expectation of return, e.g. rags, masking tape and drill bits. Just four (5%) of the events involved tools that would have been issued to personnel for which the system would have demanded their return to stores after the work had been completed.

The maintenance system requires tooling and materials to be controlled. In reality, however, only special tools owned by the maintenance organisation are subject to control. This typically involves special tools being issued to a person from a tool store who signs for it and has to return the tool at the end of the shift or task. Such systems often require a check to ensure that all tools issued have been returned prior to releasing the aircraft to service. Aircraft maintenance personnel in the UK invariably possess their own toolboxes of standard spanners, screwdrivers and pliers etc. These tools are not subject to any real system of control other than the owner being responsible for ensuring that he does not leave any in the aircraft after completing the task. The same is true of consumable materials issued to personnel. The person issued with the material is responsible for ensuring that it is not left in the aircraft.

The data suggests that the control of company owned special tools is performing its job but the control of personal tools is not as robust.

6.2.3 Incomplete Maintenance

Occurrences related to incomplete maintenance typically involved such things as not tightening pipes or screws at the end of a task or omitting wire locking. These errors are more typical of a human error or lapse rather than performing the job incorrectly, as is the case with occurrences categorised as incorrect maintenance.

6.3 ATA Chapter Headings

6.3.1 The allocation of the data to ATA Chapter headings identifies the top three most frequent as: Equipment and Furnishing (ATA 25); Landing Gear (ATA 32); and Flight Controls (ATA 27). It should be noted that when Chapters 71 through to 80 relating to Engines are combined, it makes engine maintenance second only to Equipment and Furnishings in terms of frequency.

6.3.2 This data correlates with an analysis performed by the CAA in 1995 of maintenance related data submitted between 1983 and 1994 under the MOR scheme. The four most frequently occurring ATA Chapters in the earlier study were, in order, Chapters 25, 32, 79 and 27. These are the same ATA Chapters as the current study apart from the inclusion of Oil (ATA 79), and in the same order of frequency. It also mirrors the breakdown of the data analysed during the pilot study, again with the exception of Oil.

6.3.3 Explanations for the high incidence of these particular ATA Chapters can be offered. Both Equipment and Furnishings (ATA 25) and Landing Gear (ATA 32) are subject to high maintenance traffic and therefore a higher frequency of errors might be expected. This is compounded with Equipment and Furnishings (ATA 25) by the fact that cabin maintenance is often perceived as being a ‘lesser’ maintenance task and may be undertaken more frequently by less skilled or experienced engineers. This cannot, however, be corroborated by the data due to insufficient detail.

6.3.4 The majority of the ATA Chapter data conforms to the overall pattern where incorrect maintenance accounts for the majority of occurrences with the remainder being approximately equally divided between maintenance control and incomplete maintenance. However this is not the case with ATA Chapter 25. Only 11·8% are maintenance control issues, 25·6% incomplete maintenance and 62·5% incorrect maintenance. Once again, Chapter 25 is different in that it is rare for an MOR to be classified as high risk where Equipment and Furnishings are involved.This is because they typically do not represent a direct hazard to the aircraft, lying dormant until the unlikely event the system affected is required to perform as designed. The irony is that malfunction of equipment such as escape slides, cabin dividers or the incorrect installation of a seat, could result in fatalities in an otherwise survivable accident.

6.3.5 Flight controls are less associated with high maintenance traffic but are so significant in terms of airworthiness that any anomalies are more likely to get reported. The Flap/Slat system was the most common flight control system to be affected by maintenance error. This may be due to it normally being the most complex of the flying control systems and requiring the most maintenance. A complex system with relatively high maintenance traffic would account for this.

6.3.6 Historically, the ATA Chapter system has been used to help analyse data as in the case of the present study reported here. This demarcation system, however, was designed for manufacturers and maintenance manual writers rather than data analysts and, interestingly, if ATA Chapters are combined as has been performed with engine related ATA Chapters (see Figure 3), a different perspective can be portrayed.

6.4 Quality of data supplied

6.4.1 The value and strength of any database lies in the quality of the data input and the manner in which it is subsequently analysed and employed.

6.4.2 Historically, the emphasis has been on the collection of factual data surrounding the maintenance event in terms of what happened, and where and when it occurred. Less attention is typically paid to the reasons behind actions, but the importance of this information to accident prevention is now widely accepted.

6.4.3 It was noted during the analysis of the 3,982 events that there was great variability in the style, language and the comprehensiveness of the individual entries. The lack of standardised terminology has meant that the initial data cut included events that were not maintenance related and, conversely, relevant events may have been omitted.

6.4.4 It is suggested that the MOR database would benefit by including more detailed descriptions of underlying causes of events on the MOR. Additional information is often available but is held on paper files and is difficult to access. This would avoid the need to attempt to 'second guess' contributory factors and underlying causes from brief one line descriptions some time after the occurrence.

6.5 MORs by year

6.5.1 The data show that, for the period 1996 to 2006, the overall number of all types of MORs raised is increasing year on year. This may be attributable to better levels of reporting or may be a result of the ever increasing fleet sizes. Conversely, the number of maintenance related MORs, constituting no more than 16·4% of the total in any given year within the same time frame, can be seen to be decreasing as a percentage, year on year from 1996 to 2003. The consistent decrease may be explained by the CAA's efforts in providing human factors awareness training, guidelines and policy to industry. From 2004 through 2006 the number of MORs submitted consistently increases resulting in a levelling of the proportion at 6% of all MORs. This may be explained with the introduction in 2004 of the JAR 145 requirement for all maintenance organisations to systematically and formally manage maintenance errors, resulting in errors being reported that before this time, may not have been.

6.5.2 Airworthiness Notice 71[1] laid out CAA's policy on error management and the expectation that maintenance organisations adopt good human factors principles and practices in the form of instituting error management programmes in their organisations. From this time many organisations started to introduce error management programmes in advance of the January 2004 JAR 145 mandate. Interestingly, since the JAR 145 requirement to effectively manage maintenance errors, there has been no high risk occurrence attributable to maintenance error.

6.6 Maintenance Error Types by Year

From 2000 to 2003, the number of maintenance MORs attributable to all three first level categories has decreased. This may be attributable to CAA's human factors education and other initiatives. From 2004 onwards, however, the number of MORs attributable to incorrect maintenance has remained more or less static but the numbers attributable to both incomplete maintenance and maintenance control have increased year on year.

1. Airworthiness Notice 71 has since been updated and transferred to CAP 562 Leaflet 11-50.

6.7 Maintenance Error Types in High Risk Occurrences

6.7.1 The ratio of incorrect maintenance, incomplete maintenance and poor control of maintenance is broadly similar to that of the 3,284 low risk occurrences. By far the most common first level category in the 21 high risk occurrences is incorrect maintenance actions being taken (58%). Examples include, flying controls incorrectly rigged, incorrect servicing and fitting of parts.

6.7.2 Further analysis of the data with respect to the second level error types reveals that the most common errors associated with incorrect maintenance was the incorrect fitment of parts (50%).

6.7.3 The absence of contributing and causal factors on the MORs prevents further analysis to determine underlying causes.

6.8 ATA Chapter Headings for High Risk Occurrences

6.8.1 The analysis of the 21 high risk occurrences by ATA Chapter shows a different profile to that of the 3,263 low risk occurrences. The obvious difference is the low frequency of ATA 25 (Equipment/Furnishings) related high risk occurrences that were the most frequent category of all in the lower risk data. This is most likely due to the disproportionate probability of a maintenance error in this area leading to a high risk occurrence.

6.8.2 The other noticeable difference is the appearance of ATA Chapter 72 (Engine) as the third most frequent category. This is ranked a little higher than in the lower risk data but this may be no more than a feature of the relatively small sample size for the higher risk occurrences.

6.8.3 When considering what parts or systems are most affected by maintenance errors it should be noted that combining the ATA Chapters applicable to engines (ATA 71 to 80 in principle but only ATA 71, 72 and 73 in this case) results in a total of five occurrences, indicating that engine maintenance is as prone to high risk maintenance errors as Landing Gear (ATA 32) and Flight Controls (ATA 27).

6.9 Frequency of Maintenance Related High Risk Occurrences

The number of events are small, making any trend analysis unreliable, but the peak of six high risk MORs in 2001, and the reduction since then were studied. From the information available no obvious common features or reason could be identified. The downward trend from 2001 may possibly be explained, as previously noted, by the CAA's campaigns, conferences and road shows in 1999 and 2000 on Maintenance Error Management, culminating in the issue of Airworthiness Notice 71[1] in March 2000 and changes in JAR 145 in 2004.

6.10 Detail of Information in AAIB Reports Compared to CAA MORs

6.10.1 While nine of the 21 high risk incidents had associated AAIB Bulletins, the AAIB were able to investigate them to a level sufficient for the underlying causes to be established in only three cases. The other six investigations concluded that maintenance error was the primary causal or contributing factor but, due to the nature of the incidents, the AAIB were unable to determine who was involved with making the errors or why they occurred.

6.10.2 The three AAIB investigation reports (MOR 199700323 – ref AAIB Bulletin 4/98, MOR 200000263 – ref AAIB Bulletin 7/2000, MOR 200304039 – ref AAIB Bulletin 3/2005) contained sufficient information and detail for Boeing Maintenance Error Decision Aid (MEDA) form to be easily completed. These three AAIB reports all contain details of the error type, the contributing factors and the error prevention procedures, processes or policies that were intended to prevent the error but failed in the particular instance. With the exception of the error type, all these details are usually absent from the CAA MORs.

1. Airworthiness Notice 71 has since been updated and transferred to CAP 562 Leaflet 11-50.

7 Conclusions and Recommendations

7.1 Conclusions

7.1.1 The most frequent type of maintenance error found was incorrect maintenance and, within that category, the most frequent types of error were 'incorrect fit' and 'not set correctly'.

7.1.2 The areas of the aircraft most susceptible to maintenance error were, in order, Equipment and Furnishings (ATA 25), 'Powerplant' (ATA 71 to 80), Landing Gear (ATA 32) and Flight Controls (ATA 27). For ATA 25 the most frequent issue was escape slides; for ATA 32 it was roughly equally divided between wheels, gear and brakes; for ATA 27 the most frequent problem area was flaps and slats.

7.1.3 The rate of maintenance error MORs has steadily decreased since its peak in 1997 and has levelled since 2004 at 6% as a percentage of total MORs for aircraft greater than 5,700kg MTOW. The number of MORs submitted since 2004 has steadily increased. This may be due to the requirements, introduced in 2004, for error management and their formal investigation within the maintenance organisations.

7.1.4 The review of all high risk MORs for the period covered by the study revealed that maintenance error was the primary causal factor or a contributory factor in 6% of occurrences. The breakdown of the high risk MORs was broadly similar to the lower risk occurrences, the only significant difference being that maintenance errors in the area of Equipment and Furnishings (ATA 25) did not feature significantly in the high risk occurrences.

7.1.5 There is insufficient information and detail in MORs to identify the underlying causes of maintenance errors. There was only sufficient information available to complete a Boeing MEDA form in a third of the high risk occurrences investigated by AAIB.

7.2 Recommendations

7.2.1 It is recommended that a more detailed analysis of the underlying causes of occurrences should be captured and documented at the time of data entry or MOR closure. Combining this with a much more standardised approach to data entry with regards to applied logic, language and categorisation would create a much more robust and reliable data set as well as significantly facilitating future data interrogation and trend analysis. This will benefit not only the CAA but also the individual airlines contributing to the data set.

7.2.2 A comparison with alternative sources of data (for example, the Maintenance Error Management System reports collated by CHIRP) should be made, to determine whether similar trends are apparent. The MEMS data should provide further information to establish the underlying causes of maintenance errors. This, however, would require the reclassification of the MEMS data in line with the taxonomy developed during this project.

7.2.3 A standardised on-line report form for maintenance error occurrences should be introduced to facilitate not only ongoing analysis but also initial reporting, investigation results and data entry. Standardised entry fields, constrained free text and on-line reporting from the airlines and maintainers would greatly increase the reliability of the data and reduce the requirement for speculation and deduction. The recommended system would allow for initial reporting of an event and would remain open on the system until such time as the reporter had concluded their investigations and gone back on-line to complete the required fields to record why the event happened. Consideration should be given to ease of use, robustness and comprehensiveness of any on-line form design.

7.2.4 Ongoing year on year analysis of the data should be conducted to identify and monitor themes and trends. This would allow the inclusion of aircraft type as a variable for analysis. Further studies should consider extending the analysis to include aircraft below 5,700kg MTOW given that they account for the majority of air accidents within the UK and, indeed, further still to helicopters. Given the limited legal obligations for reporting as required by the Air Navigation Order this would have to be restricted to commercially operated aircraft. Once again, the manner in which the data is entered and stored will have a significant effect on the ease of analysis.

7.2.5 The CAA should give some consideration to the prevalence of cabin issues, particularly with regard to escape slides, passenger seats, oxygen masks and lifejackets and, perhaps, look to airlines which do not appear to have issues in this area as a possible source of best practice. Although rarely a direct hazard to the aircraft, these issues can pose a direct threat to survivability in the event of an accident.

7.2.6 CAA comments regarding MOR closure should state what specific action has been taken to prevent recurrence so that the use of standard statements is meaningful in future analysis.

7.2.7 Given the high number of maintenance errors occurring while performing and managing tasks associated with ATA Chapters 27, 32 and 71 through 80, and that these feature prominently in high risk occurrences, it is recommended that the CAA investigate how to reduce such errors.

8 References

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

ICAO (2001) *Accident/Incident Reporting Manual (Doc 9156).* Montreal: ICAO.

Rankin W, Hibit R, Allen J and Sargent R (2000) Development and Evaluation of the Maintenance Error Decision Aid Process. *International Journal of Industrial Ergonomics,* 26: 261-276.

Shappell SA and Wiegmann DA (1997) A human error approach to accident investigation: The taxonomy of unsafe operations. *International Journal of Aviation Psychology,* 7(4): 269-291.

Shappell SA and Wiegmann DA (2001) Human factors analysis and classification system. *Flight Safety Digest*, February, 15-25.

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Appendix 1 Aircraft Maintenance Incident Analysis Reports

1 Boeing MEDA Form for MOR 199700323 / AAIB Bulletin 4/98

Section I -- General Information

Reference #: MOR 199700323___ ___ ___ ___ ___

Airline: Air 2000 ______________________

Station of Error: Malaga, Spain __________________

Aircraft Type: B757 – 225 ____________________

Engine Type: RR RB211-535-E4_______________

Reg. #: G-OOOV

Fleet Number: ___ ___ ___ ___ ___ ___

ATA #: 32

Aircraft Zone: ___________________________________

Ref. # of previous related event: ___ ___ ___ ___

Interviewer's Name:…………………………………..

Interviewer's Telephone #: __ __ __ __ __ __ __ __

Date of Investigation: __ __ / __ __ / __ __

Date of Event: __27 / 01 / 97__

Time of Event: _16.55hrs _ : _ _ pm

Shift of Error: Not Applicable………

Type of Maintenance (Circle):

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

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

Section II -- Event

Please select the event (check all that apply)

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

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

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

UK Reportable Accident : On leaving R/W, nosewheel stub axle sheared off (following earlier NLG bearing failure/nosewheel change).

Section III -- Maintenance Error

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

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

(e.g.,

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

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

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

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

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

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

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

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

The LAE failed to detect overheating of the axle following a bearing failure and then improperly repaired the axle by blending which increased the probability that the axle would fail.

Section IV -- Contributing Factors Checklist

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

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

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

A. 2. The Duty Engineer pre-planned the work for the LAE , printing extracts from the MM Chapter 32, but did not print Chapter 5 where the requirements for borescope inspecting the axle for signs of overheating are contained.

N/A __ **B. Equipment/Tools/Safety Equipment**

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

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

N/A __ **C. Aircraft Design/Configuration/Parts**

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

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

N/A __ **D. Job/Task**

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

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

__ **E. Technical Knowledge/Skills**

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

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

E.2. Neither the Duty Engineer or the LAE were aware of the requirement in MM Chapter 5 to inspect the axle internally for signs of overheat or of the problems associated with cadmium embrittlement.

N/A __

F. Individual Factors

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

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

N/A __

G. Environment/Facilities

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

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

__

H. Organizational Factors

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

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

H. 7. The LAE blended the mechanical damage from the axle although he had no authority to do so. This was not in accordance with the MOE that required repairs outside the SRM to be approved through the Technical Services Department.

N/A __

I. Leadership/Supervision

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

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

N/A __

J. Communication

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

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

N/A __

K. Other Contributing Factors (explain below)

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

Section V – Error Prevention Strategies

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

( ) **Maintenance Policies or Processes** (specify) *MOE – Repairs outside SRM are required to be approved through Tech Services*

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

Required Maintenance Documentation

- ( ) Maintenance manuals (specify) ____
- ( ) Logbooks (specify) ____
- ( ) Work cards (specify) ____
- ( ) Engineering documents (specify) ____
- ( ) Other (specify) ____

Supporting Documentation

- ( ) Service Bulletins (specify) ____
- ( ) Training materials (specify) ____
- ( ) All-operator letters (specify) ____
- ( ) Inter-company bulletins (specify) ____
- ( ) Other (specify) ____

( ) **Other** (specify) ____

B. List recommendations for error prevention strategies.

Recommendation #	Contributing Factor #	

(Use additional pages, as necessary)

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

Provide a brief summary of the event.

On turning off the runway after landing at Malaga, a vibration was felt through the steering and inspection revealed that the RH nosewheel was canted over at an angle, the outer bearing having disintegrated. An engineer and wheel change kit were sent from UK, with the engineer changing both nosewheels and dressing-out axle damage (caused by the wheel bearing failure). The a/c was then cleared for return flight, with the NLG axle failing (inboard of the RH outer bearing land) as the a/c turned off the runway after landing at Birmingham at the end of that sector. Subsequent metallurgical examination showed that the axle had fractured, due to cadmium embrittlement, and further weakened where the axle wall thickness had been reduced by 33% by the dressing-out action at Malaga. The a/c Maint Manual calls for a borescope inspection of the NLG axle (for overheating) after a wheel bearing failure. This requirement was not known to the engineer who planned the work or the one who carried out the repair in Malaga therefore the check was not carried out.

(Use additional pages, as necessary)

2 Boeing MEDA Form for MOR 200000263 / AAIB Bulletin 7/2000

Section I -- General Information

Reference #: MOR 200000263___ ___ ___ ___ ___Interviewer's Name:…………………………………..

Airline: Airtours Intl. _____________________________	Interviewer's Telephone #: __ __ __ __ __ __
Station of Error: Gatwick _________________________	Date of Investigation: __ __ / __ __ / __ __
Aircraft Type: A320 - 200________________________	Date of Event: __20 __ / __01 __ / __ 2000__
Engine Type: IAE V2500 ________________________	Time of Event: 06.55hrs_ _ : _ _ am
Reg. #: G-VCED___ ___ ___ ___ ___ ___ ___	Shift of Error: night shift………………………
Fleet Number: ___ ___ ___ ___ ___ ___	Type of Maintenance (Circle):
ATA #: ___54 ___ ___ ___	1. Line -- If Line, what type? Weekly Check
Aircraft Zone: _________________________________	2. Base --If Base, what type?
Ref. # of previous related event: ___ ___ ___ ___ ___	Date Changes Implemented: __ __ / __ __ / __ __

Section II -- Event

Please select the event (check all that apply)

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

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

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

1. (f) & 5. UK Reportable Accident : Nr1 engine cowling failure/separation after take-off - fuselage damaged by debris

Section III -- Maintenance Error

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

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

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

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

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

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

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

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

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

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

The number 1 engine cowlings were not latched closed after maintenance

Section IV -- Contributing Factors Checklist

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

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

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

A. 2. The LAE was not aware of the Quality Advisory Notice (QAN) that called attention to previous cases of fan cowl door detachment and required the doors to be latched any time the doors were closed. The QAN had been hung on the notice board but had since been removed.

N/A __ **B. Equipment/Tools/Safety Equipment**

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

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

__ **C. Aircraft Design/Configuration/Parts**

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

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

C. 2. The cowling latches are very difficult to see without getting under the engine to inspect. If the latches are not locked after maintenance it is possible to miss that the cowlings are not latched shut during a walk-around inspection

N/A __ D. Job/Task

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

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

__ **E. Technical Knowledge/Skills**

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

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

E.2. The LAE was not aware that a Technical Instruction had been issued requiring the latches to be made every time the cowlings are shut.

N/A __

F. Individual Factors

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

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

N/A __

G. Environment/Facilities

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

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

N/A __

H. Organizational Factors

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

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

H. 2. The company had changed from a read and sign system for technical information, to placing them on the Notice Board for a period of time. This increased the probability that LAE's would not have read them, therefore depriving them of information that may have prevented the error and its consequences.

N/A __

I. Leadership/Supervision

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

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

N/A __

J. Communication

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

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

J. 1. By only placing the QAN's and TI's on the Notice Board, the Quality and Engineering Dept had failed to adequately communicate to the LAE.

N/A __

K. Other Contributing Factors (explain below)

Describe specifically how this other factor contributed to the error.

Section V – Error Prevention Strategies

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

(**X**) **Maintenance Policies or Processes** (specify) *The policy of placing QAN's and TI's on the Notice Board is intended to effectively communicate issues and instructions to LAE's* ______

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

Required Maintenance Documentation

- ( ) Maintenance manuals (specify) ______
- ( ) Logbooks (specify) ______
- ( ) Work cards (specify) ______
- ( ) Engineering documents (specify) ______
- ( ) Other (specify) ______

Supporting Documentation

- ( ) Service Bulletins (specify) ______
- ( ) Training materials (specify) ______
- ( ) All-operator letters (specify) ______
- ( ) Inter-company bulletins (specify) ______
- ( ) Other (specify) ______

( ) **Other** (specify) ______

B. List recommendations for error prevention strategies.

Recommendation #	Contributing Factor #	

(Use additional pages, as necessary)

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

Provide a brief summary of the event.

As the aircraft rotated for take off, both fan cowl doors detached from the No 1 Powerplant and struck the aircraft. The doors were destroyed and localised damage resulted to the No 1 Powerplant and its pylon, the left wing, the left flaps and slats, the fuselage and the fin. The evidence indicated that the doors had probably remained unlatched, after having been closed following maintenance prior to the accident flight and had been torn off their pylon attachment hinges by aerodynamic forces as the aircraft rotated. There are no conspicuous cues to indicate an unlatched condition when the doors are closed and no flight deck indication. Three walk-round inspections had been conducted after the doors had been closed.

(Use additional pages, as necessary)

3 Boeing MEDA Form for MOR 200304039 / AAIB Bulletin 3/2005

Section I -- General Information

Reference #: MOR 200304039 ___ ___ ___ ___ ___Interviewer's Name:…………………………………..

Airline: British Airways_____________________________ Interviewer's Telephone #: __ __ __ __ __ __ __ __ __

Station of Error: Gatwick___________________________ Date of Investigation: __ __ / __ __ / __ __

Aircraft Type:B777_______________________________ Date of Event: 26 / 06 / 2003

Engine Type: GE 90 _____________________________ Time of Event: 10.00hrs_ _ : _ _ am

Reg. #: G-VIIA___ ___ ___ ___ ___ ___ ___ Shift of Error: Not Known………………………

Fleet Number: ___ ___ ___ ___ ___ ___ Type of Maintenance (Circle):

ATA #: 52___ ___ ___ ___
1. Line -- If Line, what type? B Check

Aircraft Zone: _________________________________
2. Base --If Base, what type?

Ref. # of previous related event: ___ ___ ___ ___ ___ Date Changes Implemented: __ __ / __ __ / __ __

Section II -- Event

Please select the event (check all that apply)

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

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

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

Air Driven Unit (ADU) bay access door separated during climb, damaging two cabin windows. PAN declared, aircraft returned. AAIB Field investigation.

Section III -- Maintenance Error

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

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

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

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

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

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

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

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

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

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

The aircraft was released to service with only one of the thirteen ADU panel catches locked.

Section IV -- Contributing Factors Checklist

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

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

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

A. 4. Duplicated work cards and the lack of panel location information on the cards encouraged/fostered a norm whereby LAE's told mechanics to close all open panels and then they inspected the aircraft to see that no panels were left open, rather than diligently checking each panel and signing for them on the specific card as the task is performed.

N/A __ **B. Equipment/Tools/Safety Equipment**

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

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

N/A __ **C. Aircraft Design/Configuration/Parts**

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

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

__ **D. Job/Task**

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

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

D. 1. The walk-round inspection by personnel is repetitive with the low likelihood of detecting anything on an aircraft supposedly fully serviceable, thus invoking complacency

N/A __ **E. Technical Knowledge/Skills**

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

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

N/A __

F. Individual Factors

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

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

N/A __

G. Environment/Facilities

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

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

__

H. Organizational Factors

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

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

H. 7. MOE procedure says that tasks defined on the cards are inspected before signing
H. 9. It was a norm for LAE's to sign for tasks that they had not checked.

N/A __

I. Leadership/Supervision

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

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

N/A __

J. Communication

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

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

N/A __

K. Other Contributing Factors (explain below)

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

Section V – Error Prevention Strategies

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

(**X**) **Maintenance Policies or Processes** (specify) *MOE procedure that says that work must be inspected before signing off the work card*

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

Required Maintenance Documentation

- ( ) Maintenance manuals (specify) ____
- ( ) Logbooks (specify) ____
- ( ) Work cards (specify) ____
- ( ) Engineering documents (specify) ____
- ( ) Other (specify) ____

Supporting Documentation

- ( ) Service Bulletins (specify) ____
- ( ) Training materials (specify) ____
- ( ) All-operator letters (specify) ____
- ( ) Inter-company bulletins (specify) ____
- ( ) Other (specify) ____

( ) **Other** (specify) ____

B. List recommendations for error prevention strategies.

Recommen-dation #	Contributing Factor #	

(Use additional pages, as necessary)

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

Provide a brief summary of the event.

AAIB Bulletin 3/2005, ref: EW/C2003/06/04 The ADU access door detached from the aircraft shortly after take off from Gatwick Airport, causing substantial damage to two cabin windows and minor damage to the fuselage and fin. Only one of the thirteen door catches had been fastened and the door had suffered overload failure due to aerodynamic forces as the aircraft accelerated, allowing it to open and detach. Eleven walk-round inspections of the aircraft by different personnel had failed to detect the open catches. The inadequate fastening had apparently occurred during a routine maintenance check due to a deviation from standard procedures; a practice that reportedly had been fostered by features of the maintenance system and may have been commonplace.

Appendix 2 Maintenance Error Definitions

1 Maintenance Control

1.1 An event that is attributed to an ineffective maintenance control system.

1.2 The following are descriptors of the elements of dysfunctional or inadequate maintenance control that produce maintenance errors:

- Airworthiness data – e.g. data that is ambiguous, incorrect or conflicting.
- Airworthiness Directive – e.g. ADs and other mandatory tasks that have been incorrectly or improperly controlled.
- Certification – e.g. omission of certification or improper certification.
- Component robbery – e.g. inadequate control of parts removed from one component or aircraft to be fitted to another.
- Configuration control – e.g. inadequate control of the design or build standard of the aircraft or component such that it remains within the approved Type Design Standard.
- Deferred defect – e.g. inadequate control of allowable deferred defects.
- Inadequate tool control – e.g. hammers, torches, pliers left in the aircraft after maintenance.
- MEL interpretation – e.g. incorrect interpretation of the aircraft MEL.
- Modification control – e.g. unapproved modification of the aircraft or component, or failing to control the modification of an aircraft or component.
- Scheduled tasks – e.g. failure to adequately control known tasks required to be performed on the aircraft or component.
- Technical Log – e.g. omissions or incorrect entries in the aircraft Technical Log.

2 Incomplete Maintenance

2.1 An event is attributed to incomplete maintenance when the prescribed maintenance activity is prematurely terminated.

2.2 This can result in components being:

- not fitted – e.g. panels not properly closed; wire locking omitted; loose caps.
- not set correctly – e.g. engine anti ice valves left in incorrect position; O_2 generator door latches in test position.
- not removed – e.g. component remaining that should have been removed; blanks; landing gear pins; slide bottle pins.

2.3 The above examples all comprise activities that appear towards the end of a maintenance procedure.

3 Incorrect Maintenance Action

3.1 An event is attributed to an incorrect maintenance action when the maintenance procedure is completed but does not achieve its aim through the actions or omissions of the maintainer.

- Incorrect fit – e.g. seals damaged on fit; cross connections; O_2 masks stowed incorrectly.
- Incorrect part – e.g. incorrect bolts and retainers.
- Incorrect procedure – e.g. wrong procedure carried out.
- Incorrect repair – e.g. unapproved weld repairs; incorrect wiring repairs.
- Not fitted – e.g. no oil in the IDG.
- Not set correctly – e.g. wheels not deflated for shipment, incorrect positioning of valves and circuit breakers for MEL release.
- Poor maintenance practice – e.g. failing to clean up residual fluids after leaks or spillage.
- Procedure not adhered to – e.g. actions not in accordance with details of Service Bulletin.
- Not removed – e.g. unapproved blank left in place; speed tape over fuel drain hole.