FINAL REPORT

EASA
European Aviation Safety Agency

Aeronautics & Space Direction

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On demand of the European Aviation Safety Agency (EASA), BUREAU VERITAS conducted a “Study on the need of a common worksheet / work card system” from January to November 2007. The present document presents the results of this study.

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ABBREVIATIONS & ACRONYMS

AAIB	Air Accident Investigation Branch (UK)
AAIU	Air Accident Investigation Unit (Ireland)
AD	Airworthiness Directive
ADREP	Accident/Incident Data Reporting
ADRES	Airbus Documentation Retrieval System
AFM	Aircraft Flight Manual
AIB	Accident Investigation Boards
AIBN	Accident Investigation Board Norway
AMC	Acceptable Means of Compliance
AME	Aircraft Maintenance Engineer
AMM	Aircraft Maintenance Manual
AMP	Aircraft Maintenance Program
ANS	Air Navigation Service
AOC	Air Operator Certificate
AOL	All Operator Letter
AOT	All Operators Telex
ATA	Air Transport Association
ATL	Aircraft Technical Log book
ATP	Advanced TurboProp
ATR	Avions de Transport Regional
BAE	British Aerospace
BEA	Bureau d'Enquête et d'Analyse pour la sécurité de l'aviation civile (France)
BN	Britten Norman
CAA	Civil Aviation Authorities
CAMO	Continuing Airworthiness Management Organisation
CAR	Canadian Aviation Regulations
CD	Compact Disc
CDL	Configuration Deviation List
CIR	Cleaning Inspection and Repair
CIRCA	Communication & Information Resource Centre Administrator
CMM	Component Maintenance Manual
CRS	Certificate for Release to Service
CS	Certification Specifications
DGAC	Direction Générale de l'Aviation Civile (France)
DHC	De Havilland Canada
EASA	European Aviation Safety Agency
EC	European Commission
ECAM	Electronic Centralized Aircraft Monitoring
ECCAIRS	European Coordination Centre for Aviation Incident Reporting Systems
ED	Executive Director of EASA
EIPC	Engine Illustrated Parts Catalog
ERP	Enterprise Resource Planning
EU	European Union
FAA	Federal Aviation Administration (US)
FCOM	Flight Crew Operating Manual
GPIAA	Gabinete de Prevenção e Investigação de Acidentes com Aeronaves (Portugal)
HAESL	Hong-Kong Aero Engine Services Limited
HF	Human Factors
ICAO	International Civil Aviation Organization
IFA	International Federation of Airworthiness

IPC	Illustrated Parts Catalog
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirements
MCC	Maintenance Control Centre
MCM	Maintenance Control Manual
MEDA	Maintenance Error Decision Aid
MEL	Minimum Equipment List
MLG	Main Landing Gear
MMEL	Master Minimum Equipment List
MOE	Maintenance Organisation Exposition
MPD	Maintenance Planning Document
MRB	Maintenance Review Board
MRO	Maintenance, Repair and Overhaul
MSM	Maintenance Safety Manager
N/A	Not Applicable
NAA	National Aviation Authorities
PC	Personal Computer
POCV	Pack Outlet Check Valve
QC	Quality Control
QEC	Quick Engine Change
RIA	Regulatory Impact Assessment
SB	Service Bulletin
SHEL	Software Hardware Environment Liveware
SIL	Service Information Letter
SMM	Safety Management Manual
SMS	Safety Management System
SOOC	System Organization Operations Centre
SOP	Standard Operating Procedure
SP	Safety Policy
STC	Supplemental Type Certificate
TC	Transport Canada
TC	Type Certificate
TSM	Trouble Shooting Manual
TTU	Tolerance Take Up
UK	United Kingdom
US	United States
VAC	Volts Alternating Current
WDM	Wiring Diagram Manual

SUMMARY

The European **Regulation 2042/2003 Annex II (Part 145)** recommends that "The [maintenance] organisation shall provide a common work card or worksheet system to be used throughout relevant parts of the organisation." 145.A.45 (e)

The European Aviation Safety Agency (EASA) entrusted BUREAU VERITAS with the "Study on the need of a common worksheet / work card system" to assess whether a non-common documentation (that is work cards coming from various sources), shared by both the operator (AOC holder) and the maintenance, repair and overhaul organisation (MRO), increases risks in terms of human factors when carrying out maintenance.

The results of the study shall give EASA useful highlights to decide whether the Rulemaking Task 145.020 scheduled to start in 2008 might be postponed or moved forward for safety reasons.

The **Rulemaking Task n° 145.20** examines four options:

1. **"Do nothing":** keep the situation as it stands.
   Commonly the operator provides maintenance data to the MRO, sometimes a few days before the maintenance performance.
2. **Operator's job card system:** the operator provides the MRO with a job card system.
   The operator prepares maintenance data that meets the Part 145 requirements. The contract should reflect this option.
3. **MRO's job card system:** the MRO uses only its internal job card system.
   The operator should use the job cards coming from the MRO. Those job cards should reflect the current status of the aircraft. The contract should reflect this option.
4. **Combined job card system:** a difference is made between line and base maintenance.
   Base maintenance mandates the MRO's job card system and line maintenance allows the operator's job card system.

BUREAU VERITAS carried out the study from January to November 2007.

This study aims at providing further insights on the use of documentation, the common practices in place between operators and maintenance organisations and to assess whether current rules and practices may contribute to incidents / accidents. It should give substantial additional data to execute rulemaking task 145-020, possibly providing new options and making safety recommendations.

Analyzing the results of the collected data, we concluded that none of the four options examined by the Rulemaking Task n° 145.20 seems to be likely to have an effective impact on aviation safety in Europe, and that the best option seems to be the first one: "Keep the situation as it stands". Nonetheless, this option states that nothing needs to be done to ensure a better control of the human factor concern when carrying out maintenance, which is not the case.

The study of common maintenance practices showed that Regulation 2042/2003 (including Part M – Continuing Airworthiness, Part 66 – Certifying Staff, Part 145 - Maintenance Organisation Approvals, and Part 147 – Training Organisation Requirements) should be revised in the aim of reducing the number of accidents or incidents related to maintenance documentation. We proposed three recommendations to improve the Part 145 Regulation. We also made a recommendation for the implementation of a model to implement the safety process in the maintenance organisations, in the aim to obtain more positive results and decrease of errors particularly those related to the documentation.

1 INTRODUCTION

1.1 Regulatory context of the study

As an agency of the European Community, the European Aviation Safety Agency (hereinafter "EASA" or "the Agency") helps the European Commission to shape new rules for aviation safety, in various areas including the approval of organisations and personnel engaged in the maintenance of aeronautical products, and approval of air operations.

Among others, the Agency is responsible for the following rulemaking activities: preparation of guidance material for the application of Community law, and amendments to the Basic Regulation or its implementing rules.

The **Commission Regulation (EC) No 2042/2003 Annex II Part 145 Maintenance Organisation Approvals** recommends that:

"The [maintenance] organisation shall provide a common work card or worksheet system to be used throughout relevant parts of the organisation. In addition, the organisation shall either transcribe accurately the maintenance data (…) onto such work cards or worksheets or make precise reference to the particular maintenance task or tasks contained in such maintenance data. (…)

Where the [maintenance] organisation provides a maintenance service to an aircraft operator who requires their work card or worksheet system to be used, then such work card or worksheet system may be used. In this case, the organisation shall establish a procedure to ensure correct completion of the aircraft operators' work cards or worksheets." 145.A.45 (e) Maintenance data

The **ED Decision No 2003/19/RM Annex II Acceptable Means of Compliance to Part-145** explains that:

"1. Relevant parts of the organisation means with regard to aircraft base maintenance, aircraft line maintenance, engine workshops, mechanical workshops and avionic workshops. Therefore, for example, engine workshops may have a common system throughout such engine workshops that can be different to that used in aircraft maintenance.

2. The work cards should differentiate and specify, when relevant, disassembly, accomplishment of task, reassembly and testing. In the case of a lengthy maintenance task involving a succession of personnel to complete such tasks, it may be necessary to use supplementary work cards or worksheets to indicate what was actually accomplished by each individual person." AMC 145.A.45 (f) Maintenance data

The **Commission Regulation (EC) No 2042/2003 Annex I Part M Continuing Airworthiness** requires that:

"All maintenance shall be performed by qualified personnel, following the methods, techniques, standards and instructions specified in the M.A.401 maintenance data. Furthermore, an independent inspection shall be carried out after any flight safety sensitive maintenance task unless specified by Part-145 or agreed by the competent authority." M.A.402 (a) Performance of maintenance

In this regulatory context, the Agency recalls the following processes:

- The engineering department inside the maintenance organisation shall develop its own maintenance documentation when there is a need, issuing work cards adapted to the nature of the work being undertaken.
- Where the Part-145 organisation provides a maintenance service to an aircraft operator who requires their work card or worksheet system to be used, then such work card or worksheet system may be used. In this case, the Part-145 organisation shall establish a procedure to ensure correct completion of the aircraft operators' work cards or worksheets.
- A difference may be made between line and base maintenance. For line maintenance and non regular operations, the operator has to provide line maintenance organisation with its documentation at outstations.

1.2 Reasons of the study

On the one hand, the Agency received from Aviation Investigation Boards some Safety Recommendations related to incidents and accidents where the documentation had been a contributing factor. EASA noted that:

- Aviation history shows that some incidents or accidents are directly or indirectly due to maintenance errors involving either a misinterpretation or a poor understanding of the documentation or a non-adapted documentation. EASA cites the example of the two following events:
    - Accident of aircraft Airbus A330-243, registration C-GITS, at Lajes Airport, Terceira Islands in the Azores, on 24 August 2001 (Report Ref. 22/ACCID/2001 of GPIAA, the Portuguese Aviation Accidents Prevention and Investigation Department).
    - Incident of aircraft Airbus A340, registration F-GTUB, at Reunion Island, in the Indian Ocean, on 19 April 2002 (registered in the ECCAIRS[1] database).
- Consequent studies demonstrated that one of the best solutions to avoid incidents / accidents related to job cards is to have a common documentation throughout the company and to provide with a parallel to "operations" by ensuring consistency with the check list used by the crew members.
- The worse case scenario in human factor terms, is a non-common documentation shared by both the operator and the maintenance organisation (work cards coming from various sources) at the very last time with a contract putting pressure on on-time delivery (at the level of the maintenance organisation).

On the other hand, the Agency noticed discrepancies among practices in the field, regarding the regulations mentioned above. EASA noted that:

- In fact, the above described processes[2] seem not to be always implemented:
    - The contracts between the operator and the maintenance organisation generally do not include the related provisions.
    - Experience shows that the organisation does rarely introduce in its Maintenance Organisation Exposition a procedure to ensure correct completion of the aircraft operators' work cards or worksheets.
    - Training to the documentation is barely achieved.
    - Correct completion of the worksheets is rarely checked.
- Experience and audits show that some operators only provide the Part 145 organisation with the documentation at a very late stage. It may even happen that the contract between the operator and the Part 145 organisation is signed at the very last moment and the maintenance documentation is not provided on time; consequently the Part 145 uses its own documentation, which may not be fully adapted to the technical status of the aircraft (airworthiness status, repairs, modifications, etc…).

Consequently, the Agency, in liaison with the industry, felt necessary to evaluate the need for ensuring a better control of the human factor elements when carrying out maintenance. The task called n°145.020 should start in 2008 and examine four options:

1. "Do nothing": keep the situation as it stands. Commonly the operators provide maintenance data to the Part 145 organisation, sometimes a few days before the maintenance performance
2. Operator work card / work sheet system: the operator provides the maintenance organisation with documentation that meets the Part 145 work card / work sheet system; the operator will prepare the documentation and the contract should reflect this option
3. Maintenance work card / work sheet system: the operator should only use the job card system coming from the maintenance organisation and reflecting the current technical status of the aircraft; the contract should reflect this option
4. Combined work sheet system: A difference is made between line and base maintenance. Base maintenance mandates the 145 maintenance work card /work sheet system and line maintenance opens the options to use the operator work card / work sheet system.

[1] European Coordination Centre for Aviation Incident Reporting Systems (Cf. § **2.1 ECCAIRS assessment**).
[2] See § **1.1 Regulatory context of the study**

1.3 Content of the study

EASA entrusted BUREAU VERITAS with the “Study on the need of a common worksheet / work card system” to evaluate the impact of maintenance documentation on the Human Factor concern.

This study aims at providing further insights on the use of documentation, the common practices in place between operators and maintenance organisations and to assess whether current rules and practices may contribute to incidents / accidents. It should give substantial additional data to execute rulemaking task 145-020, possibly providing new options and making safety recommendations.

Among other results, the study should produce a list of incidents/accidents related to the use of maintenance documentation. Some outstanding events are expected to be detailed where it is proven that the documentation was directly or indirectly a contributing factor to the incident / accident.

More specifically, EASA asked BUREAU VERITAS to analyse the two events cited above (i.e. accident of aircraft A330-243, registration C-GITS, at Lajes Airport, on 24 August 2001, and incident of aircraft A340, registration F-GTUB, at Reunion Island, on 19 April 2002) and evaluate the lessons learned in relation with the study. The main point is to assess whether contributing factors of such events, in terms of impact of the maintenance documentation, are still at stake.

Furthermore, the study shall provide the necessary instruments for defining policy orientations. Based on the conclusions of the report, EASA should be in a position to evaluate the risks of the use of documentation according to the current practices throughout Europe and assess the decisions to be taken.

Recommendations shall be made. Among others, special recommendations shall be provided in the light of the following concerns:

- Staffing issues. Guidance whenever possible about minimum technical staff quality and qualification for both the operator (or a CAMO) and the MRO to appropriately manage maintenance documentation and contracts (writing, signature, follow up).
- Contracts’ specifications. Amendment to the instructions about maintenance documentation. An estimation of “how long in advance” documentation should be provided is expected. Proposals on the training or on the procedure to ensure a safe completion of the work card / sheet system are also expected.
- The best scenario for managing the maintenance documentation and controlling the human factor elements when carrying out maintenance: What kind of regulatory precautions should be taken to enhance safety if necessary?

As a résumé, the general objectives of the study are to:

1) Bring out statistic figures and detailed reports on accidents/incidents related to maintenance documentation.
2) Gather and analyze data about current rules and common practices in place between operators and maintenance organisations throughout Europe;
3) Assess whether these rules and practices may contribute to incidents or accidents;
4) Provide recommendations that mitigate risks related to third party maintenance, from the preparation of accurate contracts’ specifications to the control of their safe completion;
5) Make suggestion to enhance safety in terms of documentation management and human factors control when carrying out maintenance;
6) Provide conclusions necessary for EASA to make a decision concerning scheduling of the Rulemaking Task 145.020;
7) Collect data and prepare framework for the execution of this rulemaking task, along with the future Regulatory Impact Assessment (RIA).

1.4 Report of the study

The present report describes the results of the "Study on the need of a common worksheet / work cards system" conducted by BUREAU VERITAS from January until November 2007.

The first part of our study aimed at analysing occurrences establishing a relationship between the use of the maintenance documentation and some air incidents or accidents (See § **2 Analysis of Incidents/Accidents**).

We gave a specific attention to the two accidents noticed by the Agency. Analysis of these two events is presented in **Annex B: Accident of aircraft A330, registration C-GITS, on 24 August 2001** and in **Annex C: incident of aircraft A340, registration F-GTUB, on 19 April 2002**.

In the second part of the study, we collected and analysed data about the common practices in place between operators and maintenance organisations, in the purpose of highlighting the current rules relating to the use of the maintenance documentation, and to assess whether these rules and practices may contribute to incidents or accidents. (See § **3 Analysis of Common Practices**).

Our analysis of the collected data is presented in next paragraph (See § **4. Data Analysis**).

Our recommendations are presented in paragraph **5 Recommendations**.

We also contacted the International Federation of Airworthiness (IFA), the French Direction Générale de l'Aviation Civile (DGAC) and Airbus, for the collection of statistical data and the understanding of common practices. We received no answer on the date we delivered this report.

2 ANALYSIS OF INCIDENTS/ACCIDENTS

This part of the study consisted of the two following main tasks, presented in next paragraphs:

- Assessment of the European ECCAIRS database that shall define whether it can be used to gather data on incidents or accidents related to maintenance documentation;
  (§ **2.1 ECCAIRS assessment**)
- Collection and analysis of reports and statistics on incidents and accidents related to maintenance documentation;
  (§ **2.2 Analysis of incidents/accidents reports and statistics**)

2.1 ECCAIRS assessment

A European central report repository exists which is the European Coordination Centre for Aviation Incident Reporting Systems (ECCAIRS). The objective of ECCAIRS is to integrate information from aviation occurrence reporting systems running in the different EU member states.

Therefore, BUREAU VERITAS performed a preliminary study to determine to what extent the ECCAIRS database contains accurate data so that we could use it in the framework of our study.

The assessment of ECCAIRS had to determine if:

- The ECCAIRS database is fully implemented;
- The ECCAIRS database is easily accessible;
- A list of incidents/accidents related to documentation may be produced from this database;
- The ECCAIRS data are complete enough to bring out statistical figures upon incidents/accidents related to maintenance documentation;
- BUREAU VERITAS may be authorized to access (directly or indirectly) to the ECCAIRS database.

In order to carry out this assessment, BUREAU VERITAS contacted members of the ECCAIRS steering committee, asking for details about the ECCAIRS database.

We receive answers from a representative of the ECCAIRS steering committee, who is also a member of the French Bureau d'Enquête et d'Analyse pour la sécurité de l'aviation civile (BEA).

The summation of our questions and associated answers is the following:

- ***Is the ECCAIRS database fully implemented throughout Europe?***

As ECCAIRS is software implementing a database, it is a not really a central database. In practice, each Agency/State of the European Union (EU) has individual installations of ECCAIRS, each using the tool to maintain its own set of data while, on request, exchanging data with other ECCAIRS users. The list of organisations using ECCAIRS is available on: http://eccairs-www.jrc.it/InTheField/Default.htm

In addition, the European Union is in a start-up phase for an integrated occurrence database under European Directive 2003/42/EC on occurrence reporting in civil aviation, but this central repository for occurrence data, although operational from a technical point of view, is not fully operational (as the required input from many States of the EU has not yet been provided).

- ***Is it easily accessible?***

Access to the central repository is subject to the Regulation on dissemination which has not yet the force of law. Thus, even if there is data at hand, no legal way allows accessing it for the moment.

- ***May the ECCAIRS database produce a list of detailed incidents/accidents related to documentation? Is it complete / accurate enough to bring out statistical figures upon incidents/accidents related to an "improper" use of the documentation throughout Europe?***

The issue of job-cards does not form part of the taxonomy. Issues related to documentation can be captured, but it would seem there are not very many reports which have this information in terms of accidents / serious incidents.

At national level, in terms of accidents/serious incidents, BEA is maintaining an ECCAIRS database for France. Some results based on a specific query are provided as an attachment (See **Annex A: Occurrences recorded by the BEA relating to maintenance documentation**).

In terms of reports on occurrences according to the European Directive 2003/42/EC 2003/42, the European Commission has not yet provided a legal base for such access.

As an aside, the ADREP 2000 taxonomy which is implemented in ECCAIRS is currently under review; maintenance is an area that should be better covered in the next revision.

- ***May the ECCAIRS database be accessed by BUREAU VERITAS with required authorizations?***

ECCAIRS is the name given to the current suite of software applications that can be used by aviation authorities, accident investigation bureaus and ANS providers to collect, exchange and analyse accident and incident information. ECCAIRS is also used by International organisations such as ICAO and EASA.

The European Commission believes that under certain conditions, and in the interest of aviation safety, usage by operators / service providers can be allowed.

♦ Conclusions

As stated above:

- The ECCAIRS database is not fully operational (as the required input from many States of the EU has not yet been provided).
- Issue of job-cards does not form part of the taxonomy. Issues related to documentation can be captured, but few reports seem to have this information in terms of accidents / serious incidents.

We concluded that the ECCAIRS database contains no accurate data which may be used to bring out statistics, and detailed reports on incidents or accidents related to maintenance documentation.

The ECCAIRS assessment reveals that the ECCAIRS database cannot produce a list of incidents or accidents related to an improper use of maintenance documentation by selecting appropriate data. Furthermore, the ECCAIRS database is not fully operational, because of a lack of input from many States of the EU. No statistical figures, where incidents or accidents are related to maintenance documentation, can be brought out from this database. This assessment confirmed us in our position that we had to explore other available sources. This exploration is presented hereafter.

Furthermore, when analysing the results of the specific query made by the BEA concerning nine occurrences (accidents or incidents) related to maintenance documentation, we noted that only two occurrences were linked to the public transport, among which only one occurred since the publication of the relevant European legislation in the matter of maintenance organisation approvals (at the end of November 2003).

The two maintenance-related occurrences recorded by the BEA and linked to the public transport, are presented as an annex to the present document (See **Annex A: Occurrences recorded by the BEA relating to maintenance documentation**).

The analysis of the incident of aircraft Airbus A340, registration F-GTUB, at Reunion Island, in the Indian Ocean, on 19 April 2002 is presented in **Annex C: Incident of aircraft A340, registration F-GTUB, on 19/04/2002**.

The serious incident of aircraft ATR 42-300, registration EI-BYO, en route to Cork Airport, on 5 August 2005, is described and analysed with other events selected from other sources (See **Annex D: List of incidents/accidents related to maintenance documentation**).

2.2 Analysis of incidents/accidents reports and statistics

The first part of the study consisted in listing and analysing incidents and accidents related to an **"improper" use** of **maintenance documentation**.

Maintenance documentation includes, but is not limited to:

- Aircraft Maintenance Program (AMP)
- Airworthiness Directives (AD)
- Aircraft Maintenance Manual (AMM)
- Illustrated Parts Catalog (IPC)
- Wiring Diagram Manual (WDM)
- Trouble Shooting Manual (TSM)
- Minimum Equipment List (MMEL) / Configuration Deviation List (CDL)
- Flight Crew Operating Manual (FCOM)
- Aircraft Flight Manual (AFM).

"Improper" use of maintenance documentation means one or more of the following:

- No use of documentation;
- Late use of documentation;
- Partial use of documentation;
- Misreading of documentation;
- No respect of documentation content;
- Use of **incorrect documentation**.

Incorrect documentation refers to:

- Missing documentation;
- Late documentation;
- Obsolete documentation;
- Incomplete documentation;
- Ambiguous documentation;
- Erroneous documentation;
- Complex documentation;
- Inadequate documentation.

On the one hand, the relevant European legislation in the matter of maintenance organisation approvals (Regulation No 2042/2003) was published at the end of November 2003. This new regulation requires the development of a safety culture, and includes the human factor concern derived from past studies of main contributing factors to incidents or accidents, thus amending the previous legislation (JAR-145) as regards the main human factors issues. BUREAU VERITAS decided to take into account those improvements, not turning our attention on past events that occurred under the previous regulation.

On the other hand, approved maintenance organisations are regularly audited by National Aviation Authorities (NAA) to assess their compliance with the current regulation. Then, taking for granted that maintenance activities are most often performed in accordance with the relevant legislation, we tried to find occurrences showing whether those maintenance activities, when performed in accordance with the relevant legislation, may contribute to incidents / accidents. More specifically, we tried to find accidents or incidents bringing into play the approved maintenance documentation under the current regulation.

For those reasons, we focused our search on events which occurred under the new regulation (since January 2004) to find evidence of gaps in this regulation.

Furthermore, according to the Terms of References of the invitation to tender ("*Based on the conclusions of the report, EASA should be in a position to evaluate the risks of the use of documentation according to the current practices throughout Europe and assess the decisions to be taken.*"), we focused our search on occurrences bringing into play either European operators or European maintenance organisations.

♦ Selection of EASA reports

Further to our ECCAIRS assessment results, the Agency proposed to ease our search of data from the ECCAIRS database:
1 – Collecting all relevant data in the ECCAIRS database (Safety Analysis).
2 – Collecting all Safety Recommendations related to the subject and their reports (Accident Investigation).
3 – Providing us with a data package on the CIRCA[3] website.

EASA gave BUREAU VERITAS an access to its Aviation Investigation directory on the CIRCA website which is a Communication & Information Resource Centre Administrator.

We analysed the six occurrences related to Safety Recommendations in the matter of maintenance documentation, put at our disposal by EASA on the CIRCA website. We noted that four occurrences were linked to the public transport, among which only two occurred since the publication of the relevant European legislation in the matter of maintenance organisation approvals (at the end of November 2003).

Thus, we retain the following accidents that we describe and analyse with other events selected from other sources (See **Annex D: List of incidents/accidents related to maintenance documentation**):

- Accident of aircraft ATR 42-320, registration OY-JRJ, at Bergen Airport, on 31 January 2005;
- Accident of aircraft Fairey BN2A Mark III-2 Trislander, registration G-BEVT, at Guernsey Airport, on 23 July 2004.

According to the Agency's request, we also analysed the accident of aircraft Airbus A330-243, registration C-GITS, at Lajes Airport, Terceira Islands in the Azores, on 24 August 2001 (See **Annex B: Incident of aircraft A330, registration C-GITS, on 24/08/2001**), together with the incident aircraft Airbus A340, registration F-GTUB, at Reunion Island, in the Indian Ocean, on 19 April 2002 (See **Annex C: Incident of aircraft A340, registration F-GTUB, on 19/04/2002**).

♦ Selection of European AIB reports

We also searched reports in reporting systems of the following Accident Investigation Boards (AIB), as they publish several reports in English or in French version:

STATE:	**AIB WEBSITE**:
• Denmark	http://www.havarikommissionen.dk
• Czech Republic	http://www.uzpln.cz/
• France	http://www.bea.aero
• Finland	http://www.onnettomuustutkinta.fi
• Germany	http://www.bfu-web.de
• Ireland	http://www.aaiu.ie
• Netherlands	http://www.safetyboard.nl
• Norway	http://www.aibn.no
• Sweden	http://www.havkom.se/index-eng.html
• United Kingdom	http://www.aaib.gov.uk/

[3] Communication & Information Resource Centre Administrator

We scanned those European Accident Investigation Boards websites, using the available selection options to filter in occurrences related to the public transport and to maintenance, as available. Some websites do not offer such possibilities of selection, so that we had to acquaint ourselves with some reports before we could consider if they were relevant or not for our study.

Thus, we read around two hundred available reports written in English or in French and relating to accidents or incidents that occurred in Europe over the last four years, from 2004 until now.

We found 121 occurrences which took place in Europe from 2004 until 2006 and which concern the public transport. We selected 14 events related to maintenance documentation and bringing into play either European operators or European maintenance organisations. The selected events (adding two events we selected for year 2007) are listed and analysed in **Annex D: List of incidents/accidents related to maintenance documentation**.

We outline the results of our selections from AIB websites (excluding the two events for year 2007) in the following table, as a rough indication (Cf. **Table 1: Rough data resulting from the selection task**).

Table 1: Rough data resulting from the selection task

Year	Number of reports related to the public transport in Europe	Number of events related to maintenance documentation	Rate of events related to maintenance documentation
2004	45	7	15.6 %
2005	37	4	10.8 %
2006	39	3	7.7 %
TOTAL	121	14	11.6 %

This shows a trend towards decrease in incidents or accidents related to maintenance documentation throughout Europe. We searched reliable data to confirm or deny this result. BUREAU VERITAS made search of statistic data from sources available on the Internet and on other relevant media (CD, paper, etc.): existing statistical reports, public or private databases…, without success.

The main reasons of this setback are the following:

- As the publication of the relevant European legislation in the matter of maintenance organisation approvals is quite recent, no tangible results of its implementation already exist as regards the safety concern.
- The European central repository for occurrence data is not fully operational (as the required input from many States of the EU has not yet been provided).

When we searched other non-European statistical reports showing the present state of affairs in matter of incidents or accidents related to maintenance documentation throughout the world, we found no evidence corroborating a trend towards decrease in occurrences related to maintenance activities or documentation, as studies do not take into account the contributing factors linked to the maintenance documentation.

♦ Conclusions

Firstly, as the objective of the European central report repository ECCAIRS is to integrate information from aviation occurrence reporting systems running in the different EU member states, a complete implementation of the ECCAIRS database throughout Europe (including the new ADREP 2000 taxonomy which is intended to better handle the maintenance area) would be probably the best means to bring out statistic figures on accidents/incidents related to maintenance documentation. Thus, it would help to measure the real progress brought by the regulation in force, concerning safety in maintenance activities throughout Europe.

That is the reason why EASA member states should be encouraged to operate fully the ECCAIRS system, taking a step beyond existing legal, procedural or cultural problems.

The current ICAO ADREP 2000 taxonomy dated 12 January 2006[4] contains thorough references to human factors detailed according to the SHEL model[5] of ICAO: see the topic "Events" of the ADREP taxonomy, section "Sequence of Events", entry "Explanatory factor subject" (Id: 392), proposing a predefined value list of human factors[6]. Moreover, the ADREP taxonomy is under revision, and should take into account the maintenance area. In this context, BUREAU VERITAS expresses a single remark:

> *In the topic "Aircraft" of the ADREP taxonomy, the section "Aircraft Status" contains an entry to describe the status of the Maintenance documents, i.e. up-to-date or not (Id: 174). This entry proposes the following predefined value list:*
>
> - *Current (The maintenance documents were up to date.)* 1
> - *Not current (The maintenance documents were not up to date.)* 2
> - *Other (Some maintenance documents were up to date others were not.)* 98
> - *Unknown (Whether the maintenance documents were current is unknown.)* 99
>
> *Our remark is that two other entries should be added to describe the status of the Manufacturer's documents, as well as the status of Operator's documents that refers to national rules, operational conditions, etc.*

Secondly, the result of our analysis of occurrences (incidents or accidents), related to maintenance documentation and bringing into play either European operators or European maintenance organisations, shows an origin upstream of the maintenance workshop (See **Annex D: List of incidents/accidents related to maintenance documentation**).

Our selection resulted in 16 events where the maintenance activities have been recognised as a contributing factor or a direct cause of an incident or accident. But a deeper analysis of those occurrences shows clearly that the quality of the manufacturer's documentation is in question. Not saying that it took systematically a direct part in the scenario of the event, but that a better quality of the manufacturer's documentation may have helped to prevent the happening of the event.

This result is reinforced by the analysis of the two accidents noticed by the Agency (See **Annex B: Incident of aircraft A330, registration C-GITS, on 24/08/2001**, **Annex C: Incident of aircraft A340, registration F-GTUB, on 19/04/2002**, **Annex D: List of incidents/accidents related to maintenance documentation**).

Based on the study of incidents/accidents reports, there are no tangible results showing that Regulation 2042/2003 (including Part M – Continuing Airworthiness, Part 66 – Certifying Staff, Part 145 - Maintenance Organisation Approvals, and Part 147 – Training Organisation Requirements) should be revised in the aim of reducing the number of accidents or incidents related to maintenance documentation.

[4] See http://www.icao.int/anb/aig/Taxonomy/R4LDICAO.pdf

[5] Software Hardware Environment Liveware
This model outlines that Human Factors deal with the relations between INDIVIDUAL (Liveware) and DATA (Software), MATERIALS (Hardware), ENVIRONMENT and the other INDIVIDUALS.

[6] See http://www.icao.int/anb/aig/Taxonomy/R4CDExplanatoryFactors.pdf

3 ANALYSIS OF COMMON PRACTICES

3.1 Our methodology

The second part of the study consisted in collecting and analysing common maintenance practices and rules which are actually in place in the European industry. The objective was to provide a good understanding of common practices and inherent difficulties between the operators and the maintenance organisations, including some statistical data about the contract and about financial penalties.

As statistical data were expected as a result of the study, the need to get in touch with a large number of European operators and maintenance organisations led BUREAU VERITAS to conduct a survey to collect data that are necessary to bring out statistics from a representative cross-section.

BUREAU VERITAS constituted a working group of internal full-time or partial-time experts working in aeronautical maintenance, airworthiness certification, quality, aircraft operations ... with a thorough practice of the ground (airline pilots, aircraft mechanics, Part-66 engineers, Part-145 quality auditors and human factors trainers...). Those experts were got together for several meetings (brainstorming) to identify relevant questions and write questionnaires, in accordance with the expectations of EASA. Our main concern was to draw out questionnaires easily and quickly understandable to get accurate answers, for the purpose of collecting relevant items of maintenance contract, maintenance procedures and maintenance working rules/habits, addressing each aspect of the contracted maintenance in terms of communication, control, cost, delay, documents, monitoring, performance, planning, responsibility, training, technical skills, and works, for both parties (i.e. operators and maintenance organisations).

BUREAU VERITAS created two questionnaires to get valuable data about common practices and current rules in place between AOC holders (operators), continuing airworthiness maintenance organisations (CAMO) and maintenance repair & overhaul stations (MRO), in the framework of maintenance sourcing. One questionnaire was dedicated to the operators and the other one was dedicated to the Part-145 organisations. It is a fact that, when reading the Specifications attached to the Invitation to Tender No. EASA/2006/OP/25, the results expected overtake widely the title of the study. Nevertheless, as EASA titled its support letter with the title of the study, we titled our questionnaires in the same way.

BUREAU VERITAS gathered contacts, from fee-paying databases, and other of our favoured contacts. We sent our questionnaires to 140 operators and another one to 46 MRO throughout 26 European countries (EASA members), independently of their fleet size or number of staff. We presented our questionnaires as an opportunity to get data in touch with the industrial reality, which required individual answers. We also ensured that all answers would remain confidential so that the addressees would feel free to answer our questions. Depending on the results of the consultation, some further information might be necessary. Thus, we asked the addressees to indicate if they were allowing us to ask them for further questions by ticking a box and providing us with some contact details. Even if these contact details were to be filled in as part of the questionnaires, according to the will of the addressees, BUREAU VERITAS decided from the beginning not to communicate these detailed data to the Agency, as we had undertaken solemnly to ensure confidentiality.

We send our questionnaires with an EASA accreditation letter on March 2007. We then posted a reminder on April 2007. As a result, and in spite of the accreditation letter that we enclosed to each of our mail and recalls, few operators and maintenance organisations filled and sent back their questionnaire.

The main reasons why we received few replies are:

- The reluctance on the part of the industry to undergo changes in their practices and rules, as EASA informed us during the kick-off meeting in Cologne on February 2007;
- The excessive number of questions (about 40) we asked in these first questionnaires on behalf of EASA;
- A lack of understanding about the relation between the asked questions and the title of the study;
- Some questionnaires never reached the relevant addressees, due to a lack of accurate, direct contact.

For those reasons, BUREAU VERITAS decided to create two simplified questionnaires that present clearly the four options of the Rulemaking Task n°145.020 and briefly ask the operators and the maintenance organisations direct questions about their opinion about these options. These new questionnaires were shorter. We limited the number of questions (10 questions for maintenance organisations and only 8 questions for operators), as a result of which statistical data about the contract and especially about financial penalties can be brought out from these questionnaires as we suppressed the related questions.

BUREAU VERITAS also took benefit of the Paris Air Show (Salon Le Bourget) to take more accurate and direct contacts near operators and maintenance organisation.

We send our simplified questionnaires with the EASA accreditation letter on end of June 2007. We noticed less reluctance on the part of the industry to answer these new questionnaires, getting rapidly answers from some other operators and MROs, in a quite short time following the sending. Nonetheless, we received no more answers, in spite of recall actions with a simplified accreditation letter provided by EASA. With this new support letter, the addressees were supposed to better understand the nature of the survey that BUREAU VERITAS conducted on behalf of the Agency.

BUREAU VERITAS made some visits on the premises of European operators and MROs to get further information, access undisclosed data, and enhance comprehension of their answers to the questionnaires. We planed these visits from mid-August until the beginning of October, according to the availability of the representatives of each organisation.

As a result, we received answers from 15 operators out of 140 contacted operators and from 9 maintenance organisations (MRO) out of 46 contacted MRO. That corresponds to return rates of 10.7 percent for operators and 19.6 percent for maintenance organisations.

The following tables shows the distribution of the 15 European operators and 9 maintenance organisations who answered our questions, according to the classifications chosen by BUREAU VERITAS in order to get the largest point of view about common practices between the operators and the maintenance organisations (See **Table 2: Distribution of the 15 European operators who answered our questions** and **Table 3: Distribution of the 9 European MRO who answered our questions**.)

Table 2: Distribution of the 15 European operators who answered our questions

Fleet size	Operators not Part 145 approved	Operators not Part 145 approved for base maintenance	Operators Part 145 approved with external overhaul contracts
< 10 aircrafts	• 2 operators	• 2 operators	• 1 operator
< 60 aircrafts	• 1 operator	• 5 operators	• 1 operator
> 60 aircrafts	• 1 operator	• 1 operator	• 1 operator

Table 3: Distribution of the 9 European MROs who answered our questions

Staff size	MROs not connected to an operator	MROs connected to an operator having overhaul contracts with other European operators
< 200 people	• 2 maintenance organisations	• 3 maintenance organisations
Between 200 and 1 000 people	• 1 maintenance organisation	• Nil
> 1 000 people	• 1 maintenance organisation	• 2 maintenance organisations

3.2 The results

Thanks to our questionnaires and visits on premises, BUREAU VERITAS collected valuable data about common practices and current rules in place throughout Europe between the different stakeholders of maintenance sourcing: AOC holders (operators), continuing airworthiness maintenance organisations (CAMO) and maintenance repair & overhaul stations (MRO).

We identified the following scenarios between the stakeholders, in the framework of maintenance sourcing:

- The MRO is connected to or subsidiary of an operator (called hereafter "associated operator"):
    - The MRO provides his associated operator with a full integrated service (activities related to Part-M and Part-145 regulations): the MRO uses the approved documentation of the operator;
    - The MRO provides other operators with a full integrated service (activities related to Part-M and Part-145 regulations): the MRO uses the approved documentation of its associated operator;
    - The MRO provides other operators with a turnkey service (activities related to the Part-145 regulation): the operator provides the MRO with the Aircraft Maintenance Manual and a work order (i.e. a list of scheduled maintenance tasks, referring to the AMM). The MRO transcribes the customer's aircraft maintenance programme onto its maintenance management system, and uses its own documents (headed with the MRO's logo);
    - The MRO provides other operators with a liaison engineering service (activities related to the Part-145 regulation): the MRO appends one or more cover-sheets to the customer's documents (because the customer asks the MRO for "dirty fingers" on the provided documentation);
- The MRO is independent (i.e. neither connected to nor subsidiary of an operator):
    - The MRO provides the operator with a turnkey service (activities related to the Part-145 regulation): the operator provides the MRO with the Aircraft Maintenance Manual and a work order (i.e. a list of scheduled maintenance tasks, referring to the AMM). The MRO appends one or more cover-sheets to the customer's documents;
    - The MRO provides the operator with a liaison engineering service (activities related to the Part-145 regulation): the operator provides the MRO with a Job Cards Manual (copied from the manufacturer's task cards). The MRO appends one or more cover-sheets to the customer's documents;
    - For non-routine/out-of-phase inspections and modifications, the operator provides the job cards. For all routine tasks, the MRO's job cards are used (when the MRO owns a job card system, otherwise the manufacturer's job cards are used);
- Case of engine overhaul:
    - The MRO provides the operator with a turnkey service (activities related to the Part-145 regulation): the operator provides the MRO with a list of tasks. The MRO uses the Engine Shop Manual;
- Case of line maintenance:
    - The operator provides the MRO with job cards. The MRO staff is trained by the operator.

Contracts between the operators and the maintenance organisations are not available for commercial and competition reasons. Nonetheless, during discussions we had with operators and maintenance organisations, we noticed that:

- Some contracts require a delivery of the main package at least six weeks before the beginning of the works;
- Some contracts require the provision, at the end of the job, of a document which lists signatures of people who performed the tasks (to enable the control of the correct completion of the tasks).

About the moment when the documentation is given to the MRO, we noticed that:

- In most cases, the main package is delivered at least two weeks before the beginning of the works: up to six weeks for an heavy check (formerly "C-check"), and eight months for the heaviest check (formerly "D-check");
- Very rarely (no slot available, or change in the schedule), the work package is delivered late;
- Few low-cost airlines do some shopping: they discuss the prices with different competitors until the beginning of the job. In that case, job cards are delivered at the very last time.

About the way provisions on the use of documentation are usually carried out, BUREAU VERITAS noticed that, in most cases, the operators presents its work package, and expectations on how to fill it, during a briefing which takes place at least two weeks before the beginning of the works.

Usual procedure to ensure correct completion of the aircraft operators’ work cards or worksheets, when provided by the operator, is the following:

- The MRO appends one or more cover-sheets to the operator's work cards. These coversheets are formatted according to the procedures specified in the Maintenance Organisation Exposition. They contain the MRO's steering information, the accounting information and adding columns for signatures, stamps, etc. (Technical points are taken into account via the job cards while procedural aspects are addressed by the coversheet);
- A copy of the Aircraft Maintenance Manual is attached to the job card;
- An operator's representative (a high-degree engineer) stays on the MRO premises for the follow-up of the job.

No provisions about the financial penalties or statistical data about aircraft leaving the hangar beyond schedule are available for commercial and competition reasons. Nevertheless, some operators complains about the hardness of the market leading some MROs to make up causes of the late delivery of an aircraft, pretending that the operator's responsibility is involved where the real cause is due to findings on another aircraft or due to staff shortage or parts shortage.

About the technical human resources at the engineering department for both the operator and the MRO, in charge of the documentation, we collected the following data;

- Some MROs have strong requirements as regards staff training and qualification, implementing systematically a training module for subcontractors;
- Concerning the training in English, some MROs promotes the following measures:
    - Qualification level depending on the proficiency in English;
    - Training programme supported by incentive bonuses;
    - Use of a simplified technical English (to improve understanding and use of job cards written in English).

About the documentation usually provided either by the operator or by the MRO, we noticed that:

- The maintenance documentation provided by the MRO or by the operators is based on the manufacturer's maintenance documentation: AMM, CMM, IPC, MEL, etc.
- The operator often transmits the revised Aircraft Maintenance Manual to the MRO on CD. MRO's engineers print necessary copies ;
- The MRO produces the extra tasks cards related to the preparation of the job.

Other data we collected about actual practices throughout European contracted maintenance are the following:

- Some activities dedicated to the associated operator contain some tasks subcontracted to a Part-145 organisation located outside the European Union. In that case, the MRO does not systematically control the contractor. The MRO relies on the contractor's Part-145 approval. Nevertheless, the MRO selects people who are proficient in English. In some rare cases of uncertainty about a given contractor, the MRO goes to investigate him;

- Occurrences' reporting is performed accordingly to the Part-145 regulation. Most of them are not given an answer by the manufacturer;
- Engineers most often work with paper documents (paper tasks);
- Some MROs are positioning themselves on the market of urgent checks (differed because of slot unavailability; the latter being often due to staff shortage);
- MROs and operators are subjected to differences in terms of cultures and supervision authorities. The NAA's point of view is the final control;
- Many MROs have no access to the manufacturer's maintenance data;
- Many organisations notice that the number of aircraft increases while the number of available maintenance engineers is decreasing;
- The operator chooses a MRO with the adequate airframe/engine capability for the demanded level of check. Then, the MRO is considered as being competent to understand the operator's documentation (which is often quite the same as the manufacturer's documentation);
- When asked if they had noted events related to job cards, we were answered that the only rare incidents related to job cards were due to their use (problems of negligence), independently of their content or origin (no problem of comprehension);
- Some statistics on internal errors (drawn by operators) show that problems related to the use of job cards are due to:
    - Complexity of the manufacturer's documentation (Aircraft Maintenance Manual). As an example, the change of wheel on landing gear corresponds to 70 pages in the AMM, among which legal terms represent the greatest part;
    - Complacency (the engineer does not refer to the documentation because he deems that he knows it off by heart);
    - Discrepancy in the handover process (no recording of the works done before a task interruption);
- Labour shortage is more and more at stake, so that maintenance works are more frequently differed before being re-scheduled in other slots. In these cases, the operator's approved documentation is lately transmitted to the maintenance organisation. As a result, engineers are lately trained on the operator's documents and have less time to digest their structure and contents before the beginning of the works.

Furthermore, BUREAU VERITAS considered that operators' and maintenance organisations' opinion about the options examined by the Rulemaking Task 145.020 was a valuable input for our study, as they are in touch with the industrial reality.

♦ Option 1: "Do nothing"

This option proposes to keep the situation as it stands. Commonly the operator provides maintenance data to the MRO, sometimes a few days before the maintenance performance.

The raw results of the survey about Option 1 of the Rulemaking Task n° 145.20 (i.e. keep the situation as it stands) are presented in the following table beside corrected results we obtain after interviews with some operators and maintenance organisations (Cf. **Table 4: Results of the survey about Option 1 of the Rulemaking Task n° 145.20**).

Table 4: Results of the survey about Option 1 of the Rulemaking Task n°145.20

Opinion of operators and maintenance organisations about Option 1 of the Rulemaking Task n° 145.20 (i.e. keep the situation as it stands)	**Raw results**		**Corrected results**	
	Agree	Disagree	Agree	Disagree
Opinion of Operators	**75%**	25%	**80%**	20%
Opinion of Maintenance Organisations (MRO)	**75%**	25%	**86%**	14%
TOTAL	**75%**	25%	**82%**	18%

Most **operators** and **maintenance organisations agree** with this option because they have already implemented compromise solutions between different existing scenarios of work and the regulatory requirements.

Some **operators** are **opposed** to this option because the current regulation contains the following gaps and shortcomings:

- Concerning the task cards:
    - Some issues related to task cards are the following:
        - Colour coding disappears in a black and white copy;
        - Some manufacturers' task cards are written in English by people whose English is a foreign language. This leads to an ambiguous wording, meaningless phrases, etc.;
        - Task cards are partially deciphered and interpreted, rather than entirely read and well understood;
    - Standardization of the task cards (depending on each type of aircraft), and of procedures on how to fill those task cards in (using stamps or signatures), may help operators when controlling the correct completion of the tasks;
    - Format of task cards (depending on each type of aircraft), and of procedures on how to fill those task cards in (using stamps or signatures), should be stipulated;
    - Different formats with different contents are manageable. Different formats with the same content are acceptable. Same formats with same contents are beneficial. Same formats with different contents are dangerous;
    - As regards the content of task cards, numerous difficulties come from application of limitations by operators. Especially as concern definition and detection of defects, which may differ from an operator to another, and between the operator and the MRO;
- Concerning the training concern:
    - It would be desirable that the MRO is trained in both aircraft systems and manufacturer's documentation in the framework of the corresponding aircraft qualification (this is not the case since the manufacturer's documentation is only provided to aircraft owners[7]). This training should be completed with a training in STC owner's documentation;

[7] *Note from EASA:* Regulation No 1702/2003 Annex Part 21 states that *"The holder of the type-certificate or restricted type-certificate shall (…) make those instructions [for continued airworthiness, comprising descriptive data and accomplishment instructions] available on request to any (…) person required to comply with any of the terms of those instructions." 21.A.61(a) Instructions for continued airworthiness.* On request should mean for free.

  - Some licensed engineers (Part 66) feel better educated, and develop an excessive feeling of self-confidence (complacency), not consulting necessary data;
  - It is more and more difficult to find experienced licensed engineers (Part 66) on some given type of aircraft, in Europe;
- Concerning the supervision concern:
  - As different supervision authorities do not interpret the regulatory text in the same way, all European operators are not subjected to same regulatory constraints. It leads to problems of unfair competition. Examples of discrepancies are the following:
    - authorisation or interdiction of ramp checks, without the use of a hangar;
    - necessity to sign each item or only each task;
    - necessity to sign each job card or only the coversheet;
    - etc.

Some **maintenance organisations** are **opposed** to this option because the current regulation contains the following gaps and shortcomings:

- Concerning the task cards:
  - Standardization of the task cards (depending on each type of aircraft), and of procedures on how to fill those task cards in (using stamps or signatures), may help maintenance engineers to better understand how to perform the tasks;
  - Standardization of the task cards should be the same for operators and MRO so that those cards would be easily usable whoever provide them;
  - As no specific format exists to design work sheets and work cards, engineers have to manage different formats, which may bother them, thus increasing the number of errors during preparation of the works;
  - Standardization of the task cards would lead to the standardization of the work constraints among all maintenance workshops, creating same conditions of competition for all (for example, same rate of work preparation);
  - Standardization of manufacturer's task cards may help creating homogeneity among operators' and authorities' requirements. Manufacturers' task cards should indicate:
    - Tasks which are critical for the safety concern;
    - Minimum Part-66 qualification required to perform, control, or deliver a CRS for, a given task;
    - Indication on the moment when the control should be performed (end of task, aircraft CRS, etc.);
    - Etc.
  - Manufacturer's task cards should be written using a simplified technical English (to prevent errors of understanding or of translation);
  - Manufacturer's documents should present legal terms and task cards separately (to simplify and encourage their use).
- Concerning the supervision concern:
  - As different supervision authorities do not interpret the regulatory text in the same way, all European maintenance organisations are not subjected to same regulatory constraints. It leads to problems of unfair competition. Examples of discrepancies are the following:
    - Tasks which are critical for the safety concern;
    - Minimum Part-66 qualification required to perform, control, or deliver a CRS for, a given task;
    - Indication on the moment when the control should be performed (end of task, aircraft CRS, etc.);
    - Etc.
  - It is quite easy to address discrepancies between Aviation Authorities. It is more difficult when discrepancies exist between operators under the same Authority.

♦ Option 2: Operator's job card system

This option proposes that the operator provides the MRO with a job card system. The operator prepares maintenance data that meets the Part 145 requirements. The contract should reflect this option.

The raw results of the survey about Option 2 of the Rulemaking Task n° 145.20 (i.e. the operator provides the MRO with a job card system) are presented in the following table beside corrected results we obtain after interviews with some operators and maintenance organisations (Cf. **Table 5: Results of the survey about Option 2 of the Rulemaking Task n° 145.20**). While opinion of MROs seemed to be equally divided between agreement and disagreement when we analysed the answers to our questionnaires, interviews in the field revealed that some maintenance organisations had misunderstood this option. In fact most maintenance organisations were against this option.

Table 5: Results of the survey about Option 2 of the Rulemaking Task n°145.20

Opinion of operators and MRO about Option 2 of the Rulemaking Task n° 145.20 (i.e. the operator provides the MRO with a job card system)	**Raw results**		**Corrected results**	
	Agree	Disagree	Agree	Disagree
Opinion of Operators	**75%**	25%	**70%**	30%
Opinion of Maintenance Organisations (MRO)	**50%**	**50%**	29%	**71%**
TOTAL	**67%**	23%	**53%**	42%

Most **operators agree** with this option because the operator is responsible for continuous airworthiness of its aircraft, which includes delivery of work orders for maintenance activities. So he must provide a job card system.

Other **operators** are **opposed** to this option, due to the following issues:

- This option is incompatible with the possibility given to the operator to subcontract the continuous airworthiness management of its aircraft[8];
- If the MRO's job card system is compatible with the operator's requirements, then it should be possible to use the MRO's job card system.

Considering this option (the operator provides the MRO with a job card system), operators raised the following issues:

- The person who is in charge of the AMP needs to be familiar with maintenance processes and procedures. The operator does not always have the experience needed to create the job cards for example base maintenance or even non-routine cards;
- The operator does not always feel enough competent to train the MRO on its job cards system (i.e. on the manufacturer's job cards system);
- Anyway, the Part M organisation (generally the operator) has the possibility to check and confirm that all the tasks applicable and due are performed in accordance with the Aircraft Maintenance Program (AMP), even if the job cards are prepared by the MRO.

Some **MROs agree** with this option because, in spite of many record and work card systems, as long as work cards contain the same data and are produced in a standardised format, engineers have no difficulty in using different systems.

Most **MROs** are **opposed** to this option, due to the following issues:

- The person who is in charge of the AMP needs to be familiar with maintenance processes and procedures. The operator does not always have the experience needed to create the job cards for example base maintenance or even non-routine cards;
- The operator does not have the experience needed to adapt the manufacturer's task cards in accordance with maintenance processes and procedures (specifying who performs the job, who controls the job, who releases the job, etc.);
- For logistical and planning purposes, some MRO prefer to have their own job cards system (ERP). From the generation of the work package in the acquisition phase of the contract, the production

[8] *Note from EASA:* the regulation allows operators to subcontract some activities of the continuous airworthiness management of an aircraft only under the operators' quality systems. Full control and active involvement is required by the Commercial Air Transport operator.

documentation can be put together in accordance with the work order of the customer;

- Operator's job card system may not be suitable for processes (e.g. production control) in maintenance organisations and may as well not suit MRO's qualification structure;
- Some operators don't have base maintenance job cards because they never do the base maintenance by themselves;
- The operator does not have the knowledge needed to create the job cards that fit into the maintenance organisation;
- The operator does not always have the experience needed to create the job cards for example base maintenance or even non-routine cards.

♦ Option 3: MRO's job card system

This option proposes that the MRO uses only its internal job card system. The operator should use the job cards coming from the MRO. Those job cards should reflect the current status of the aircraft. The contract should reflect this option.

The raw results of the survey about Option 3 of the Rulemaking Task n° 145.20 (i.e. the operator should use the job cards coming from the MRO) are presented in the following table beside corrected results we obtain after interviews with some operators and maintenance organisations (Cf. **Table 6: Results of the survey about Option 3 of the Rulemaking Task n° 145.20**).

Table 6: Results of the survey about Option 3 of the Rulemaking Task n°145.20

Opinion of operators and MRO about Option 3 of the Rulemaking Task n° 145.20 (i.e. the operator should use the job cards coming from the MRO)	**Raw results**		**Corrected results**	
	Agree	Disagree	Agree	Disagree
Opinion of Operators	0%	**100%**	0%	**100%**
Opinion of Maintenance Organisations (MRO)	25%	**75%**	14%	**86%**
TOTAL	9%	**91%**	6%	**94%**

All **operators** are **opposed** to this option, due to the following issues:

- This option rules that the operator makes the choice to contract its Part-M subpart-G activities out to the MRO. This is not always in keeping with the operator's global strategy[9];
- As the operator is responsible for continuous airworthiness of its aircraft, he should retain control of the used documentation (especially in case of line maintenance);
- Only the operator has the full knowledge of the status of the aircraft;
- Using the same task cards, whatever the status of the aircraft can be, may lead to inattention (danger of confusion);
- The operator is responsible for the maintenance programme and is therefore responsible for the content of each task. It is the responsibility of the MRO to carry out the tasks that the operator requires;
- As the operator is responsible for the records, holding completed work cards of the same layout is the easiest option, especially when several different MROs are contracted;
- From the Part-M regulation point of view, the operator has the responsibility of the airworthiness of the fleet and should have the full mastery of the documentation used;
- Some operators use a combination of job cards: for non-routine/out-of-phase inspections and modifications, the operator provides the job cards. For all routine tasks, the MRO's job cards are used (when the MRO owns a job card system, otherwise the manufacturer's job cards are used);
- If the MRO's job card system is not compatible with the operator's requirements, then it should be possible to use the operator's job card system;

[9] *Note from EASA:* Option 3 of the Rulemaking Task n°145.020 is not meant to allow the operator to contract out the Part-M subpart-G activities because the operator has always the final responsibility to check that job cards prepared by the maintenance organisation MRO covers the Aircraft Maintenance Programme (AMP). (Same as previous footnote.)

- Some tasks may result out from reliability experiences, which is the responsibility of the operator. It is the operator who should create cards for these kind of tasks;
- This option would only suit if the MRO is managing the operator's fleet under contract. The MRO should then be responsible for ensuring that the maintenance package is complete, including all relevant mandatory tasks and inspections;
- The job cards should come from the one who transmits the work order (the operator).

Considering this option (the operator should use the job cards coming from the MRO), operators raised the following issues:

- The operator needs maintenance data feedback in the paperwork system compatible with its records system. The operator should provide training to the MRO in the use of his paperwork;
- If the MRO only provides his own paperwork, this may result in significant extra cost and possibility of transcription error in transferring the information into the operator's records system.

Most **MROs** are **opposed** to this option, due to the following issues:

- This option may result in significant extra delays whilst the MRO produces the task cards;
- This option may result in significant extra cost for the MRO who would have to pay an access to the manufacturer's documentation;
- This option may result in significant extra cost and time for the MRO when the manufacturer's task cards are not suitable for the MRO processes (e.g. production control) or the MRO qualification structure or the aircraft status;
- Some operators introduce additional or changed tasks to the Maintenance Program content, to deal with national rules, operational tasks, local conditions, etc. which may not be contained in the MRO system;
- Some operators insist on the use of their job cards (sometimes forced by their legal system: e.g. FAA). MRO sometimes have to make cross references from their own job cards to the operator's job cards to satisfy those requests;
- The operators are responsible for the content of the task cards. The basis for the task cards is in most cases the MRB/MPD or an operator's request. Aim should be to use them everywhere to have a unified standardized task card system, for line and base maintenance activities (same layout).

♦ Option 4: Combined job card system

This option proposes a difference be made between line and base maintenance. Base maintenance mandates the MRO's job card system and line maintenance allows the operator's job card system.

The raw results of the survey about Option 4 of the Rulemaking Task n° 145.20 (i.e. a difference is made between line and base maintenance) are presented in the following table beside corrected results we obtain after interviews with some operators and maintenance organisations (Cf. **Table 7: Results of the survey about Option 4 of the Rulemaking Task n° 145.20**).

Table 7: Results of the survey about Option 4 of the Rulemaking Task n°145.20

Opinion of operators and MRO about Option 4 of the Rulemaking Task n° 145.20 (i.e. a difference is made between line and base maintenance)	**Raw results**		**Corrected results**	
	Agree	Disagree	Agree	Disagree
Opinion of Operators	**50%**	**50%**	40%	**60%**
Opinion of Maintenance Organisations (MRO)	25%	**75%**	14%	**86%**
TOTAL	42%	**58%**	29%	**71%**

Some **operators agree** with this option because a clear segregation between base and line maintenance would be achieved.

Most **operators** are **opposed** to this option, due to the following issues:

- This option shows same drawbacks than Option 3, as concerns base maintenance;

- For line maintenance, the operator's technical log and individual work requests should be accomplished on the operator's paperwork system. For base maintenance, the option of using either the MRO's or operator's job cards should be permitted (defined by contract);
- As the operator is responsible for the records, holding completed work cards of the same layout is the easiest option, especially when several different MROs are contracted;
- From the Part-M regulation point of view, the operator has the responsibility of the airworthiness of the fleet and should have the mastery of the documentation used;
- This is likely to lead to confusion and possible errors;
- Keeping the same layout for a given procedure would avoid incomprehension.

Some **MROs agree** with this option because line work cards tend to be used by dedicated line staff. Then, it is important that the work cards fit the environment.

Most **MROs** are **opposed** to this option, due to the following issues:

- This option shows same drawbacks than Option 3, as concerns base maintenance;
- To have one system is better to prevent possible administrative deficiencies within the performance of MRO. Line maintenance is often registered in the Aircraft Technical Log book (ATL), so this will be no problem at all;
- This option is not flexible enough;
- There should be no difference between line and base maintenance task cards. In most cases, the maintenance personnel perform tasks for both line and base maintenance. To reduce human errors, the architecture of both task cards systems should be the same.

3.3 Conclusions

None of the four options examined by the Rulemaking Task 145.020 fully satisfy the regulatory, organisational, economical constraints that operators and maintenance organisations are faced with. Nevertheless, as stakeholders have already implemented compromise solutions between different existing scenarios of work and the regulatory requirements, in the framework of their Part-M and Part-145 agreement, the best option seems to be the first one: “Keep the situation as it stands”. Nonetheless, this option states that nothing needs to be done to ensure a better control of the human factor concern when carrying out maintenance, which is not the case.

The study of common maintenance practices shows that Regulation 2042/2003 (including Part M – Continuing Airworthiness, Part 66 – Certifying Staff, Part 145 - Maintenance Organisation Approvals, and Part 147 – Training Organisation Requirements) should be revised in the aim of reducing the number of accidents or incidents related to maintenance documentation. This analysis is presented in next paragraph (See § **4. Data Analysis**).

4 DATA ANALYSIS

The third part of the requested study consisted of analyzing the collected data. The objective was to highlight the critical or weak points of scenarios that may currently exist throughout Europe.

Analyzing the data we collected, BUREAU VERITAS identified six different scenarios that describe different relationships that exist between operators and maintenance organisations. The six scenarios synthesize the scenarios we identified between the stakeholders in the framework of maintenance sourcing (See top of paragraph **3.2 The results**). Those scenarios are presented in the following table (See **Table 8: Identified scenarios of relationship between operators and MROs**).

Table 8: Identified scenarios of relationship between operators and MROs

Identified scenario between operators and maintenance organisations	**The operator provides the MRO with a list of tasks linked to the AMM (The operator has no engineering department)**	**The operator demands that the MRO uses the operator's task cards (The operator has an engineering department)**
The MRO has a job card system connected to the operator (The operator has no engineering department)	Scenario 1: The MRO prints the task cards from the operator's AMM by using the related job card system	N/A
The MRO is connected to an operator (with a related job card system) and is contracted by an other operator	Scenario 2: The MRO prints the task cards from the connected operator's AMM by using the related job card system	Scenario 4: The MRO uses the operator's task cards in addition with its own job card system
	Scenario 3: The MRO prints the task cards from the operator's AMM by using its own job card system	
The MRO has an independent job card system	Scenario 3: The MRO prints the task cards from the operator's AMM by using its own job card system	Scenario 4: The MRO uses the operator's task cards in addition with its own job card system
The MRO has no specific job card system	Scenario 5: The MRO prints the task cards from the operator's AMM	Scenario 6: The MRO uses the operator's task cards

Using the collected data, we assessed the risks linked to each of these six scenarios, together with the risks related to four options examined by the Rulemaking Task n° 145.20. The results of the risk assessment, proposing solutions to mitigate the risks, are annexed to the present document (see **Annex E: Risk assessment**).

All of the four options examined by the **Rulemaking Task n° 145.20** shows gaps and shortcomings without any effective positive impact on aviation safety. Risks exist for the different scenarios that describe the relationship between the operators and the maintenance organisations, no matter if they reflect the actual existing practices (Scenarios 1 to 6) or envisaged future practices (Options 2, 3 and 4 of the Rulemaking Task).

Nevertheless, concerning the four options considered by the Rulemaking Task, BUREAU VERITAS considers that, for economical, organisational and safety reasons, Options 2, 3 and 4 do not satisfy the Agency's objective to enhance aviation safety throughout Europe. As concerns Option 1, it is acceptable on the condition that the following solutions are implemented:

- **Solution A**: Standardization of the task cards and of procedures on how to fill them, including:
  - Part-145 requirements;
  - Specific tags to introduce operator's specific tasks and requirements related to the status of the aircraft and to the local conditions of operation;
  - Specific tags to introduce specific tasks and requirements related to the MRO's processes and procedures.
- **Solution B**: Standardization of the interpretation of the regulatory text that is allowed by the supervision authorities.
- **Solution C**:
  Raising consciousness on risks related to complacency during continuous human factors training.

Thus, BUREAU VERITAS brings out the following recommendations from each above solution:

- **Recommendation 1**: The job cards (including the manufacturers' job cards) should be standardized, as regards the layout and the procedure on how to fill them. This standardization should:
  - Describe the Part-145 requirements:
    - Tasks which are critical for the safety concern;
    - Minimum Part-66 qualification required to perform, control, or deliver a CRS for, a given task;
    - Indication on the moment when the control should be performed (end of task, aircraft CRS, etc.);
    - Etc.
  - Contain specific tags to introduce operator's specific tasks and requirements related to the status of the aircraft and to the local conditions of operation;
  - Contain specific tags to introduce specific tasks and requirements related to the MRO's processes and procedures.
  - Be written using a simplified technical English (to prevent errors of understanding or of translation);
  - Present legal terms and task cards separately (to simplify and encourage their use).
- **Recommendation 2**: Explicit guidance should be given to standardize the interpretation of the regulatory texts for all supervision authorities. This standardization should:
  - Clarify the Part-145 requirements:
    - Tasks which are critical for the safety concern;
    - Minimum Part-66 qualification required to perform, control, or deliver a CRS for, a given task;
    - Indication on the moment when the control should be performed (end of task, aircraft CRS, etc.);
    - Authorisation or interdiction of ramp checks;
    - Necessity to sign each item or only each task;
    - Necessity to sign each job card or only the coversheet;
    - Etc.
- **Recommendation 3**: Consciousness on risks related to complacency should be better developed during continuous human factors training.

Recommendation 3 is also connected to the data we collected in the field. In fact, our study revealed that two human factors still create discrepancies between the intended activities and the real acts, in the use of documentation.

These two human factor issues are the following:

- Complacency: documentation is not consulted because it is considered as being well-known.
- Absence of changeover / handover documentation: as they are inherent to their activity, workers do not formalize all momentary interruptions.

These two human factors are already addressed during the continuous human factors training, as required by the Human Factors Training Syllabus (document titled GUIDELINES OF SAFETY SYSTEM AND HUMAN FACTORS APPROACH FOR PART 145 MAINTENANCE ORGANISATIONS), in paragraph 7 Communication (7.1 Shift / Task handover) and paragraph 9 Professionalism and Integrity (9.2 Error provoking behaviour).

Special attention should be given to these two subjects, especially during mandatory refreshing sessions.

Other results of our collection of data are the following:

- Time pressure is an aggravating factor for confusing tasks (unclear task cards, ambiguous instructions, etc.). Nonetheless, time pressure is an economical reality. It is due to numerous factors like staff shortage, or parts shortage.
- Some operators and maintenance organisations complain for shortcomings as concern the manufacturer's documentation quality:
    - The Part-21 regulation does not address the whole human factor concern; CS-25 addresses only the piloting ergonomics (flight deck and piloting instruments);
    - The AMM (general overview) are not approved in the same way than the MOE (detailed review of the content) by the NAA.

  All these gaps forces operators and MRO to implement replacement solutions (less efficient for the safety concern than a root action).

5 RECOMMENDATIONS

5.1 Recommendations as concerns the regulatory texts

♦ **Recommendation 1**

Concerning **Recommendation 1** proposed in paragraph **4 Data Analysis**:

(a) Regulation N°2042/2003 Annex II Part 145 and/or the related ED Decision No 2003/19/RM Annex II Acceptable Means of Compliance to Part 145 should be amended to require a standardized layout for the job cards, and standardized procedures on how to fill them.

(b) Regulation N°1702/2003 Annex Part 21 and/or the related AMC should be amended to require a standardized layout for the manufacturers' job cards, and standardized procedures on how to fill them.

♦ **Recommendation 2**

Concerning **Recommendation 2** proposed in paragraph **4 Data Analysis**:

Regulation N°2042/2003 **Section B Procedure for Competent Authorities** and/or the related ED Decision No 2003/19/RM **Section B** should be amended to require a standardized interpretation of the regulatory texts for all supervision authorities.

♦ **Recommendation 3**

Concerning **Recommendation 3** proposed in paragraph **4 Data Analysis**:

Regulation N°2042/2003 paragraph **145.A.47(c) Production Planning** and the related ED Decision No 2003/19/RM paragraph **AMC 145.A.47(c)** should be amended to take into account all handover issues.

Words underlined in bold in the following texts should be revised to take into account the cases where a single worker faces momentary interruptions. In this case, the regulatory text should stress that the outgoing and incoming personnel may be the same person.

Regulation N°2042/2003
145.A.47 Production planning
(c) When it is required to hand over the continuation or completion of maintenance tasks **for reasons of a shift or personnel changeover**, relevant information shall be adequately communicated between outgoing and incoming personnel.

ED Decision No 2003/19/RM
AMC145.A.47(c) Production planning
The primary objective of the changeover / handover information is to ensure effective communication at the point of handing over the continuation or completion of maintenance actions. 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**.
- 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 planned shift overlap and a place for such **exchanges** to take place.

5.2 Recommendations as concerns the safety policy and HF training

♦ **Recall**

❖ ***Human factors/ error management through the regulation:***

Facility requirements 145.A.25

Manpower / man-hour plan 145.A.30(d)

Competence in human factors 145.A.30(d)

Human factors training for certifying staff 145.A.35(d)

Human factors training for all staff 145.A.30(e)

Human factors training syllabus 145.A.30(e)

Availability of equipment and tools 145.A.40(a)

Procedure for reporting poor or inaccurate maintenance 145.A.45(c)

Availability of maintenance data 145.A.45(f)

Production planning 145.A.47

Production planning taking into account fatigue 145.A.47(b)

Task and shift handover 145.A.47(c)

Occurrence reporting and investigation 145.60(b)

Safety and Quality policy 145.A.65(a) 145.A.70(a)

Procedures to take into account human factors 145.A.65(b)

Design and presentation of procedures 145.A.65(b)

Error capturing 145.A.65(b)

Signing off tasks 145.A.65(b)

MOE additions 145.A.70

Whilst the training requirement for competent authorities does not specifically itemise human factors training, the implication is that such training would need to be included since the requirements states that staff should "be appropriately qualified and have all necessary knowledge, experience and training to perform their allocated tasks" (Part 145.B.10).

❖ ***Safety Management Systems:***

"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."

♦ Impact of maintenance documentation on the Human Factor concern

During this study, it was identified that the human factors and the safety policy were in the centre of the maintenance errors:

- Shift/task handover procedures;
- Procedures for notification of maintenance data inaccuracies and ambiguities to the Type Certificate (TC) holder;
- Human factors training procedure.

This is explained by ICAO through the SHEL model[10].

BUREAU VERITAS thinks the best recommendation in this matter is to **help MROs to implement a safety policy process.**

Presently in most of cases, the Human Factors and Safety Policy (chapter 1.2 of the M.O.E.) are an administrative answer and in the best MRO a good information for their people. In the majority, the MRO haven't understood that Human Factors (HF) & Safety Policy (SP) are the base of the maintenance safety culture and the main base to develop the Safety Management System (SMS).

Finally, we propose a model to implement the safety process in the maintenance organisations to obtain more positive results and the decrease of errors particularly in documentation (See **Annex F: Model to implement a safety process in a maintenance organisation**).

Remark: It could be interesting to train the Civil Aviation Authorities' (CAA) inspectors about HF and SMS. It's one of the ways to have a good understanding about these basic safety concepts through a specific training. Presently there is too much interpretation of the regulation; for example the signature by the certifying staff is only required on the cover sheet for some CAA, while for other all tasks must be "signed"...

The implementation of safety policy and the human factors training should be more developed in the MRO. The objective is to have a best approach of the Safety Management System.

[10] Software Hardware Environment Liveware
This model outlines that Human Factors deal with the relations between INDIVIDUAL (Liveware) and DATA (Software), MATERIALS (Hardware), ENVIRONMENT and the other INDIVIDUALS.

6 CONCLUSION

To meet the objectives of the present study, we firstly assessed the European ECCAIRS database to define to what extent it could be used to gather data on incidents or accidents related to maintenance documentation. We concluded that the ECCAIRS database cannot yet produce such data. Nevertheless, EASA member states should be encouraged to operate fully the ECCAIRS system, as a valuable means to measure the real progress brought by the regulation in force, concerning safety in maintenance activities throughout Europe.

Secondly, we collected and analyzed reports and searched statistics on incidents and accidents related to maintenance documentation, throughout Europe. Our analysis showed an origin upstream of the maintenance workshop, clearly putting in question the quality of the manufacturer's documentation.

It is important to note that preventive measures are more efficient when they are taken early in scenarios leading to an accident/incident. Then, as our results show that the manufacturers' activities play a direct or indirect part in accidents or incidents related to maintenance documentation, we can conclude that a revision of the Regulation 1702/2003 Part 21[11] should be undertaken. Otherwise, modifications in Regulation 2042/2003 would constitute patches that compensate for shortcomings in Regulation 1702/2003. In such a case, operators and maintenance organisations would have to support additional measures to compensate for probable shortcomings in manufacturers' activities (and documentation).

Revision of Regulation 1702/2003 Part 21 seems to be necessary to guarantee that a minimum level of safety is required concerning manufacturers' documentation, including human factor issues.

In the second part of the study, we collected and analyzed common maintenance practices and rules which are actually in place in the European industry. The objective was to provide a good understanding of common practices and inherent difficulties between the operators and the maintenance organisations, including some statistical data about the contract and about financial penalties.

We noticed reluctance on the part of the industry to disclose information about their current working practices. Then, BUREAU VERITAS decided to establish a more casual contact with operators and maintenance organisations, considering that their opinion about the options examined by the Rulemaking Task 145.020 was a valuable input for our study, as they are in touch with the industrial reality.

Analyzing the results of the collected data, we concluded that neither Options 2, 3 & 4 examined by the Rulemaking Task n° 145.20 seem to be likely to have an effective impact on aviation safety in Europe, and that the best option seems to be the first one: "Keep the situation as it stands". Nonetheless, things need to be done to improve control of the human factor concern when carrying out maintenance.

The study of common maintenance practices showed that Regulation 2042/2003 (including Part M – Continuing Airworthiness, Part 66 – Certifying Staff, Part 145 - Maintenance Organisation Approvals, and Part 147 – Training Organisation Requirements) should be revised in the aim of reducing the number of accidents or incidents related to maintenance documentation. We proposed three recommendations to improve the Part 145 Regulation.

As aviation is a human activity, any aviation operation (including maintenance activities) can lead to an accident.

ICAO, Eurocontrol, the European Commission, and even the States, promote safe operations among aviation organizations through statutory and local regulations.

ICAO goes further, promoting an **adaptive** approach to safety, through an SMS implementation. "A rapidly expanding industry and limited resources at oversight authorities make it increasingly difficult to efficiently and effectively sustain a **prescriptive** approach to the management of safety based upon regulatory compliance exclusively."

"Given the nature of the maintenance function, the working environment for AMEs [Maintenance Engineer/Mechanic/Technician], and the many Human Factors issues which may compromise their

[11] Commission Regulation (EC) No 1702/2003 Annex Part 21 Certification of aircraft and related products, parts and appliances, and of design and production organisations

expected performance, a systematic approach to safety is called for, i.e. a safety management system (SMS)." (ICAO – Doc 9859 – Safety Management Manual, §19.2.1)

Preparing the questionnaires, our experts described a lot of bad practices (likely to lead to an accident) they have observed in the field of maintenance, in spite of existing regulations. Reasons are more often a lack of safety culture, at any level of the organizations.

"Safe maintenance organizations foster the conscientious reporting of maintenance errors, especially those that jeopardize airworthiness, so that effective action can be taken. This requires a culture in which staff feels comfortable reporting errors to their supervisor once the errors are recognized." (ICAO – Doc 9859 – Safety Management Manual, §19.3.4)

Even if accidents (and incidents) cost money, those costs are often not taken in account, as they are not as tangible as costs of production. The same problem was encountered few years ago with costs of non-quality.

Even more, as well described by ICAO in its Safety Management Manual, job cards (and more generally maintenance documentation) is not the sole issue when considering maintenance safety.

"The maintenance world incorporates a combination of safety defences, including multiple redundancies of aircraft systems, to strengthen the system. These defences also include such things as certification of maintenance organizations, licensing of AMEs [Maintenance Engineer/Mechanic/Technician], airworthiness directives, detailed SOPs [Standard Operating Procedures], job cards, inspection of work, and sign-offs and records of work completed." (ICAO – Doc 9859 – Safety Management Manual, §19.1.3)

"Risk potential may be created by the conditions under which maintenance is often conducted, including such variables as organizational issues, work site conditions and human performance issues pertinent to aircraft maintenance." (ICAO – Doc 9859 – Safety Management Manual, §19.1.4)

"Maintenance errors are often facilitated by factors beyond the control of the AME, for example:
a) information required to do the job;
b) equipment and tools required;
c) aircraft design limitations;
d) job or task requirements;
e) technical knowledge or skill requirements;
f) factors affecting individual performance (i.e. SHEL factors);
g) environmental or workplace factors;
h) organizational factors such as corporate climate; and
i) leadership and supervision." (ICAO – Doc 9859 – Safety Management Manual, §19.3.3)

There is no doubt that maintenance documentation is linked to a significant number of incidents and accidents. Some occurrences are also avoided thanks to documentation review. Such a good practice should be united, together with other good practices

BUREAU VERITAS is more and more convinced that the safety concern must be addressed as a performance-based approach, as much for maintenance activities as for all other fields in aeronautics.

Seamless management systems, such as the Safety Management System (SMS), give already good results for Air Navigation Providers.

As a conclusion, operators and Part 145 organisations should be encouraged to implement a minimum SMS, depending on their size, to best manage the maintenance documentation, and control human factors when carrying out maintenance. For those reasons, we also recommend the implementation of a model to implement the safety process in the maintenance organisations, in the aim to obtain more positive results and decrease of errors particularly those related to the documentation.

Blagnac, 10 December 2007

Jean-Pierre BATIGNE **Hélène MARTEAU** **Hubert ROUX**

7 ANNEXES

Annex A

Occurrences recorded by the BEA relating to maintenance documentation

Date Heure locale	Lieu Etat d'occurrence	Immat. Catégorie Etat d'immat.	Constructeur / Modèle	Exploitant	Activité	Morts/blessés/indemnes	Dommages	Description succincte	Organisation

Transport public

Incident

Date / Heure locale	Lieu / Etat d'occurrence	Immat. / Catégorie / Etat d'immat.	Constructeur / Modèle	Exploitant	Activité	Morts/blessés/indemnes	Dommages	Description succincte	Organisation
19/04/2002	1h après décollage La réunion Océan Indien	F-GTUB Avion France	AIRBUS A340 - NO SERIES SPECIFIED	Air Lib	Service régulier Intérieur Passagers	0 0 0	Aucun	*Fumée cabine*	BEA France

Déroulement du vol Après une heure trente de vol, alors que l'avion, un A 340, est en croisière au niveau de vol 310, l'équipage sent l'odeur caractéristique d'un court-circuit électrique puis aperçoit de la fumée. Il applique la procédure d'urgence « SMOKE/AVIONICS SMOKE » et fait demi-tour vers l'aérodrome de départ. Quelques minutes plus tard, le message Circuit Breaker Tripped Integrated Light 5LF (système d'éclairage intégré des panneaux et des instruments) s'affiche à l'ECAM. La fumée se dissipe. Après avoir vidangé quarante-trois tonnes de kérosène, l'équipage se pose sans autre problème. Au sol, il est constaté dans la soute avionique que le disjoncteur 5LF INTG LT s'est déclenché. Ce disjoncteur a pour fonction d'isoler le réseau en cas de défaut sur la ligne d'alimentation entre la barre d'alimentation et l'entrée des deux contrôleurs d'éclairage du poste de pilotage 2LF et 6LF (voir schéma ci-après). Il est également constaté que le fusible A d'alimentation du boîtier lighting controller 2LF (boîtier de contrôle d'une partie de l'éclairage intégré du poste de pilotage) est d'un ampérage nettement supérieur à celui requis (6,3 A au lieu de 0,4 A) ; le fond du boîtier présente une coulure de surface importante et les parois latérales et supérieures montrent des traces d'échauffement. Renseignements complémentaires Origine de la fumée L'examen de l'équipement a montré que la fumée provenait d'une surchauffe interne du transformateur de puissance, surchauffe due à l'alimentation simultanée, intempestive et répétée de deux des enroulements du transformateur. L'anomalie de commande des enroulements est issue d'une dérive de fonctionnement de l'un des optocoupleurs TIL 188 de la carte de gestion électronique du contrôleur d'éclairage 2LF. Cette dérive intervient de manière aléatoire en vieillissement sur ce modèle d'équipement. Comme il n'y a pas eu coupure dans les dix secondes, contrairement à la spécification du fusible A du contrôleur d'éclairage 2LF, la surchauffe a entraîné une détérioration profonde des enroulements, le processus de dégradation progressant jusqu'à ce que le seuil de déclenchement du disjoncteur 5LF (3 A) soit atteint. Non conformité du fusible Le boîtier d'éclairage 2LF avait fait l'objet d'une évolution de standard le 23 juin 2000. A la suite d'incidents similaires à celui d'avril 2002 (odeurs de brûlé et émissions de fumée), un Bulletin Service à statut recommandé avait prévu le renforcement du circuit imprimé et l'adjonction d'un fusible de protection sur l'alimentation (fusible A). Ce bulletin avait été appliqué à l'avion. Ni la boîte de fusibles de rechange dans l'avion ni le stock de fusibles de rechange de l'organisme d'entretien n'avaient été actualisés ; il faut noter que le Bulletin Service ne mentionnait pas cette actualisation dans les dispositions à prendre. Un marquage spécifique sur le boîtier indiquant le calibre des fusibles avait été introduit sur les équipements délivrés après juin 2000 pour faire suite aux erreurs constatées régulièrement lors du retour d'équipements chez le fabriquant. Toutefois les documents de référence, à l'exception de l'Aircraft Maintenance Manual, n'ayant pas encore été mis à jour ne représentaient pas ces marquages additionnels. Remarque : les indications gravées sur les fusibles correspondent aux spécifications mais sont difficiles à déchiffrer ; de plus, elles sont différentes de la référence de pièce (part number) figurant dans la documentation à la disposition de l'intervenant. Une SIL (Service Information Letter), rappelant aux exploitants les standards exclusifs à employer lors de remplacements des fusibles, avait été émise par le constructeur le 29 mars 2002, mais elle n'aurait été reçue par l'exploitant que le 5 juin, soit postérieurement à l'incident. Il n'existe aucune trace dans les documents de maintenance quant à une éventuelle intervention sur le fusible A. Toutefois, il y avait eu une intervention en ligne dix jours avant l'incident lors de laquelle, les deux fusibles du boîtier 2LF avaient été vérifiés en continuité, position après position. À cette occasion, le fusible J avait été constaté défectueux, avec un calibre de 0,4 A au lieu de 6,3, et remplacé par croisement avec le fusible N du lighting controller 6LF. Le vol avait ensuite été effectué en tolérance technique. Cette intervention impliquant aussi que le fusible A avait été contrôlé et considéré comme conforme, on ne peut exclure qu'une substitution se soit produite par erreur à cette occasion. Par ailleurs, l'exploitant a vérifié au sol que la tenue d'un fusible de calibrage 0,4 A en position J n'était pas affectée par la mise en fonctionnement du système en consommation maximum, même pendant une durée significative ; ceci conduit à penser que l'origine de la non-conformité de ce fusible pouvait même remonter à la fabrication avec un montage selon la configuration croisée observée (fusibles de 6,3A en position A et 0,4A en position J). Ainsi, il n'est pas possible de dater le montage du fusible non conforme. Il est clair toutefois que les opérations d'entretien n'ont jamais mis en évidence l'inadéquation du calibre du fusible A. Remarques sur la propagation de la fumée. Il n'y a pas eu d'alarme de détection de fumée, bien que la soute avionique soit équipée de détecteurs à ionisation au niveau de ses aérations (ces détecteurs ne sont pas obligatoires). La courte durée d'émission de la fumée, ainsi que la probable dilution de celle-ci par le flot d'air de la conduite d'aération, peuvent expliquer ce non déclenchement des alarmes. Il convient de noter que la philosophie de conception d'Airbus en matière de lutte contre le feu exclut l'utilisation de matériaux inflammables dans la soute avionique. Une fumée dans cette zone ne pourrait donc provenir que d'un feu électrique nécessairement limité. Enseignements A la suite de l'événement, une campagne de vérification de conformité du standard des fusibles a été effectuée par l'exploitant au sein de sa flotte d'A340 . De plus, les TIL188, de conception ancienne, ont été remplacés par des MOC 8050. Les circonstances de cet incident ne conduisent pas à remettre en cause les caractéristiques techniques de l'avion ou la procédure appliquée par l'équipage. En revanche, cet événement a mis en évidence, une nouvelle fois, le rôle de tous les composants d'un avion en matière de sécurité : il est donc indispensable que les documents et procédures d'entretien soient précis et complets et que le système de retour d'expérience y veille en permanence, au-delà des simples modifications de détail.

Date / Heure locale	Lieu / Etat d'occurrence	Immat. / Catégorie / Etat d'immat.	Constructeur / Modèle	Exploitant	Activité	Morts/blessés/indemnes	Dommages	Description succincte	Organisation

Total des Incident (Transport public) : 1

Incident grave

Date / Heure locale	Lieu / Etat d'occurrence	Immat. / Catégorie / Etat d'immat.	Constructeur / Modèle	Exploitant	Activité	Morts/blessés/indemnes	Dommages	Description succincte	Organisation
05/08/2005 13:28:00	En croisière vers Cork Irlande	EI-BYO Avion Irlande	AVIONS DE TRANSPORT REGIONAL ATR 42-300	Aer Arann Teoranta Non applicable	Service régulier Intérieur Passagers	0 0 48	Aucun	*Perte progressive de puissance du moteur n°1, fuite de carburant*	Irlande (AAIU)

- Vol Dublin - Cork (Eire). En croisière, le moteur n°1 perd progressivement de la puissance. L'équipage maintien le moteur en fonctionnement. Après l'atterrissage, une importante fuite de carburant est observée sur les capotages du moteur n°1. Le moteur est coupé lors du roulage. Une canalisation de carburant est trouvée déserrée au niveau du "fuel flow divider". Enquête du AAIU.

Total des Incident grave (Transport public) : 1

Total des occurrences en Transport public : 2

Annex B

Accident of aircraft A330, registration C-GITS, on 24/08/2001

Date: 24/08/2001	*Aircraft Type:* Airbus A330-240	*Aircraft Registration:* C-GITS
Location: Lajes Airport, Azores	*Injuries to persons:* Sixteen minor injuries and two serious injuries, during the emergency evacuation	*Damages to aircraft:* Structural damage to fuselage and main landing gear

Facts: **ACCIDENT**

Emergency all engines-out landing as a result of fuel exhaustion.

Causes:

Use of mismatched fuel and hydraulic lines during the right engine change, causing an in-flight fuel leakage due to the rupture of the high-pressure fuel pump inlet fuel tube, which failed as a result of hard contact with the hydraulic line.

Summary of related engine maintenance events

Source: GPIAA, Portuguese Aviation Accidents Prevention and Investigation Department, Report Ref. 22/ACCID/2001

On 15 August 2001, during a routine inspection of the Airbus 330-243, metal chips were found on the master chip detector in the oil system of the right (Number 2) engine (Rolls-Royce RB211 Trent 772B). On 17 August 2001, there was a second incidence of metal particles in the oil system, and because the origin of the metal could not be identified, the operator decided to replace the engine. Operator’s spare engine was not available; consequently, a Rolls-Royce loaned engine, previously positioned at the operator’s facilities, was used.

The engine change, which commenced at midnight on 17 August 2001, proceeded normally up to the point when it was discovered that the rear hydraulic pump, taken from the removed engine, could not be fitted onto the replacement engine due to an interference with the high pressure fuel pump inlet tube already on the replacement engine.

A search through the Airbus Illustrated Parts Catalogue (IPC) revealed the existence of a Service Bulletin SB.29-C625. It was then realized that the loaned engine, last certified by Hong-Kong Aero Engine Services Limited (HAESL), was in a pre-SB configuration, and the engine being replaced was in a post-SB configuration. The technician leading the engine change could not access the SBs from the available computer terminals, and accepted advice from the maintenance-engineering department that only the rear fuel tube from the engine being replaced needed to be used. According to the technicians, a clearance between the fuel and the adjacent hydraulic tube was obtained.

Upon completion of the engine replacement, inspections were conducted by both the lead technician and another technician and no discrepancies were noted. The engine was successfully ground run and the aircraft was released for flight with a post-SB hydraulic pump, a post-SB.29-C625 fuel tube and a pre-SB.29-C625 hydraulic line.

An examination of the aircraft following the accident determined that both engines stopped due to fuel exhaustion, which was precipitated by a rupture of the high-pressure fuel pump inlet fuel tube on the right engine, which failed as a result of hard contact with the hydraulic line. The engine had accumulated 67.5 flight hours since the engine installation.

Nota:

- *The lease status of the aircraft had no bearing on the control of the aircraft. The maintenance of the aircraft was the responsibility of the air operator.*
- *The aircraft had a valid Certificate of Airworthiness issued on 28 April 1999 when the aircraft was registered to the operator.*

Technical personnel information

Source: GPIAA, Portuguese Aviation Accidents Prevention and Investigation Department, Report Ref. 22/ACCID/2001

♦ Engine Controller

Each engine model of this operator is assigned to an Engine Controller, who liaises with the manufacturer to obtain additional expertise as needed. The controller's responsibility centres on the off-wing maintenance of the engine. The operator's Trent Engine Controller was assigned to this position because of his previous experience with Rolls-Royce engines. He did not hold an Aircraft Maintenance Engineer (AME) licence, nor was he required to.

The Trent Engine Controller worked Monday to Friday, and was on call during the weekend that the engine was being replaced.

♦ Maintenance Technicians

The engine change was carried out by different crews of four to six technicians. Each crew had at least one A330-rated technician, and the crews worked normal 8-hours shifts. The technicians normally worked a sequence of 4 days on then 3 days off. Some worked an extra day with overtime compensation.

The crews were lead by a lead technician holding an AME licence endorsed on the A330 aircraft. He had been selected to supervise the engine change because of his previous experience with three A330 engine changes within the last year. The lead technician normally worked day shift Monday to Friday. On Friday, 17 August 2001, he was called at home around 19:00 hours and asked to lead an engine change the next day. He reported to work on Saturday at 06:30 and worked until 19:00 hours. He was back to work the next morning at 06:30 hours and left upon completion of the engine change at 17:30 hours.

♦ In-house Rolls-Royce Representative

A provision of the aircraft leasing agreement was that the aircraft lessor would position a Rolls-Royce representative with the operator. The representative functioned mainly as a facilitator, assisting the operator and providing a direct communication link with the engine manufacturer. The representative could offer advice, but was not part of, nor responsible for decision-making.

♦ Maintenance Control Centre

The Maintenance Control Centre (MCC) is located in the company's System Organization Operations Centre (SOOC) which operates 24/7 and coordinates all airline operations. The MCC is manned by two aircraft technicians, who analyse anomalies reported by the flight crew and coordinate maintenance resources where and when required. The MCC technicians keep the SOOC informed of time of completion on ongoing maintenance. If requested, and if time is available, the technicians can also provide technical support to maintenance crews.

During the engine change, both AMEs on duty at MCC were endorsed on the A330.

♦ Quality Control

The quality of maintenance carried out is monitored by the Quality Control (QC) manager and delegated inspectors who are all licensed AMEs. The accuracy and quality of work is ensured by two methods: the first is by physical inspection of work done on aircraft; and the second is through the review of logbooks and documentation for accuracy, completeness and validity of certification.

There was no QC person on site during the time that the engine was replaced, nor there was a requirement for one specified in the Maintenance Control Manual (MCC). At the time of the accident, the staff worked Monday to Friday.

Designated supervisors do the day-to-day quality control of work being done. In addition, following the completion of major maintenance tasks, independent inspections are carried out.

Right engine information

Source: GPIAA, Portuguese Aviation Accidents Prevention and Investigation Department, Report Ref. 22/ACCID/2001

♦ Right Engine History

The right engine underwent a post-lease (off-wing) shop visit at Hong-Kong Aero Engine Services Limited (HAESL), which is a Rolls-Royce-approved facility; and, on 31 July 2000, the engine was certified to 772 & 772B rating.

Correspondence with HAESL and Rolls-Royce indicated that the plan was to embody SB.29-C625, modifying the engine dressing of this engine. However, this modification was not done due to parts shortage. Upon completion of the shop visit, the engine was test-run without the hydraulic pumps installed, which is an accepted practice.

Following the HAESL shop visit, the engine was shipped to, and stored at the Air Canada facilities in Toronto at the end of July 2000. On 1 August 2001, in response to a request from the A330 operator that a spare engine be made available at its facilities in Mirabel, Quebec, the engine was sent to the A330 operator. Included in the documentation forwarded with the engine from HAESL were the Rework Summary Sheet, the Carry-Forward Items List and the Engine Log Book.

As requested by Rolls-Royce, the engine was stored in a restricted area to ensure its integrity in the event that it urgently was required by another airline, because this was the only available loaned engine in North America. Access to the engine required notifying the in-house Rolls-Royce representative. Because the engine had to remain available to other world wide users, it was kept in an "as received" status.

♦ Rework Summary Sheet

The Rework Summary Sheet recorded several modifications that were embodied during the post-lease shop visit. It also detailed modifications found embodied, but not documented by the last operator. The Rework Summary Sheet only addressed the SBs for which some action had been taken place during the shop visit. The Rework Summary Sheet did not contain any reference to SB.29-C625, showing that it had not been embodied during the shop visit.

There was no requirement on the part of HAESL to comply with an Airbus recommendation that SBs be embodied at the earliest opportunity, nor a requirement for HAESL to advise potential users of the engine about any SBs that had not been embodied. *The French BEA notes that in fact, it is a requirement for the airline who installs the core engine to check its configuration and receipt and ensure that it complies with the manufacturer's' specifications.*

♦ Carry-forward Items List

Typically, owner-operated and leased engines are forwarded without some accessories, such as starter and hydraulic pumps. These accessories are often referred to as a Quick Engine Change (QEC) kit. The Carry-Forward Items List indicated that 60 additional components would be required when the engine was installed on an aircraft. The list provided pertinent component information, such as the Air Transportation Association (ATA) number, the part number, the part name or description, and the quantity required.

The 60 components on the list included 13 major parts, with the remaining components required for their installation. Items 58 and 61 on the Carry-Forward Items List attached to the loaned engine showed that both front and rear hydraulic pumps required for the installation were post-modification-model hydraulic pumps (of a new Part Number type). Because the engine dressing was not changed during the last shop visit at HAESL, the engine was in the pre-mod configuration, which required a pre-modification-model hydraulic pump (of some previous Part Number type).

♦ Engine Log Book

Regulations require that technical records be maintained on major aircraft components, such as engines. The technical record that accompanied engine received from HAESL was the Engine Log Book, which contained a record of all maintenance performed on the engine, including the SBs embodied. The Engine Log Book, which is the primary document for the engine, accurately reflected the configuration of the engine.

♦ Engine Fuel Tube Rupture

The initial inspection of the right engine following the accident uncovered the presence of an L-shaped crack on the inlet fuel tube wall. In addition, the hydraulic outlet tube (pressure) for the rear hydraulic pump was found to be in hard contact with the fuel tube. The cracking on the fuel tube extended to both sides of a mechanically worn (chafed) area where the tubes came into contact. It was evident that the interference and chafing occurred due to the mismatched installation of the post-mod fuel tube and pre-mod hydraulic tube.

The hydraulic and fuel tubes were sent to the Rolls-Royce Laboratory in Derby, England, for further analysis under the supervision of the United Kingdom Air Accidents Investigation Branch (AAIB). The analysis concluded that the fuel and hydraulic tubes fully matched the drawing characteristics for material, form and shape. The examination concluded that the fuel tube fractured in high cycle fatigue at multiple initiation sites in the bore and the outside diameter, due to combination of vibratory stresses being superimposed on the tube deformation. Also noted were some scratches and deep scores around the chafed location on both tubes. A report stated that these marks are believed to have been made at the time of installation of the engine because this was the only time the post-SB fuel line and pre-SB hydraulic lines were mounted adjacent to one another. The report concluded that the scratches and scores were directionally aligned and that they could have been caused from repeated contact from a blunt instrument, such as a screwdriver being inserted between the tubes in order to force clearance between them. There were no cracks initiated from the score or scratch marks.

Maintenance and technical factors

Source: GPIAA, Portuguese Aviation Accidents Prevention and Investigation Department, Report Ref. 22/ACCID/2001

♦ Review of Service Bulletins

Air Transport Association (ATA) Specification 100 specifies that Service Bulletins (SBs) shall be the only document used by manufacturers to notify operators of recommendations and modifications to their products. An SB is to be used for actions that require a record of accomplishment. If the SB has an airworthiness implication, the regulatory authorities of the country of manufacture generate an Airworthiness Directive (AD) on the related matter to mandate the embodiment of the SB.

SBs carried out or embodied must be documented in the pertinent log book (airframe, engine and/or appliance). SBs determined to be unrelated to a given airframe, engine or component, and those not embodied are not documented. When a modification associated with an SB is embodied during production, the annotation provided in log book by Airbus will be the modification number with a brief description of the modification; the description does not reference the SB number.

On 21 April 1999, in reaction to several cases of hydraulic fluid leakage at the hydraulic pump or attached hydraulic lines, Airbus published an optional SB offering a modified hydraulic pump.

Because the pump was mounted on the engine, Rolls-Royce issued the following two SBs (from 15 January 1999): an optional SB detailing the replacement of the hydraulic pump; and SB.29-C625 detailing modifications to the engine dressing to accommodate the widened pump housing and the resulting interference with the adjacent fuel line. Modification of the dressing consisted of the replacement of the three fuel tubes and two hydraulic tubes for the front and rear hydraulic pumps. The optional SB outlined the requirement that SB.29-C625 be fitted prior to or concurrently with its embodiment. SB.29-C625 stated that it was essential that the tubes be fitted as a set.

The two Rolls-Royce SBs were not incorporated at the time of manufacture of the loaned engine, nor during the last shop visit due to the unavailability of parts. The A330 aircraft involved in the event was post-mod status when acquired by the operator. Embodiments of the SB are documented by Airbus in the airframe log as modification.

The common method used by maintainers to determine the current status of an aircraft is to compare the pertinent airframe, engine or component logbooks against the list published by the manufacturer. There is no requirement to re-examine the content of the SBs that are recorded as being embodied.

The most thorough method of confirming parity between an engine being removed and the one replacing it; is to mirror each engine log book against one another. In addition, the SB main index list would have to be scrutinized for every unmatched SB to assess the possibility of concurrent requirements.

This method would have required the comparison of 167 SBs in the case of the replacement engine.

An alternative method, suggested after the accident by the engine manufacturer as a quicker means of establishing SB parity, would be to inspect the major components that are to be installed, against the Engine Illustrated Parts Catalogue (EIPC) to check for any associated SB. This method, in the case of the loaned engine, would have reduced the number of SBs to be checked for applicability from 167 to 13.

If and when an SB is found to apply, it would have to be reviewed for other part number applicability and for any concurrent requirement.

Because of the airworthiness implication, Transport Canada (TC) audits the lists of ADs and mandatory SBs, as well as the completeness of their embodiment. Recommended or optional SBs are not given the same level by the operator, nor are they audited by Transport Canada.

Non-mandatory SBs (having an optional or recommended compliance) are not reviewed by the maintenance supervisors of the A330 operator. The operator's Engineering Section leads these reviews with senior management. Although maintenance crews may be aware of specific SBs, the crews are not part of the embodiment decision-making process.

None of the two Rolls-Royce SBs went through the reviewing process of the A330 operator, specifically because its A330 aircraft, including the one involved in the event, were post-SB mod status when acquired. This situation also meant that the operator's maintenance management had not been exposed to these pre-SB aircraft or to the associated SBs.

♦ Review of Illustrated Parts Catalogues

An Illustrated Parts Catalogue (IPC) is a document that is intended for use in identifying, provisioning, requisitioning, storing and issuing line replacement aircraft parts and units. An IPC includes all parts for which a maintenance practice has been provided.

There are two IPCs that can be referenced by technicians when performing maintenance on the Tren-772 engine dressing: the Airbus A330 IPC, and the Rolls-Royce Engine Illustrated Parts Catalogue (EIPC).

The Airbus IPC, also referred to as ADRES (Airbus Documentation Retrieval System) specifies the configuration status of each aircraft by serial number. It lists the current aircraft parts applicability and includes a note informing the reader of the embodied SB.

The Rolls-Royce EIPC for the Trent 772B engine series also contains relevant SBs.

The Airbus IPC, Rolls-Royce EIPC and associated SBs are available on the company computer network. These documents are also available on standalone PCs and CDs at the MCC station and in the operator's Technical Library. Additionally, a paper copy of each SB is held in the operator's Technical Library, under controlled access, in order to preserve its integrity. Technicians rarely, if ever, access either the library's hard copy or the standalone CDs; maintenance management more commonly uses them.

Neither the Airbus IPC, nor Rolls-Royce EIPC was referenced at the time of engine receipt, or during review by engineering prior to the engine installation. The Airbus IPC was referenced by the lead technician during the engine installation.

♦ Receipt and Inventory of Engines

Subpart 571.13 of Canadian Aviation Regulations (CARs) requires that no person shall install a part on an aeronautical product unless the part is inspected and its accompanying documentation verified in accordance with a procedure that ensures that the part conforms to its type design, as is indicated by the maintenance release.

In this regard, the operator's Maintenance Control Manual (MCM) contains a procedure that requires incoming parts and materials be subjected to a receiving inspection in order to verify that the subject items are acceptable for use on company aircraft.

When the loaned engine arrived at the operator's facility, the engine controller compared the status of the engine to the Rework Summary Sheet and the Carry-Forward Items List. He was satisfied that the components on the Carry-Forward Items List were available either in stock, or off any engine that might require replacement. The review of documentation and receiving inspection did not detect that the engine condition was in the pre-mod (SB.29-C625) configuration.

♦ Engine Change Planning

Maintenance falls into two major categories: scheduled routine maintenance; and unscheduled defect rectification.

The presence of metal particles on the original right engine on 17 August 2001 required an unscheduled engine change. Various options for the engine replacement were considered, including outside contracting. Notwithstanding, after confirming the availability of experienced operator technicians, it was decided, late Friday afternoon, that the work could be done using in-house resources, with the work starting at midnight the same day.

To support the work required for the engine change, the relevant work-card package was extracted from the Airbus ADRES. The package contained all applicable references to the Maintenance Manual. As per the maintenance procedure of the Maintenance Control Manual (MCM), the installation of the carried-forward items was to be documented on additional work sheets.

These sheets were to be completed during the course of the engine change. Because the pre-mod configuration of the engine had not been identified, no work sheets were issued to address the applicable SBs.

♦ Right Engine Replacement

Subpart 571.02 of Canadian Aviation Regulations (CARs) requires that a person who performs maintenance or elementary work on an aeronautical product shall use the most recent methods, techniques, practices, parts, materials, tools, equipment and test apparatuses, as follows:

- Those that are specified for the aeronautical product in the most recent maintenance manual or instructions for continued airworthiness developed by the manufacturer of that aeronautical product;
- Those that are equivalent to those specified by the manufacturer of that aeronautical product in the most recent maintenance manual; or,
- Those instructions for continued airworthiness, or in accordance with recognized industry practices at the time the maintenance or elementary work is performed.

Subpart 571.13 of CARs requires the inspection of a part to be installed and verification of the accompanying documentation to that the part to ensure that it conforms to its type design, as is indicated by the maintenance release. Subpart 571.08 (1) (a) states that these requirements do not apply for used parts which are removed serviceable from an aircraft and which are immediately installed on another aircraft. Notwithstanding, Subpart 571.08 applies to components of identical part number; the IPC must be referenced in every other case.

The engine change started around midnight on Friday, 17 August 2001, with the removal of accessories from the engine being removed. It was assessed that the work could be completed by Sunday, noon to meet the commitment of the aircraft for the scheduled flight and commitment of the hangar space for another use. On Saturday morning, at 06:30, 18 August 2001, the lead technician met with the night crew for a shift hand-over briefing.

Some delays were incurred around midday due to the late arrival of a leased jacking pad. The Rolls-Royce representative visited the hangar during the day to keep updated on the progress of the engine change. At the end of the day, the lead technician handed over the hanging of the replacement engine to the night shift. Even though the work had progressed at a somewhat slower pace than planned, no remarkable difficulties were encountered.

The lead technician returned to work early on Sunday morning. Shortly after commencing his shift, he was advised that the rear hydraulic pump could not be fitted due to interference with the high-pressure fuel pump inlet tube. A search through the Airbus IPC revealed the existence of SB.29-C625 and of pre- and post-SB configurations. At this time, the lead technician realized that the replacement engine was in a pre-SB configuration, while the removed engine was post-SB.

The lead technician attempted to access the SB from Rolls-Royce EIPC CD installed on the network using three different computer stations. All attempts resulted in access being denied, as a result of a computer network malfunction.

The lead technician then contacted the MCC, who in turn paged the operator's Trent Engine Controller for advice. While waiting for the Trent Engine Controller to return the call, the MCC technician attempted to access the Rolls-Royce EIPC and the SBs through the computer network, but was also denied access. While MCC had its own stand-alone maintenance EIPC CDs, including the SBs, they were not used.

The use of the EIPC CDs was not considered by the lead technician because he was not aware of this capability in the MCC. The use of the CDs by the MCC technicians was not considered because their role in providing technical assistance to maintenance crews was to locate resources and not to provide technical assistance in searching for technical references.

When the Trent Engine Controller called back, he readily recalled the rationale for the pump modification as being excess vibration. He also recalled that the modified pump interfered with the fuel lines, and that these would need to be replaced. He further advised the lead technician to confirm that, when the pump and lines were installed, adequate clearances existed between lines and components. The lead technician queried the possibilities of using a pre-mod pump to save time, because the work was already running late. Based on his knowledge that all operator's aircraft were of post-mod status, as were all other Roll Royce powered A330 flown in Canada by other operators, the Engine Controller informed the lead technician that such a pump was not available on short notice. Both agreed that there was no choice other than to replace the fuel tubes. In discussing the estimated time required to complete the transfer of the tubes, the controller suggested that the time outlined in the SB should be used.

At this time, the controller was told, in passing, that the crew had not been able to access the SB. While the difficulty in accessing the SB initially was a concern, the discussion quickly reverted to the time required to complete the work, without further discussion of the SB. The controller was advised that he would be kept informed of the situation.

Both segments of the post-SB fuel tube assembly were taken from the removed engine and installed on the replacement engine. The different shape and routing of the new fuel line overcame the earlier difficulties encountered in installing the hydraulic pump. The pre-SB hydraulic tube, received with the loaned engine, was retained. The installing technician recalled that, during the installation of the hydraulic line when trying to achieve the required separation between the fuel and hydraulic line, the hydraulic line had a tendency to spring back. Notwithstanding, according to the technician who did the installation, clearance between components was easily obtained by positioning and holding the hydraulic tube, while applying torque to the "B" nut. He also stated that a tool was not used to force the separation between the fuel and hydraulic tubes. There was no additional installation difficulties reported.

The Rolls-Royce representative telephoned MCC during the engine installation on Sunday to inquire about the work progress and to offer help if required. He was informed that the pre-mod status of the loaned (right) engine did not permit installation of the hydraulic pump and was informed that the fuel tube was being changed over from the removed engine to the loaned (right) engine to allow the pump installation. The Rolls-Royce representative was unaware of the engine dressing SB modification status of the loaned engine and of the status of the operator's engine fleet. The Rolls-Royce representative was not specifically told of the difficulties in accessing the SBs nor was he specifically asked to consult his documentation. His offer to attend on-site if required was not taken up.

The installation of the post-mod hydraulic pump, the pre-mod hydraulic tube and the post-mod fuel tube assembly resulted in a mismatch between the fuel and hydraulic tubes.

When the engine change was completed, the lead technician arranged for an independent inspection.

♦ Pressure Line Installation

Both ends of the hydraulic line connecting the pump to the pylon are rigid; the middle section is flexible to assist in dampening hydraulic pump pulsations. The line routing includes a 90-degree bend near the hydraulic pump connector.

During the installation of the line on the loaned engine, pulling to position the line away from the fuel tube would have resulted in some rotation of the hydraulic tube flange under the "B" nut. Torquing of the "B" nut would have provided force on the flanges to counteract the tendency for the flange to rotate back to its normal position. Pressurizing the hydraulic line would result in a force to straighten the line, which would result in force to rotate the flange to a position that would eliminate the separation between the fuel and hydraulic lines.

The standards and procedures for installing hydraulic lines built with middle, flexible portion are not specified in the training manuals. The issue also is not addressed in widely known technical aviation reference manuals. All these manuals treat rigid tubing and flexible hoses as different issues. The illustration provided in these manuals for flexible hoses indicates that a slight bow is desirable to allow for shortening when pressurized.

A visit to a government-sponsored regional aerospace training school in Canada also revealed that, although training covers the installation of both rigid and flexible lines, training is not given on the installation of mixed-construction lines similar the hydraulic line on the Trent engine. The criteria for training programs and practical tests do not comment on the risks of using torque as a means of positioning such lines during component installation.

Tubes constructed of both rigid and flexible sections are used throughout the aviation industry. They are used extensively in many airframe and engine combinations for a variety of hydraulic fluid, oil, or fuel system applications.

♦ Documentation of Work Done

Operator's MCM section 1.4.3 outlines that the rectification of defects must be appropriately entered in the log. Consequently, the switching of the tubes from the removed engine to the loaned (right) engine should have been recorded in both, the removed and installed engine logs.

A review of the log book, after the accident, showed that entries for all expected components changed over to the installed right engine had been properly made, signed and countersigned by the supervisor; however, the recording of the unexpected replacement of the fuel tubes was not documented.

♦ Quality Control

Following completion of the engine change, the lead technician inspected all the work done and the tasks documented on the work cards and additional work sheets. The inspection was to ensure that the work was complete, within tolerances and secured. His inspection did not uncover any anomaly with the engine installation.

Another inspection called "the independent inspection" was done by a qualified technician, who had not been involved with the work being inspected. The independent inspection was done to ensure that engine controls are properly connected and secured. This scope of this inspection was not intended to include the fuel or hydraulic system components.

Following these inspections, the engine was ground run, without problems, and was released for flight.

The company MCM specifies a requirement for a quality control inspection of the documentation after an engine installation; however, company manuals do not specify a time frame for this inspection. There was no QC representative on site on the weekend of the engine installation. The company plan was to do the document verification when preparing the removed engine for shipment for repair. As of the occurrence date, 24 August 2001, the engine change documentation had not yet been reviewed by the quality control staff.

Analysis of technical issues

Source: GPIAA, Portuguese Aviation Accidents Prevention and Investigation Department, Report Ref. 22/ACCID/2001

♦ General

The investigation determined that the double-engine flameout was caused by fuel exhaustion, which was precipitated by a fuel leak developing in the right engine as the result of the use of mismatched fuel and hydraulic lines during the installation of the hydraulic pump.

The maintenance managers, supervisors and technicians responsible for the receipt, planning, installation and associated inspections were qualified to do their assigned responsibilities.

Part of the GPIAA analysis focused on determining why the aircraft maintenance organisation did not detect the mismatch in engine configurations prior to starting the engine change; then why, once the configuration difference was detected during the engine change, the installation of the hydraulic pump and hydraulic and fuel lines was not completed in accordance with manufacturer's specifications.

♦ Engine Receipt

When the spare engine arrived at the company's premises on 1 August 2001, it was processed in accordance with the operator's MCM procedures. The process only involved an inventory check and verification that the parts on the Carry-Forward Items List were available. Because the engine was positioned at Mirabel, solely as a contingency measure, and there were no immediate plans to install the engine on a company aircraft, the engine remained under the control of the engine manufacturer's representative. Neither the MCM, nor Canadian regulations, require SBs to be checked as part of this type of inventory check.

This check was based on a comparison of the spare engine against the Rework Summary Sheet and the Carry-Forward Items List provided by the company that had completed the last shop visit of the engine. Based on the available information and a visual inspection of the condition of the engine, it was assessed that the required parts were available if and when an engine change to one of the company's A330 became necessary. Of importance to this occurrence, the engine receiving process did not identify that the configuration of the loaned engine did not match the configuration of the other A330 engines at the company.

The following factors may have influenced this incorrect assessment:

- Because all the A330 engines in use at the company were in the post-SB configuration and the company personnel had never been involved with pre-SB configured engines, there was no information that would have caused a heightened concern regarding the configuration of the loaned engine.
- The physical appearance of the pre-SB and post-SB configurations are similar and cannot be identified through a cursory inspection such as is conducted during engine receipt.
- The part number of the hydraulic pump, as documented in the carry-forward list, was incorrectly identified as a post-SB hydraulic pump, with a post-SB Part Number; and
- Hydraulic pump, with a post-SB Part Number, was installed on other company A330 aircraft.

♦ Engine Change Planning

ATA identifies SBs as the only means for the manufacturer to notify operators of a product modification. Comparing the status of non-mandatory SBs on components of the same part number, such as an engine, is not a method generally used to assure inter-changeability, for the following reasons:

- There is no regulatory requirement to do so;
- The absence of documentation on non-mandatory SBs does not constitute a risk to safety;
- The number of non-mandatory SBs that may apply to a major aircraft component may be very large, and conducting the comparison would be time consuming; and
- The IPC contains all the information regarding the applicability of SBs.

A comprehensive comparison of SBs embodied on the engines is the fullest guarantee to confirm the lack of disparities during planning phases. Such a check would only be reasonable once it is known which engine is to be replaced.

The TC-approved MCM did not require that non-mandatory SBs be checked when planning for an engine change; consequently, a comparison of SBs was not carried out at the time of engine receipt, nor during the planning of the engine change.

Although the spare engine had been positioned at the company's Mirabel location to facilitate an engine change to one of the company's A330 aircraft, there was no immediate intent to use the engine. Consequently, planning for the engine change did not commence until after the metal particles were found in the engine oil system of the occurrence aircraft and the decision was made to replace the engine in-house.

Because the company maintenance planners were not aware of the differences in configuration between the two engines, the only work cards that were generated were those associated with a normal engine change. Additional work sheets for the installation of the carry-forward items were to be completed during the course of the engine change.

The fact that the differences in engine configuration were not identified during the receipt and planning phases, resulted in a situation wherein the responsibility to detect the incompatibility between the hydraulic pump and the fuel and hydraulic lines was deferred to the technicians doing the engine change.

♦ Engine Installation

❖ *Initial Detection of the Configuration Problem*

During the course of the engine replacement, the interference noticed between the hydraulic pump and the fuel tube was the first indication of a problem with the changeover of the hydraulic pump to the engine that was being installed on the occurrence aircraft.

Once it was realised that the difficulty with the hydraulic pump installation could be related to the differing SB status, the lead technician attempted to view the SB. However, he could not access the SB on the Rolls-Royce EIPC CD from his work station due to a network problem. Not being able to access the SB through the network, the lead technician sought engineering guidance via MCC as per the MCM procedures. Neither the lead technician nor the MCC considered accessing the SB through the Trent EIPC on a stand-alone computer. Had the Trent EIPC been used, access to the SB would have been achieved. Access to the SB would have revealed that there were two interrelated SBs that required replacement of the fuel tube and the hydraulic line, as well as other associated components.

When the lead technician contacted the Engine Controller, the Engine Controller's knowledge of the SB and its background comforted the lead technician into feeling that the Engine Controller had a good grasp of the problem at hand. Acknowledgement by the Engine Controller that the fuel tube needed to be replaced confirmed the lead technician's mental model that this was the only requirement for completion of the installation. The confirmation was reinforced by the fact that the Engine Controller was associated with the engineering department, which had the responsibility for resolving unexpected or non-routine maintenance issues.

During discussions on the estimated time for completing the engine change, the Engine Controller was made aware that the lead technician had been unable to access the SB. Although both individuals acknowledged that the unavailability of the SBs was of concern, the discussion reverted to the issue of work completion time, and no further discussion of the SB took place. Effectively, the Engine Controller and the lead technician agreed to the fuel tube transfer with no further reference to the SB.

There was also the time-pressure factor to complete the work in time for a scheduled flight and to clear the hangar for an upcoming event. This pressure also may have played a role in reliance on direct and personal information about the SB, rather than trying to resolve the existing problem of not being able to access the SBs.

With the solution at hand, being behind schedule, and having spoken to the Engine Controller, the lead technician felt confident that the fuel tube replacement was the only remaining requirement to complete the hydraulic pump installation.

❖ *Fuel Tube Installation*

Exchanging the fuel tube was considered by the lead technician to be a maintenance action similar to the changing-over of other components on the Carry-Forward Items List. He believed that the replacement of the fuel tube would establish the engine configuration in the post-mod status.

Although it was recognized that the fuel tube from the replaced engine was different from the one being removed from the engine being installed, the aircraft IPC entry was not referenced.

Adequate clearance between the fuel and hydraulic lines reportedly was achieved during the installation of the hydraulic pump line by applying some force to position the line and holding the line while applying torque to the "B" nut. This clearance subsequently was verified by the lead technician.

Although it is not abnormal that a line be positioned to achieve clearances in this manner, if clamping is not used, the tendency is for a flexible line to straighten when pressurised. This is particularly critical when there is a 90º bend in the tube adjacent to the "B" nut, as was the case for this installation. The risk associated with the application of force while installing mixed construction lines is not well known in the maintenance community, and is not covered in the training of maintenance technicians.

Although the marks on the fuel and hydraulic tubes suggest that some implement may have been used to assist in establishing clearance between the tubes, technicians denied that tools were used in this manner. The investigation could not resolve this issue.

The pressurization of the hydraulic line would have been sufficient to cause the hydraulic line to move back to its natural position and come in contact with the fuel line, which resulted in the chafing and failure of the fuel line.

♦ Quality Control Issues

❖ *Maintenance inspection*

Post-installation inspections of the engine change were done both by the lead technician and another independent inspector. However, the inspections were limited to ensuring that engine controls were properly connected and secured, and that the remaining work was complete, was within tolerances and was secured. The methods used for these inspections would not very likely detect a mismatch in components, and for the occurrence engine did not detect the incompatibility of the fuel and hydraulic lines that existed.

❖ *Quality Assurance Documentation Checks*

Neither the aircraft nor the engine log recorded the fuel line change because the technician forgot to make the entry. In addition the verification of the documentation associated with the engine change completed on 18 August 2001 was not done before the occurrence flight. Consequently, the opportunity for the quality assurance review of the documentation to detect the installation error was negated.

Notwithstanding, because it is limited to verifying that the documentation is complete, the quality assurance verification of the aircraft and engine maintenance logs would likely not have detected that the installation of the hydraulic pump and fuel line was not in accordance with applicable SBs.

Rather than relying on a post-maintenance review of the engine documentation, the presence of a quality control representative during the engine installation may have facilitated the research into the interference problem and the full implementation of the SB prior to the release of the aircraft.

❖ *Configuration Control*

The investigation determined that the engine was received in an unexpected pre-SB configuration to which the operator had not previously been exposed. Also, the identification of a component is first and foremost carried out through its part numbering. The documentation attached to the loaned engine, in using a part number for a post-SB hydraulic pump, may have masked the pre-SB engine configuration until near completion of the engine change. Typically components of different configurations are identified via a part number prefix, suffix or dash number; however, this is not practical for complex components, such as modern aircraft engines.

Non-mandatory SBs may not directly impact on airworthiness when embodied on their own. However, when two or more interrelated non-mandatory SBs, with interacting components, are not carried out in tandem they have the potential to degrade airworthiness, as seen in this occurrence.

Although the use of SBs was the only viable method for determining the compatibility of the replacement engine with the engine being removed, the comparison of SBs is not a commonly used means of configuration control, as evidenced in this occurrence.

Even though aircraft configuration is affected by SBs, there is no airworthiness requirement to review all non-mandatory SBs on a component prior to its installation nor is there a system in place to facilitate the checking of SB parity. Although Transport Canada audits include the scrutiny of the implementation of SBs, the management of SBs (assessment of applicability, implementation time frame, embodiment and recording) is left to the carrier's discretion.

In the absence of a requirement to conduct an SB parity check, and of an easy-to-use method of carrying this check out, there is a risk that incompatible components may be installed on aircraft and not be detected by existing maintenance planning processes.

Conclusions related to maintenance events

Source: GPIAA, Portuguese Aviation Accidents Prevention and Investigation Department, Report Ref. 22/ACCID/2001

♦ Findings as to Causes and Contributing Factors

1. The replacement engine was received in an unexpected pre-SB configuration to which the operator had not previously been exposed.
2. Neither the engine-receipt nor the engine-change planning process identified the differences in configuration between the engine being removed and the engine being installed, leaving complete reliance for detecting the differences upon the technicians doing the engine change.
3. The lead technician relied on verbal advice during the engine change procedure rather than acquiring access to the relevant SB, which was necessary to properly complete the installation of the post-mod hydraulic pump.
4. The installation of the post-mod hydraulic pump and the post-mod fuel tube with the pre-mod hydraulic tube assembly resulted in a mismatch between the fuel and hydraulic tubes.
5. The mismatched installation of the pre-mod hydraulic tube and the post-mod fuel tube resulted in the tubes coming into contact with each other, which resulted in the fracture of the fuel tube and the fuel leak, the initiating event that led to fuel exhaustion.
6. Although the existence of the optional Rolls-Royce SB RB.211-29-C625 became known during the engine change, the SB was not reviewed during or following the installation of the hydraulic pump, which negated a safety defence that should have prevented the mismatched installation.
7. Although a clearance between the fuel tube and hydraulic tube was achieved during installation by applying some force, the pressurization of the hydraulic line forced the hydraulic tube back to its natural position and eliminated the clearance.

♦ Findings as to Risk

1. The carry-forward items list that accompanied the replacement engine listed a post-modification hydraulic pump model, whereas the fuel and hydraulic tubes installed on the engine were pre-mod.
2. Time pressures, difficulties in accessing the SB and the apparent knowledge of the engine specialist influenced the lead technician to curtail his search for the SB and to rely on verbal advice.
3. The post-installation quality control checks following the engine change did not specifically require checking the installation of the hydraulic pump, hydraulic tube and the fuel tube.
4. In the absence of a requirement to conduct a pre-installation, configuration (SB) parity check, and of a commonly accepted method of carrying out this check, there is a risk that incompatible components may be installed on aircraft and not be detected by existing maintenance planning processes.
5. The CD on the company's network containing the Rolls-Royce EIPC for the Trent 772B and related SBs could not be accessed due to a company computer system fault.

♦ Other Findings

1. There is not a readily available, effective, commonly accepted method to compare the SB (configuration) status of engines, placing reliance on other processes to detect configuration differences.
2. The logbook entry detailing the installation of the fuel line from the replaced engine was not recorded.
3. The risk associated with the application of force while installing mixed-construction lines is not well known in the maintenance community, and is not covered in the training of maintenance technicians.

Safety Action related to maintenance events

Source: GPIAA, Portuguese Aviation Accidents Prevention and Investigation Department, Report Ref. 22/ACCID/2001

♦ Action Taken

❖ ***Action Taken by Transport Canada***

- On 24 August 2001, Transport Canada initiated a Special Purpose Audit of the company's maintenance and operations. None of the findings of this audit played a role in this fuel exhaustion occurrence.
- On 28 August 2001, at Transport Canada's request, Canadian air operators inspected all of their A-330 aircraft to ensure that the same mechanical conditions that may have contributed to the considered emergency landing did not exist on other aircraft.
- Transport Canada recommended that a Human Performance in Aviation Maintenance course be given to the company's maintenance personnel. The company provided this training through the Boeing Aircraft Corporation.
- Transport Canada provided regulatory guidance and assistance in the development of the company's safety management system (SMS).
- In November 2003, Transport Canada performed a regulatory assessment of the SMS to determine the company's progress and the effectiveness of the program.

❖ ***Action Taken by the Company***

- The company initiated a comprehensive review of the safety of their maintenance and operations program. The company also established a corrective action plan that will improve the performance of maintenance activity, including the hiring of additional maintenance and quality assurance personnel. It instituted human factors training for all technical personnel; reviewed and enhanced quality assurance and quality control procedures; and, introduced a system for detecting and analyzing maintenance errors.

❖ ***Action Taken by Airbus***

- On 29 August 2001, Airbus issued an All Operators Telex (AOT) A330-73A3033 requiring a one-time visual inspection to verify that no interference exists between the fuel and hydraulic lines on all A-330 aircraft equipped with Rolls-Royce 700 series engines.

❖ ***Action Taken by Rolls-Royce***

- On 29 August 2001, Rolls-Royce issued a World Wide Communication (DBY/CS/00697/2001), advising operators, in part, to check all engines to ensure that adequate clearance exists between the fuel and hydraulic lines.
- On 29 August 2001, Rolls-Royce issued a Non-Mandatory Service Bulletin 73-D-578 recommending the inspection of the clearance between the fuel and hydraulic lines.

♦ Action Required

❖ ***Major Component Change Planning***

Current regulations and industry standards do not mandate that the configuration of major components, such as an engine, be determined prior to the components being installed on the aircraft. In particular, the current method used for assigning a part number to an engine results in a part number that does not reflect which service bulletins have and which service bulletins have not been embodied. The overall number of involved service bulletins complicates the task of determining parity between similar major components. Because there is not a requirement for a major component-change planning process, nor a requirement to determine the precise configuration of the component during such a process, the responsibility for detecting differences in configuration is deferred to subsequent stages of the maintenance process.

For this occurrence, the differences in configuration between the engine being removed and the engine being installed were not detected prior to the start of the engine change.

As a result, determining part parity and ensuring integrity of the installation of the right engine rested solely with the level of the technician responsible for the engine change. Effectively, there was only one defence layer that could ensure the safety of the installation. The integrity of the engine changed hinged on using the Illustrated Parts Catalogue and the referenced service bulletins to verify the compatibility of each part being changed with associated/adjacent lines and components. The incompatibility of the hydraulic pump with the adjacent fuel pipe was eventually detected and lead to reference being made to the catalogue. However, difficulty in accessing the SBs, time pressures, prime focus on completing the installation, and other factors caused this one-level of defence to be ineffective in preventing an improper installation.

Therefore, it is recommended that Transport Canada, and Direction Genérale de l'Aviation Civile of France (DGAC), and the Civil Aviation Authority of the United Kingdom, as well as the EASA and civil aviation authorities of other states responsible for the manufacture of aircraft and major-components:

- *Review applicable airworthiness regulations and standards, as well as aircraft, engines and component maintenance manuals, to ensure that adequate defences exist in the pre-installation, maintenance planning process to detect major configuration differences and to establish the required support resources for technicians responsible for the work.*

  SAFETY RECOMMENDATION AK/2004

It is also recommended that Transport Canada, Direction Genérale de l'Aviation Civile of France, and the Civil Aviation Authority of the United Kingdom, as well as the European Aviation Safety Authority and civil aviation authorities of other states, in conjunction with aircraft and major component manufacturers:

- *Review the adequacy of the current standards for identifying the configuration and modification status of major components to ensure that differences between major components of similar part numbers can be easily identified.*

  SAFETY RECOMMENDATION AL/2004

Bureau Veritas analysis

♦ History of facts

On 15/01/1999, Rolls-Royce issued SB.29-C625 detailing modifications to the engine dressing. Rolls-Royce anticipated the issuance of an Airbus' Service Bulletin (SB), dated 21/04/1999, offering a modified hydraulic pump (in reaction to several cases of hydraulic fuel leakage).

Modification of the dressing consisted of the replacement of the three fuel tubes and two hydraulic tubes for the front and rear hydraulic pumps.

On 28/04/1999, the aircraft Airbus A330 was registered to the operator. This aircraft was in a post-mod (SB.29-C625) status.

On 31/07/2000, a post-lease shop visit at Hong-Kong Aero Engine Services Limited (HAESL) planned to embody SB.29-C625 (modification of the engine dressing) in a loaned engine. This embodiment was not done due to parts shortage.

The loaned Engine was stored until 01/08/2001 at an operator's facilities in Toronto, in a pre-SB.29-C625 configuration, with:

- A Rework Summary Sheet not referencing the necessity to embody SB.29-C625;
- A Carry-Forward Items List requiring post-SB.29-C625 front and rear hydraulic pumps;
- An Engine Log Book reflecting the actual pre-SB.29-C625 configuration of the engine.

The loaned engine was stored until 17/08/2001 in a restricted area at the A330 operator's facilities, in an "as received" status (that is available to other North-American users).

When the loaned engine arrived at the operator's facility, the review of documentation and receiving inspection did not detect that the engine condition was in the pre-mod (SB.29-C625) configuration.

The presence of metal particles on the A330 original right engine, on Friday 17 August 2001, required an unscheduled engine change. It was decided that the work could be done using in-house resources, with the work starting at midnight the same day.

To support the work required for the engine change, the relevant work-card package was extracted from the Airbus Documentation Retrieval System (ADRES). Because the pre-mod configuration of the engine had not been identified, no work sheets were issued to address the applicable SBs.

The right engine replacement of the aircraft began around midnight on 17/08/2001.

On 19/08/2001 morning, it was established that the rear hydraulic pump could not be fitted due to interference with the high-pressure fuel pump inlet tube. A search through the Airbus IPC revealed the existence of SB.29-C625 and of pre- and post-SB configurations. At this time, the lead technician realized that the replacement engine was in a pre-SB configuration, while the removed engine was post-SB.

All attempts to access the SB from Rolls-Royce EIPC CD installed on the network failed, as a result of a computer network malfunction.

Being paged for advice, the Trent Engine Controller recalled that the modified pump interfered with the fuel lines, and that these would need to be replaced. He confirmed that, when the pump and lines were installed, adequate clearances existed between lines and components. The lead technician queried the possibilities of using a pre-mod pump to save time, because the work was already running late. The Engine Controller informed the lead technician that such a pump was not available on short notice. Both agreed that there was no choice other than to replace the fuel tubes.

Both segments of the post-SB fuel tube assembly were taken from the removed engine and installed on the replacement engine. The pre-SB hydraulic tube, received with the loaned engine, was retained. Clearance between components was obtained by positioning and holding the hydraulic tube, while applying torque to the “B“ nut.

The Rolls-Royce representative telephoned MCC during the engine installation on Sunday to inquire about the work progress and to offer help if required. He was informed that the pre-mod status of the loaned (right) engine did not permit installation of the hydraulic pump and was informed that the fuel tube was being changed over from the removed engine to the loaned (right) engine to allow the pump installation. The Rolls-Royce representative was unaware of the engine dressing SB modification status of the loaned engine and of the status of the operator’s engine fleet. The Rolls-Royce representative was not specifically told of the difficulties in accessing the SBs nor was he specifically asked to consult his documentation. His offer to attend on-site if required was not taken up.

The installation of the post-mod hydraulic pump, the pre-mod hydraulic tube and the post-mod fuel tube assembly resulted in a mismatch between the fuel and hydraulic tubes.

Following completion of the engine change on 19/08/2001 evening, the lead technician inspected all the work done and the tasks documented on the work cards and additional work sheets. The inspection was to ensure that the work was complete, within tolerances and secured. His inspection did not uncover any anomaly with the engine installation.

Another inspection called “the independent inspection” was done by a qualified technician, who had not been involved with the work being inspected. The independent inspection was done to ensure that engine controls are properly connected and secured. This scope of this inspection was not intended to include the fuel or hydraulic system components.

Following these inspections, the engine was ground run, without problems, and was released for flight.

There was no Quality Control (QC) representative on site on the weekend of the engine installation. The company plan was to do the document verification when preparing the removed engine for shipment for repair.

As of the occurrence date, 24 August 2001, the engine change documentation had not yet been reviewed by the quality control staff.

A review of the log book, after the accident, showed that entries for all expected components changed over to the installed right engine had been properly made, signed and countersigned by the supervisor; however, the recording of the unexpected replacement of the fuel tubes was not documented.

♦ Analysis of facts

❖ *Detection and Adjustment of the Loaned Engine Configuration*

The loaned engine has been kept stored over one year under the control of the engine manufacturer's representative, without any embodiment of SB.29-C625.

As all other Rolls-Royce powered A330 flown in Canada were of post-mod status, this created a sensible gap between the loaned engine configuration and the in-service engine configurations.

On the one hand, keeping the loaned engine in a pre-SB configuration jeopardized its inter-changeability with any in-service engine. Furthermore, as no pre-mod pump was available on short notice, keeping the loaned engine in a previous configuration was a contributing factor to an incorrect engine replacement.

On the other hand, the detection of the pre-SB configuration of the loaned engine was rendered difficult because:

- There was no information that would have caused a heightened concern regarding the configuration of the loaned engine.
- The physical appearances of the pre-SB and post-SB configurations are similar and cannot be identified through a cursory inspection.
- The part number of the hydraulic pump, as documented in the Carry-Forward Items List, was incorrectly identified as a post-SB hydraulic pump, with a post-SB Part Number.

Thus, the existence of such pre-SB configuration was in itself a contributing factor to the incorrect assessment of the loaned engine configuration.

Neither the Airbus IPC, nor Rolls-Royce EIPC was referenced at the time of engine receipt, or during review by engineering prior to the engine installation. The approved MCM did not require that non-mandatory SBs be checked when planning for an engine change; consequently, a comparison of SBs was not carried out at the time of engine receipt, nor during the planning of the engine change.

In the absence of a requirement to conduct an SB parity check, and of an easy-to-use method of carrying this check out, there was a risk for incompatible components to be installed on aircraft and not be detected by maintenance planning processes. Then, determining part parity and ensuring integrity of the installation of the right engine rested solely with the level of the technician responsible for the engine change.

The engine change was expected to last 36 hours. As the pre-configuration of the loaned engine was detected more than 30 hours after the beginning of the works, the time-pressure factor to complete the work in time for a scheduled flight and to clear the hangar for an upcoming event may have played a role in the incorrect engine replacement. Considering this matter of fact, there is no certainty that a successful access to the SBs would have prevented the decision that the fuel tube replacement was the only remaining requirement to complete the hydraulic pump installation.

Nevertheless, the presence of a quality control representative during the engine installation may have prompted the full implementation of the SB prior to the release of the aircraft.

❖ *Training to Lines Installation*

Adequate clearance between the fuel and hydraulic lines was achieved during the installation of the hydraulic pump line by applying some force to position the line and holding the line while applying torque to the "B" nut. As there was a 90º bend in the tube adjacent to the "B" nut, and as a flexible line tends to straighten when pressurised, this manner to achieve adequate clearance was critical: the pressurization of the hydraulic line would have been sufficient to cause the hydraulic line to move back to its natural position and come in contact with the fuel line, which resulted in the chafing and failure of the fuel line.

The risk associated with the application of force while installing mixed construction lines was not well known in the maintenance community, and was not covered in the training of maintenance technicians.

❖ *Quality Control*

Neither the aircraft nor the engine log recorded the fuel line change because the technician forgot to make the entry. In addition the verification of the documentation associated with the engine change completed on 18 August 2001 was not done before the occurrence flight. Consequently, the opportunity for the quality assurance review of the documentation to detect the installation error was negated.

The presence of a quality control representative during the engine installation may have facilitated the research into the interference problem and the full implementation of the SB prior to the release of the aircraft.

♦ Conclusions

The fact that the loaned engine was kept one year long in a pre-SB configuration with a Carry-Forward Items List referencing post-SB parts, under the responsibility of the manufacturer, was a contributing factor to its wrong installation.

Furthermore, when kept under the responsibility of the manufacturer, the loaned engine was neither stored with any information heightening concern regarding its pre-SB configuration, nor modified in a way allowing the visual detection of its configuration. Keeping the loaned engine in a pre-SB configuration, which physical appearance is similar to the post-SB configuration and cannot be identified through a cursory inspection, was a contributing factor to the wrong assessment of its configuration.

In this case, the operator and the maintenance organisation are a sole company. A clear, accurate and consistent documentation was necessary to prevent that integrity and safety of an installation rest solely with the level of the technician responsible for the task. No matter if the job card system was provided by the operator or by the maintenance organisation, the source documentation was the manufacturer's documentation. Thus, non-quality of the manufacturer's documentation was a contributing factor to non-quality of the task.

Nevertheless, the operator was required to perform a receipt inspection, to check the loaned engine configuration and ensure that it complies with the manufacturer's specifications.

For those reasons, GPIAA, the Portuguese Aviation Accidents Prevention and Investigation Department, put forward the following safety recommendation:

"Review applicable airworthiness regulations and standards, as well as aircraft, engines and component maintenance manuals, to ensure that adequate defences exist in the pre-installation, maintenance planning process to detect major configuration differences and to establish the required support resources for technicians responsible for the work." **Safety Recommendation AK/2004**

This recommendation is implemented in the Part 145 and Part M regulations as follows:

- The Part 145 Regulation recommends that: "*Prior to installation of a component, the organisation shall ensure that the particular component is eligible to be fitted when different modification and/or airworthiness directive standards may be applicable.*" 145.A.42 (b) Acceptance of Components
- The Acceptable Means of Compliance (AMC) to Part 145 specifies that: "*The EASA Form 1 identifies the eligibility and status of an aircraft component. Block 13 "Remarks" on the EASA Form One in some cases contains vital airworthiness related information which may need appropriate and necessary actions. The receiving organisation should be satisfied that the component in question is in satisfactory condition and has been appropriately released to service. In addition, the organisation should ensure that the component meets the approved data/standard, such as the required design and modification standard. This may be accomplished by reference to the manufacturer's parts catalogue or other approved data (i.e. Service Bulletin). Care should also be exercised in ensuring compliance with applicable airworthiness directives and the status of any life limited parts fitted to the aircraft component.*" AMC 145.A.42 (b)
- The Part M Regulation, in Section A Subpart E dedicated to Components, recommends that: "*Prior to installation of a component on an aircraft the person or approved maintenance organisation shall ensure that the particular component is eligible to be fitted when different modification and/or airworthiness directive configurations may be applicable.*" M.A.501 (b) Installation
- The Acceptable Means of Compliance (AMC) to Part 145 specifies that: "

  "1. The EASA Form 1 identifies the airworthiness and eligibility status of an aircraft component. Block 13 "Remarks" on the EASA Form 1 in some cases contains vital airworthiness related information (see also Part-M Appendix II) which may need appropriate and necessary actions.

  2. The fitment of a replacement components/material should only take place when the (…) maintenance organisation is satisfied that such components/material meet required standards in respect of manufacture or maintenance, as appropriate.

> *3. The (…) approved maintenance organisation should be satisfied that the component in question meets the approved data/standard, such as the required design and modification standards. This may be accomplished by reference to the TC holder or manufacturer's parts catalogue or other approved data (i.e. SB). Care should also be exercised in ensuring compliance with applicable AD and the status of any service life limited parts fitted to the aircraft component."* AMC M.A.501 (b)

Training to lines installation is taken into account by the Part 66 Regulation that establishes the basic knowledge requirements[12] for licensed maintenance personnel: the certified personnel should have *"a general knowledge of the theoretical and practical aspects of the subject, and an ability to apply that knowledge, concerning:*

- *Identification of, and types of rigid and flexible pipes and their connectors used in aircraft*;
- *Standard unions for aircraft hydraulic, fuel, oil, pneumatic and air system pipes."*

Quality control issue is taken into account by the Part 145 Regulation, stating that:

"The organisation shall establish a quality system that includes the following:
1. Independent audits in order to monitor compliance with required aircraft/aircraft component standards and adequacy of the procedures to ensure that such procedures invoke good maintenance practices and airworthy aircraft/aircraft components. In the smallest organisations the independent audit part of the quality system may be contracted to another organisation approved under this Part or a person with appropriate technical knowledge and proven satisfactory audit experience; and

2. A quality feedback reporting system (…) that ensures proper and timely corrective action is taken in response to reports resulting from the independent audits established to meet paragraph (1)."

145.A.65 (c) Safety and quality policy, maintenance procedures and quality system.

Causes and contributing factors that were attributable to the operator and to the maintenance organisations are covered by the Part 145 and Part M regulations. Then, the only means to prevent such an accident is to ensure compliance with the current regulatory requirements, together with improving the quality of the manufacturer's documentation.

[12] Appendix I of the Part 66 regulation

Annex C

Incident of aircraft A340, registration F-GTUB, on 19/04/2002

Date:	Aircraft Type:	Aircraft Registration:
19/04/2002	Airbus A340	F-GTUB
Location:	Injuries to persons:	Damages to aircraft:
Reunion Island	None	None

Facts: **INCIDENT**

Emergency return and landing because of smoke in the cabin.

Causes:

Malfunction of an optocoupler in a lighting controller which led to overheating in the transformer, due to the installation of an over-calibrated fuse in the lighting controller. Overheating of the lighting controller casing caused smoke in the cabin.

Fumée en poste de pilotage (avril 2002)

Source : http://www.bea-fr.org/itp/events/fumeepostepilotage/fumeepostepilotage.html (Novembre 2007)

Déroulement du vol

Après une heure trente de vol, alors que l'avion, un A 340, est en croisière au niveau de vol 310, l'équipage sent l'odeur caractéristique d'un court-circuit électrique puis aperçoit de la fumée. Il applique la procédure d'urgence « SMOKE/AVIONICS SMOKE » et fait demi-tour vers l'aérodrome de départ.

Quelques minutes plus tard, le message Circuit Breaker Tripped Integrated Light 5LF (système d'éclairage intégré des panneaux et des instruments) s'affiche à l'ECAM. La fumée se dissipe. Après avoir vidangé quarante-trois tonnes de kérosène, l'équipage se pose sans autre problème.

Au sol, il est constaté dans la soute avionique que le disjoncteur 5LF INTG LT s'est déclenché. Ce disjoncteur a pour fonction d'isoler le réseau en cas de défaut sur la ligne d'alimentation entre la barre d'alimentation et l'entrée des deux contrôleurs d'éclairage du poste de pilotage 2LF et 6LF (voir schéma ci-après). Il est également constaté que le fusible A d'alimentation du boîtier lighting controller 2LF (boîtier de contrôle d'une partie de l'éclairage intégré du poste de pilotage) est d'un ampérage nettement supérieur à celui requis (6,3 A au lieu de 0,4 A) ; le fond du boîtier présente une coulure de surface importante et les parois latérales et supérieures montrent des traces d'échauffement.

Renseignements complémentaires

Origine de la fumée

L'examen de l'équipement a montré que la fumée provenait d'une surchauffe interne du transformateur de puissance, surchauffe due à l'alimentation simultanée, intempestive et répétée de deux des enroulements du transformateur. L'anomalie de commande des enroulements est issue d'une dérive de fonctionnement de l'un des optocoupleurs TIL 188 de la carte de gestion électronique du contrôleur d'éclairage 2LF. Cette dérive intervient de manière aléatoire en vieillissement sur ce modèle d'équipement.

Comme il n'y a pas eu coupure dans les dix secondes, contrairement à la spécification du fusible A du contrôleur d'éclairage 2LF, la surchauffe a entraîné une détérioration profonde des enroulements, le processus de dégradation progressant jusqu'à ce que le seuil de déclenchement du disjoncteur 5LF (3 A) soit atteint.

Non conformité du fusible

Le boîtier d'éclairage 2LF avait fait l'objet d'une évolution de standard le 23 juin 2000. A la suite d'incidents similaires à celui d'avril 2002 (odeurs de brûlé et émissions de fumée), un Bulletin Service à statut recommandé avait prévu le renforcement du circuit imprimé et l'adjonction d'un fusible de protection sur l'alimentation (fusible A). Ce bulletin avait été appliqué à l'avion. Ni la boîte de fusibles de rechange dans l'avion ni le stock de fusibles de rechange de l'organisme d'entretien n'avaient été actualisés ; il faut noter que le Bulletin Service ne mentionnait pas cette actualisation dans les dispositions à prendre.

Un marquage spécifique sur le boîtier indiquant le calibre des fusibles avait été introduit sur les équipements délivrés après juin 2000 pour faire suite aux erreurs constatées régulièrement lors du retour d'équipements chez le fabriquant. Toutefois les documents de référence, à l'exception de l'Aircraft Maintenance Manual, n'ayant pas encore été mis à jour ne représentaient pas ces marquages additionnels.

Remarque : les indications gravées sur les fusibles correspondent aux spécifications mais sont difficiles à déchiffrer ; de plus, elles sont différentes de la référence de pièce (part number) figurant dans la documentation à la disposition de l'intervenant.

Une SIL (Service Information Letter), rappelant aux exploitants les standards exclusifs à employer lors de remplacements des fusibles, avait été émise par le constructeur le 29 mars 2002, mais elle n'aurait été reçue par l'exploitant que le 5 juin, soit postérieurement à l'incident.

Il n'existe aucune trace dans les documents de maintenance quant à une éventuelle intervention sur le fusible A. Toutefois, il y avait eu une intervention en ligne dix jours avant l'incident lors de laquelle, les deux fusibles du boîtier 2LF avaient été vérifiés en continuité, position après position. À cette occasion, le fusible J avait été constaté défectueux, avec un calibre de 0,4 A au lieu de 6,3, et remplacé par croisement avec le fusible N du lighting controller 6LF. Le vol avait ensuite été effectué en tolérance technique. Cette intervention impliquant aussi que le fusible A avait été contrôlé et considéré comme conforme, on ne peut exclure qu'une substitution se soit produite par erreur à cette occasion.

Par ailleurs, l'exploitant a vérifié au sol que la tenue d'un fusible de calibrage 0,4 A en position J n'était pas affectée par la mise en fonctionnement du système en consommation maximum, même pendant une durée significative ; ceci conduit à penser que l'origine de la non-conformité de ce fusible pouvait même remonter à la fabrication avec un montage selon la configuration croisée observée (fusibles de 6,3A en position A et 0,4A en position J).

Ainsi, il n'est pas possible de dater le montage du fusible non conforme. Il est clair toutefois que les opérations d'entretien n'ont jamais mis en évidence l'inadéquation du calibre du fusible A.

Remarques sur la propagation de la fumée.

Il n'y a pas eu d'alarme de détection de fumée, bien que la soute avionique soit équipée de détecteurs à ionisation au niveau de ses aérations[1]. La courte durée d'émission de la fumée, ainsi que la probable dilution de celle-ci par le flot d'air de la conduite d'aération, peuvent expliquer ce non déclenchement des alarmes.

Il convient de noter que la philosophie de conception d'Airbus en matière de lutte contre le feu exclut l'utilisation de matériaux inflammables dans la soute avionique. Une fumée dans cette zone ne pourrait donc provenir que d'un feu électrique nécessairement limité.

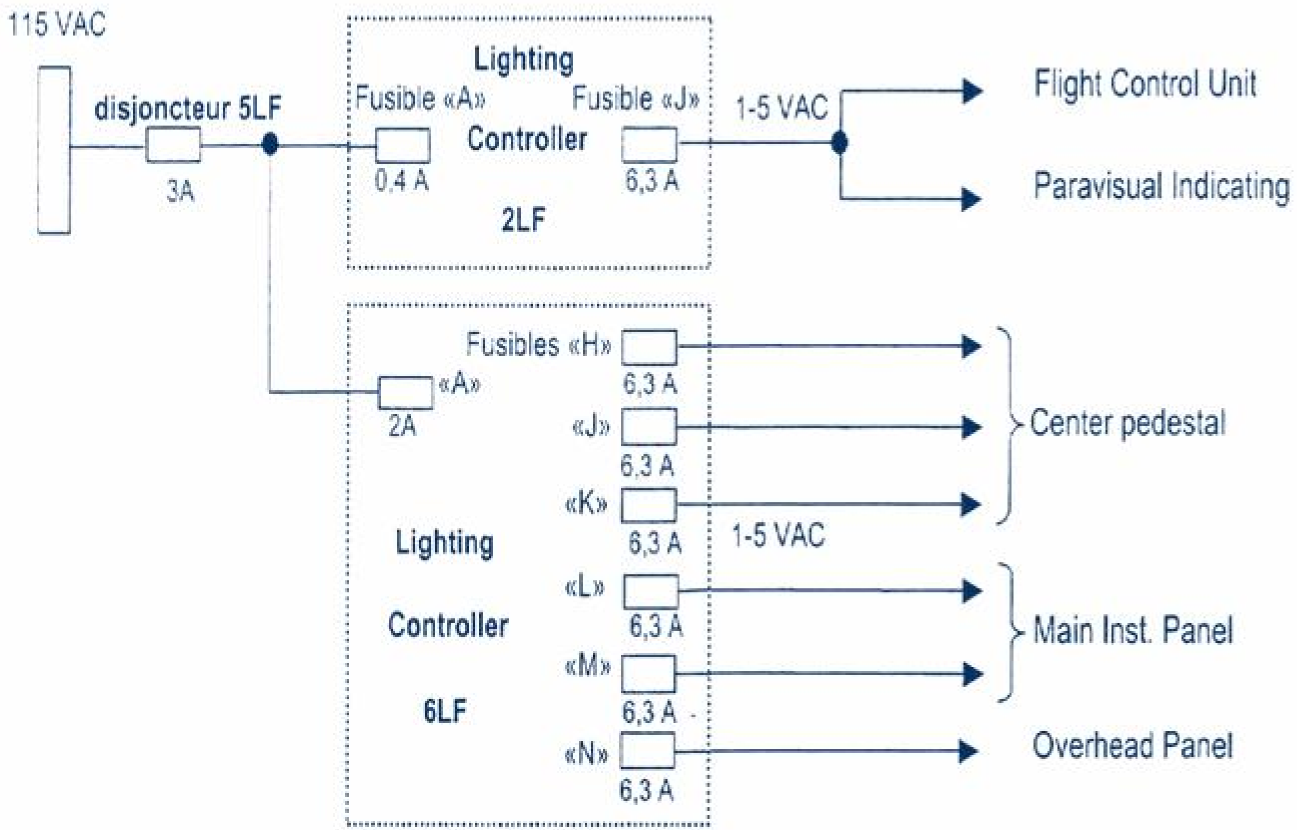
Enseignements

A la suite de l'événement, une campagne de vérification de conformité du standard des fusibles a été effectuée par l'exploitant au sein de sa flotte d'A340. De plus, les TIL188, de conception ancienne, ont été remplacés par des MOC 8050.

Les circonstances de cet incident ne conduisent pas à remettre en cause les caractéristiques techniques de l'avion ou la procédure appliquée par l'équipage. En revanche, cet événement a mis en évidence, une nouvelle fois, le rôle de tous les composants d'un avion en matière de sécurité : il est donc indispensable que les documents et procédures d'entretien soient précis et complets et que le système de retour d'expérience y veille en permanence, au-delà des simples modifications de détail.

[1] Ces détecteurs ne sont pas obligatoires.

- Position des protections électriques systèmes (réf. Wiring Diagram Manual) :



Bureau Veritas analysis

♦ History of facts

On 23/06/2000, was issued a Service Bulletin (SB) detailing modifications to the Lighting Controller 2LF (in reaction to several cases of smell of burning and smoke).

Modification of the lighting controller consisted of the reinforcement of the printed circuit, and of the addition of a protecting fuse (fuse "A") on the electricity supply.

This SB was embodied in the A340 aircraft, without updating the spare fuse boxes in the aircraft and in the maintenance workshop. Such requirement was not mentioned in the SB.

After June 2000, the manufacturer added a specific marking on the lighting controller casing, clearly indicating fuse calibres (in reaction to several cases of errors). Except the Aircraft Maintenance Manual, other reference documents were not updated with this additional marking.

Indications engraved on fuse corresponded to specifications, but were hard to decipher. Moreover, they differed from the part number appearing in the available documentation.

No maintenance operation highlighted the incorrect calibre of fuse "A".

On 29/03/2002, the manufacturer issued a Service Information Letter (SIL) to operators, recalling standard requirements for the fuse replacement.

The A330 operator received this letter on 05/06/2002, after the incident which occurred on 19/04/2002.

♦ Analysis of facts

This event highlights the role played by all aircraft components to ensure safety: a clear, accurate and consistent documentation is necessary to prevent that integrity and safety of an installation rest solely with the level of the technician responsible for a maintenance task or a maintenance check.

No matter if the job card system was provided by the operator or by the maintenance organisation, the source documentation was the manufacturer's documentation. Thus, non-quality of the manufacturer's documentation was a contributing factor to non-quality of the task.

♦ Conclusions

Causes and contributing factors that were attributable to the operator and to the maintenance organisations are covered by the Part 145 and Part M regulations. Then, the only means to prevent such an accident is to ensure compliance with the current regulatory requirements, together with improving the quality of the manufacturer's documentation.

Annex D

List of incidents/accidents related to maintenance documentation

BUREAU VERITAS selected fourteen events which took place from 2004 until 2006, in the field of the European public air transport, and which are related to the maintenance documentation.

The selected events (including two events for year 2007) are the following:

- 1 occurrence from the Czech AIB website (http://www.uzpln.cz):
  - ❖ Incident of aircraft Airbus A320-200, registration F-GKXJ, at Prague/Ruzyne Airport, on 12 February 2006 (Final Report – Ref. No 040/06/ZZ).
- 1 occurrence from the German AIB website (http://www.bfu-web.de):
  - ❖ Accident of aircraft Fokker F28 Mark 0070, near Munich Airport, on 5 January 2004 (Investigation Report – Ref. No AX001-0/04).
- 1 occurrence from the Norwegian AIB website (http://www.aibn.no):
  - ❖ Accident of aircraft ATR 42-320, registration OY-JRJ, at Bergen Airport, on 31 January 2005 (Report Ref. SL RAP.:8/2006).

    Note: This report was also put at our disposal by EASA on the CIRCA website.
- 1 occurrence from the Swedish AIB website (http://www.havkom.se/index-eng.html):
  - ❖ Accident of aircraft Piper PA 31-310, registration SE-GIT, at Umeaa Airport, on 13 March 2006 (Report Ref. RL 2007:8e).
- 8 occurrences from the UK AIB website (http://www.aaib.gov.uk/):
  - ❖ Accident of aircraft Boeing 737-59D, registration G-BVKC, at Cardiff Airport, on 21 February 2004 (Report Ref. EW/C2004/02/03).
  - ❖ Incident of aircraft Boeing 777-236, registration G-YMME, at London/Heathrow Airport, on 10 June 2004 (Report Ref. EW/C2004/06/01 – Formal Report No 2/2007).
  - ❖ Accident of aircraft Fairey BN2A Mark III-2 Trislander, registration G-BEVT, at Guernsey Airport, on 23 July 2004 (Report Ref. EW/C2004/07/06 – Formal Report No 1/2006).

    Note: This report was also put at our disposal by EASA on the CIRCA website.
  - ❖ Incident of aircraft Fokker F28 Mark 0100, registration G-BXWE, at London/Heathrow Airport, on 14 August 2004 (Report Ref. EW/C2004/08/01).
  - ❖ Incident of aircraft BAE ATP, registration G-JEMC, 10 miles southeast of Isle of Man Airport, on 23 May 2005 (Report Ref. EW/C2005/05/05 – Formal Report No 1/2007).
  - ❖ Incident of aircraft Avro 146-RJ100, registration G-CFAA, at Birmingham Airport, on 26 September 2006 (Report Ref. EW/G2006/09/26).
  - ❖ Incident of aircraft BAE Systems Jetstream 4100, registration G-MAJI, at Durham Tees Valley Airport, on 26 February 2007 (Report Ref. EW/G2007/02/11).
  - ❖ Accident of aircraft DHC-6 Twin Otter Series 310, registration G-BZFP, at Glasgow Airport, on 22 March 2007 (Report Ref. EW/G2007/03/10).
- 4 occurrences from the Irish AIB website (http://www.aaiu.ie):
  - ❖ Incident of aircraft Airbus A321-200, registration EI-CPD, en route London to Dublin, on 26 January 2004 (Report No 2005-020).
  - ❖ Incident of aircraft Airbus A330-301, registration EI-JFK, at Dublin Airport, on 4 June 2004 (Report No 2006-006).
  - ❖ Incident of aircraft ATR 42-300, registration EI-BYO, en route to Cork Airport, on 5 August 2005 (Report No 2006-029).

    Note: This report was also put at our disposal by the ECCAIRS steering committee (BEA).
  - ❖ Incident of aircraft Airbus A300-301, registration EI-CRK, at Shannon Airport, on 18 August 2005 (Report No 2007-011).

Facts, causes and damages linked to the selected occurrences are summarized in the following table. (See **Table D 1: List of incidents/accidents related to maintenance documentation**.) We have added our conclusions regarding the causes (and the possible safety recommendations), which have been drawn by the Accident Investigation Boards.

Table D 1: List of incidents/accidents related to maintenance documentation

Date:	Aircraft Type:	Aircraft Registration:	Location:	Injuries to persons:	Damages to aircraft:
05/01/2004	Fokker F28 Mk 0070	Not reported	Near Munich Airport	Three minor injuries	Fuselage severely damaged

Facts: **ACCIDENT**

Emergency landing because of heavy vibrations on the right-hand engine and unusual noises coming from the rear of the airplane during the approach.

BUREAU VERITAS conclusions:

A correct manufacturer's documentation may have helped to prevent this incident, mentioning applicable, clear instructions for the bonding of the ice impact panels.

Causes:

The vibrations on the right-hand engine and noises in the rear of the airplane were to be attributed to ice formation on the fan. Improper preparation of the bonding surfaces, ingress of moisture and poor elasticity of the adhesive caused the bonded joints of the ice impact panels to progressively fail over an extended period of time. The instruction of the engine manufacturer for the bonding of the ice impact panels was difficult to accomplish and unclear concerning the preparation of the bonding surfaces.

After the conclusion of the investigation, the German Federal Bureau of Aircraft Accidents Investigation has issued the following safety recommendation:

Recommendation no. 09/2005: The Luftfahrt-Bundesamt responsible for the type support of the Rolls Royce TAY 620-15 engine should check:
• If the engine manufacturer eliminated the errors and deficiencies, as revealed by the investigation, in the manufacturer's instructions for the implementation of the ice impact panel modification;
• If the deficiencies found in the manufacturer's instructions are attributable to fundamental deficiencies of the engine manufacturer's quality assurance system.

Date:	Aircraft Type:	Aircraft Registration:	Location:	Injuries to persons:	Damages to aircraft:
26/01/2004	Airbus A321-200	EI-CPD	En route London to Dublin	None	None

Facts: **INCIDENT**

Emergency descent and diversion to Cardiff Airport because of rapid depressurisation.

BUREAU VERITAS conclusions:

A correct manufacturer's documentation may have helped to prevent this incident, mentioning detailed instructions to inspect the bellows when a blow-out panel is found open.

Causes:

The flight crew reported a noise from the forward hold area on the inbound flight to London. Following a normal landing at Heathrow a blow out panel was found open. As an inspection revealed nothing abnormal, the panel was closed. A more exhaustive search on the ground could have revealed the loose bellows and broken clamp. The manufacturers' Trouble Shooting Manual directs personnel, on finding a blow-out panel in the open position, to examine the pack outlet bellows for correct condition.
The Trouble Shooting Manual (TSM) was amended in May 2004 and the Aircraft Maintenance Manual (AMM) in May 2005 and now includes a direction and method for a detailed inspection of the Pack Outlet Check Valve (POCV) flappers as part of a general inspection of the bellows when a blow-out panel is found open.

Date:	Aircraft Type:	Aircraft Registration:	Location:	Injuries to persons:	Damages to aircraft:
21/02/2004	Boeing 737-59D	G-BVKC	Cardiff Airport	None	Damage to left main landing gear

Facts: **ACCIDENT**

Steering difficulties and shimmying during braking after a normal landing.

BUREAU VERITAS conclusions:

A correct manufacturer's documentation may have helped to prevent this incident, mentioning clear instructions to prevent an excessive play in the anti-torque links apex joint.

Causes:

The shimmying resulted from excessive wear of the torsion link apex joint that reduced the effectiveness of the shimmer damper. Maintenance records indicated that the main landing gear (MLG) had been maintained in accordance with the manufacturer's recommendations, but it was considered that relevant Aircraft Maintenance Manual (AMM) procedures could be difficult to follow.

As a result, AAIB considered that measures, including an assessment of the need for improved methods of checking for excessive play in the torsion link apex joint and an increased check frequency, improvement to relevant sections of the AMM and assessment of the need for modification of the joint, need to be implemented.

The following safety recommendation has been made:

Safety Recommendation 2004-103: The Federal Aviation Authority and the Boeing Commercial Airplane Group should take effective measures aimed at preventing further cases of Boeing 737 main landing gear shimmy and resultant torsion link fracturing brought about by excessive play in the anti-torque links apex joint.

Date:	Aircraft Type:	Aircraft Registration:	Location:	Injuries to persons:	Damages to aircraft:
04/06/2004	Airbus A330-301	EI-JFK	Dublin Airport	None	None

Facts: **INCIDENT**

Emergency return and landing with No 2 engine inoperative because of a fire alarm in this engine.

BUREAU VERITAS conclusions:

A correct manufacturer's documentation may have helped to prevent this incident, directing attention to the TTU wirelocking and duct length adjustment.

Causes:

The tolerance take up (TTU) adjustment sleeves had separated and its inner duct suffered distortion. Tension loading in the 14th Stage Manifold, due to the unsupported duct, initiated a fatigue fracture in the coupling, which then failed. A V-band clamp at the 14th Stage Manifold lower engine port detached, allowing hot air (greater than 600ºC) to bleed into the engine core compartment.

On the 10th February 2005 the Manufacturer issued an All Operator Letter (AOL-CF6-80E-NAC-012) advising operators of a requirement to inspect the lockwire installation on the TTU duct. A Service Bulletin (CF6-80E1-NAC-71-039) was also issued which, besides directing attention to the TTU wirelocking and duct length adjustment, also provides recommended maintenance procedures and adjustment checks to the engine bleed system hardware installation.

Date:	Aircraft Type:	Aircraft Registration:	Location:	Injuries to persons:	Damages to aircraft:
10/06/2004	Boeing 777-236	G-YMME	London/Heathrow Airport	None	None

Facts: **INCIDENT**

Emergency return and landing because of fuel leaking from the centre wing fuel tank.

BUREAU VERITAS conclusions:

A correct manufacturer's documentation may have helped to prevent this incident, mentioning cross references within the AMM about the purge door.

Causes:

The fuel leak was caused by fuel escaping from the centre wing tank through the open purge door. The purge door was removed from G-YMME during base maintenance, between 2 May and 10 May 2004, and not re-installed prior to departure. Contrary to the maintenance organisation's procedures, the removal of the purge door was not recorded on a defect job card.

The centre wing tank leak check did not reveal the open purge door because:
a. The purge door was not mentioned within the AMM procedures for purging and leak-checking the centre wing fuel tank.
b. With no record of the purge door removal, the visual inspection for leaks did not include the purge door.
c. The fuel quantity required to leak check the purge door was incorrectly stated in the AMM.

Awareness of the existence of a purge door on the Boeing 777 was low among the production staff working on G-YMME, due in part to an absence of cross references within the AMM.

Date:	Aircraft Type:	Aircraft Registration:	Location:	Injuries to persons:	Damages to aircraft:
23/07/2004	Fairey BN2A Mark III-2 Trislander	G-BEVT	Guernsey Airport	Two severe injuries	Substantially damaged

Facts: **ACCIDENT**

Emergency return and landing because of injured passengers and a broken cabin window.

BUREAU VERITAS conclusions:

A correct manufacturer's documentation may have helped to prevent this incident, stressing the importance of the filler.

Causes:

The accident was caused by the separation of a de-icer boot from the left propeller during takeoff. The de-icer boot separated due to peel stresses generated by forces on the propeller. The peel stresses arose because of physical or contamination damage to the adhesive bond which occurred because the required filler material was not used at the root of the de-icer boot.

The propeller overhaul agency had overhauled approximately 100 propellers without using the required filler. This investigation has not determined the reason why filler was not applied other than that it was probably related to a real or perceived supply difficulty. The importance of the filler may not have been realised fully, since some de-icer boots with short lead straps are installed without the filler.

Date:	Aircraft Type:	Aircraft Registration:	Location:	Injuries to persons:	Damages to aircraft:
14/08/2004	Fokker F28 Mk 0100	G-BXWE	London/Heathrow Airport	None	None

Facts: **INCIDENT**

Landing committed with a nose landing gear unsafe indication.

BUREAU VERITAS conclusions:

A correct manufacturer's documentation may have helped to prevent this incident, mentioning clear instructions to obtain an accurate measurement of the downlock plunger clearance.

Causes:

The nose landing gear was replaced in June 2003, following a towing incident. The aircraft experienced a nose landing gear unsafe condition on approach on 26 September 2003. No anomalies were found during troubleshooting after this event and the following one in August 2004.

On reviewing the Aircraft Maintenance Manual (AMM) procedure for checking the downlock plunger clearance, the airline's Engineering Quality Department noted that the procedure was ambiguous, in that it did not make it clear that it is necessary to apply a rearward force on the nose landing gear when checking the downlock plunger clearance. Failing to do so will result in an incorrect measurement being obtained.

In response to the airline's recommendation, the aircraft manufacturer has agreed to amend AMM to include a step to clarify that a second person is required to apply a rearward force to the nose gear when measuring the downlock plunger clearance, in order to obtain an accurate measurement.

Date:	Aircraft Type:	Aircraft Registration:	Location:	Injuries to persons:	Damages to aircraft:
31/01/2005	ATR 42-320	OY-JRJ	Bergen Airport	None	Damage to the right elevator

Facts: **ACCIDENT**

Immediate return and emergency landing due to control problems related to the elevator function.

Causes:

The self-locking nuts have not been tightened with the required torque when the elevator was fitted, following a major service and repaint of the aircraft in 1999.

The following safety recommendation has been made:

Incorrect installation of the nuts on the hinge bolts on the elevator was not discovered.

The manufacturer's maintenance documentation does not specify that installation of elevators must be double checked.

The maintenance organisation has responsibility for identifying which maintenance tasks and processes are critical to safety and require special measures for discovering and correcting any errors found.

BUREAU VERITAS conclusions: A correct manufacturer's documentation may have helped to prevent this accident, mentioning that installation of elevators must be double-checked.	At the same time, the operator is responsible for specifying what maintenance work should be carried out, and to what standard it should be carried out, when it purchases maintenance services from a maintenance organisation. In the opinion of the AIBN this division of responsibility may lead to the systematic assessment and specification of which tasks should be double checked not taking place. For this reason, the AIBN recommends that JAA/EASA consider whether the regulations should be amended in order that systems that are critical to safety are double checked following maintenance work. Special consideration should be made as to whether the manufacturer should be given a responsibility on this matter. (AIBN recommendation 12/2006).

Date:	*Aircraft Type:*	*Aircraft Registration:*	*Location:*	*Injuries to persons:*	*Damages to aircraft:*
23/05/2005	BAE ATP	G-JEMC	10 miles southeast of Isle of Man Airport	None	Substantially damaged

Facts: **ACCIDENT** Emergency return and landing because of misting in the forward section of the cabin.	*Causes:* The failure of the hydraulic seal associated with the airstairs operating mechanism occurred in-flight; this resulted in the fluid contents of the main hydraulic system being discharged as a fine mist into the passenger cabin. At the time of the incident, there were no periodic inspection or maintenance checks required on the airstairs operating system.
BUREAU VERITAS conclusions: A correct manufacturer's documentation may have helped to prevent this accident, mentioning inspection or checks required on the airstairs operating system.	

Date:	*Aircraft Type:*	*Aircraft Registration:*	*Location:*	*Injuries to persons:*	*Damages to aircraft:*
05/08/2005	ATR 42-300	EI-BYO	En route to Cork Airport	None	None

Facts: **INCIDENT** Abnormal parameters during the flight and the approach due to from No 1 engine progressive loss of power.	*Causes:* Fuel leaked from the fuel flow divider of No. 1 engine during flight causing a loss of engine power. A nut on the fuel flow divider was incorrectly wire-locked and allowed the nut to back off, thereby causing the fuel leakage. The Operator found that an incorrect thrust pin configuration may be found due to an error in the engine shop Cleaning Inspection and Repair Manual (CIR). The above CIR Manual 72-09-20 page 901/902 was amended by the engine manufacturer on 25 November 2005.
BUREAU VERITAS conclusions: A correct manufacturer's documentation may have helped to prevent this incident, mentioning instructions to ensure a correct thrust pin configuration on the fuel flow divider.	

Date:	Aircraft Type:	Aircraft Registration:	Location:	Injuries to persons:	Damages to aircraft:
18/08/2005	Airbus A300-301	EI-CRK	Shannon Airport	None	None

Facts: **INCIDENT**

Immediate turn, emergency descent and overweight landing because of pressurisation problems.

BUREAU VERITAS conclusions:

A correct manufacturer's documentation may have helped to prevent this incident, mentioning clear instructions and using clear markings for the installation of the aft cargo door seal.

Causes:

The absence of adequate pressurisation was due to a faulty installation of the aft cargo door seal. The door seal had not been correctly installed as the aircraft manufacturer intended.
Safety Recommendations were made:
1. The aircraft manufacturer should review the instructions given in the AMM in order to make them less ambiguous.
2. The aircraft manufacturer should improve the markings on the seal in order to identify its orientation in the door retainer during installation.

Date:	Aircraft Type:	Aircraft Registration:	Location:	Injuries to persons:	Damages to aircraft:
12/02/2006	Airbus A320-200	F-GKXJ	Prague/Ruzyne Airport	None	None

Facts: **INCIDENT**

Immediate return and emergency landing because of a loss of power on the right-hand engine after take-off.

BUREAU VERITAS conclusions:

A correct manufacturer's documentation may have helped to prevent this incident, mentioning proper checks in the maintenance procedure of aircraft with given types of engines.

Causes:

The PS3 sensor hose had been damaged due to contact with the starter air supply tube. The last repair in this place was carried out on 21 January 2006. The likely cause of the failure was that clearance between the PS3 sensor hose and the starter lower air supply duct had not been adjusted properly when assembling the hose. That made the hose comes in contact with the air tube during engine operation, leading to damage of the hose that was difficult to detect visually.

The following safety recommendation has been made:

Based on what the aircraft operator learned from the hose damage, a number of aircraft with CFM56 engines were checked for enough space between the PS3 sensor hose and the starter lower air supply duct to make sure the hose will not come in contact with the air tube.

The Civil Aviation Authority should verify if there are proper checks in the maintenance procedure of aircraft with CFM56-B4 engines in operation to make sure the PS3 hose and the starter lower air supply duct will not get in contact.

Date:	Aircraft Type:	Aircraft Registration:	Location:	Injuries to persons:	Damages to aircraft:
13/03/2006	Piper PA 31-310	SE-GIT	Umeaa Airport	None	Substantially damaged

Facts: **ACCIDENT**

Emergency landing because of a failure on the left main landing gear during the approach.

BUREAU VERITAS conclusions:

As this accident was caused by an inadequate directive from the manufacturer, a correct manufacturer's documentation may have helped to prevent this accident.

Causes:

The landing gear door had fatigue damages and had broken during the gear extension. The incident was caused by an inadequate directive from the manufacturer in respect of crack inspection of the inboard main landing gear door front suspension arrangement.

Swedish AIB recommended that EASA takes action so that the hinge assemblies of this particular type are inspected at suitable intervals in respect of crack generation.
(RL 2007:08e R1).

Date:	Aircraft Type:	Aircraft Registration:	Location:	Injuries to persons:	Damages to aircraft:
26/09/2006	Avro 146-RJ100	G-CFAA	Birmingham Airport	None	None

Facts: **INCIDENT**

Immediate return and emergency landing because of smoke in the cabin deck.

BUREAU VERITAS conclusions:

A correct manufacturer's documentation may have helped to prevent this incident, mentioning full functioning of the air-conditioning system after the replacement of the engine.

Causes:

The oil contamination of the air-conditioning system occurred during the previous flight, due to internal damage to No 2 engine. Its removal had not been carried out successfully during the maintenance activities. Ground running following the replacement of the engine did not involve full functioning of the air-conditioning system.

Date:	Aircraft Type:	Aircraft Registration:	Location:	Injuries to persons:	Damages to aircraft:
26/02/2007	BAE Systems Jetstream 4100	G-MAJI	Durham Tees Valley Airport	None	None

Facts: **INCIDENT**

Prior to taking-off, when conducting the 'full and free' flight control checks, a restriction was felt in the elevator circuit.

BUREAU VERITAS conclusions:

A correct manufacturer's documentation may have helped to prevent this incident, mentioning appropriate frequency of lubrication of the flight controls gust lock system.

Causes:

Examination revealed that there was a lack of appropriate lubrication of the gust mechanism associated with an elevator circuit. As a result of this finding, the operator now applies lubrication on an annual basis, instead of once every four years, and the manufacturer is amending the Maintenance Schedule to increase the frequency of lubrication of the flight controls gust lock system.

Date:	*Aircraft Type:*	*Aircraft Registration:*	*Location:*	*Injuries to persons:*	*Damages to aircraft:*
22/03/2007	DHC-6 Twin Otter Series 310	G-BZFP	Glasgow Airport	None	Damage to nose leg and fuselage skin

Facts: **ACCIDENT**

Whilst taxiing after landing, the lower section of the nose landing gear, including the wheel, detached form the nose leg.

BUREAU VERITAS conclusions:

A **correct** manufacturer's **documentation** may have helped to prevent this accident, giving guidance about corrosion inspections and correct cap-fitting.

A **correct documentation** refers to:

- existing documentation;
- in-time documentation;
- updated documentation;
- complete documentation;
- accurate documentation;
- erroneous documentation;
- simple documentation;
- adequate documentation.

Causes:

This resulted from corrosion damage to the screw threads of a lock nut used to secure the wheel fork to the lower extremity of the sliding element of the oleo strut.

As a result of this accident, the operator has revised its maintenance procedures as follow:

1. In light of the company's frequent operation of the Twin Otter from beach landing strips:
   a. The aircraft's maintenance program has been amended to include disassembly and inspection of the shock strut piston tube and locknut assembly, to check for corrosion, as part of the annual inspection.
   b. The operator has obtained approval from the manufacturer for wet assembly of the locknut to the piston tube, using an approved primer, in accordance with procedures laid down in the manufacturer's Corrosion Prevent on Manual**.**
   c. The interval between inspections of the torque links has been reduced from 2,400 hours to 200 hours.

2. No rubber sealing disc (or any other part not called up in the appropriate documentation) is permitted to be installed, and a quality and safety notice has been issued stressing adherence to the CMM.

3. The manufacturer's attention has been drawn to the lack of guidance in the maintenance manual regarding the need to ensure that the cap fitting at the lower attachment to the fuselage is installed the correct way up. The maintenance manual instructions called simply for the cap to be re-fitted, and contained no caution highlighting the possibility, or the implications, of it being fitted upside down. Whilst awaiting a response from the manufacturer, the operator has issued additional guidance, in accordance with its own internal procedures, which supplement the maintenance manual instructions in this regard.

Annex E

Risk assessment

Through the analysis of collected data on common practices between operators and maintenance organisations throughout Europe, BUREAU VERITAS identified six scenarios that describe existing relationships between operators and maintenance organisations (See § **4 Data Analysis**). Risks related to these scenarios are presented in the following tables (See **Table E 1: Risks related to scenarios 1 & 2 between operators and MROs**, **Table E 2: Risks related to scenarios 3 & 4 between operators and MROs**, and **Table E 3: Risks related to scenarios 5 & 6 between operators and MROs**).

This six scenarios correspond to the existing situation, which corresponds to the "Do-nothing" Option 1 of the Rulemaking Task n°145.020. Risks related to the other options of this Rulemaking Task are presented in **Table E 4: Risks related to the Options 2, 3 and 4 of the Rulemaking Task n°145.020**.

➧ *Solutions to mitigate the risks are proposed under each risk, in this way.*

Table E 1: Risks related to scenarios 1 & 2 between operators and MROs

	Scenario 1: The MRO prints the task cards from the operator's AMM by using the related job card system	**Scenario 2: The MRO prints the task cards from the connected operator's AMM by using the related job card system**
Financial risks for the operator		• Significant extra cost may result for the operator to ensure that the maintenance package is complete, including all relevant mandatory tasks and inspections; ➧ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when controlling the correct completion of the tasks*
Organisational risks for the operator		• Significant extra time may result for the operator to ensure that the maintenance package is complete, including all relevant mandatory tasks and inspections; ➧ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when controlling the correct completion of the tasks*
Safety risks on the operator's side		• The operator may face difficulties to ensure that the maintenance package is complete, including all relevant mandatory tasks and inspections; ➧ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when controlling the correct completion of the tasks* • The notion and detection of defects may differ from an operator to another, creating discrepancies with the expected results for the operator (as regards its supervision authority's requirements); ➧ *S2: Standardization of the interpretation of the regulatory text that is allowed by the supervision authorities may help to prevent discrepancies with the expected results*

Safety risks on the MRO's side	• The MRO workers may feel over-confident because of a well-known documentation (risk of no consultation of the documentation); ➧ *S3: Raising consciousness on risks related to complacency during continuous human factors training may help to prevent such human error*	• The MRO may omit to carry out a required task related to the status of the aircraft; ➧ *S4: Standardization of the task cards including specific tags to introduce operator's specific tasks and requirements may help MROs to pay attention to such data*

Table E 2: Risks related to scenarios 3 & 4 between operators and MROs

	Scenario 3: The MRO prints the task cards from the operator's AMM by using its own job card system	**Scenario 4: The MRO uses the operator's task cards in addition with its own job card system**
Financial risks for the operator	• Significant extra cost may result for the operator when the MRO provides maintenance data feedback with a paperwork which is not compatible with the operators system; ➧ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when transferring the feedback information in their record system*	
Financial risks for the MRO		• Significant extra cost may result from the planning process for the MRO, when the operator's task cards are not suitable for the MRO processes (e.g. production control) or the MRO qualification structure; ➧ *S5: Standardization of the task cards including Part-145 requirements may help MROs to introduce (under specific tags) specific tasks and requirements related to their processes and procedures*
Organisational risks for the operator	• Significant extra time may result for the operator when the MRO provides maintenance data feedback with a paperwork which is not compatible with the operators system; ➧ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when transferring the feedback information in their record system*	

	Scenario 3: The MRO prints the task cards from the operator's AMM by using its own job card system	Scenario 4: The MRO uses the operator's task cards in addition with its own job card system
Organisational risks for the MRO		• Significant extra time may result from the planning process for the MRO, when the operator's task cards are not suitable for the MRO processes (e.g. production control) or the MRO qualification structure; ➧ *S5: Standardization of the task cards including Part-145 requirements may help MROs to introduce (under specific tags) specific tasks and requirements related to their processes and procedures*
Safety risks on the operator's side	• The operator may face difficulties to record several different MRO's work cards which layouts are different; ➧ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when transferring the feedback information in their record system* • The operator may face difficulties to ensure that the maintenance package is complete, including all relevant mandatory tasks and inspections; ➧ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when controlling the correct completion of the tasks* • A transcription error may occur when transferring maintenance data feedback into the operator's records system; ➧ *S1: Standardization of the task cards and of procedures on how to fill them may help operators to prevent such error when transferring the feedback information in their record system* • The notion and detection of defects may differ between the operator and the MRO, creating discrepancies with the expected results for the operator (as regards its supervision authority's requirements); ➧ *S2: Standardization of the interpretation of the regulatory text that is allowed by the supervision authorities may help to prevent discrepancies with the expected results*	• The notion and detection of defects may differ between the operator and the MRO, creating discrepancies with the expected results for the operator(as regards its supervision authority's requirements); ➧ *S2: Standardization of the interpretation of the regulatory text that is allowed by the supervision authorities may help to prevent discrepancies with the expected results* • The operator may not have the required experience to adapt its job card system in accordance with maintenance processes and procedures; ➧ *S6: Standardization of the manufacturer's task cards including Part-145 requirements may compensate for the operator's lack of experience as concerns maintenance processes and procedures*

	Scenario 3: **The MRO prints the task cards from the operator's AMM by using its own job card system**	**Scenario 4:** **The MRO uses the operator's task cards in addition with its own job card system**
Safety risks on the MRO's side	• The MRO workers may feel complacency so that they could forget operator's specific tasks; ➨ *S3: Raising consciousness on risks related to complacency during continuous human factors training may help to prevent such human error* • The MRO may omit to carry out a required task related to the status of the aircraft; ➨ *S4: Standardization of the task cards including specific tags to introduce operator's specific tasks and requirements may help MROs to pay attention to such data* • The MRO may omit to carry out an additional task related to the local conditions of operation of the aircraft; ➨ *S4: Standardization of the task cards including specific tags to introduce operator's specific tasks and requirements may help MROs to pay attention to such data*	• The MRO workers may feel disturbed because of differences with an usual way of working; ➨ *S1: Standardization of the task cards and of procedures on how to fill them may help MRO workers when performing the tasks* • A defect may be added during the integration of the operator's task cards in the MRO job card system, due to an incompatibility of the operator's task cards with the MRO job card system; ➨ *S5: Standardization of the task cards including Part-145 requirements may help to prevent an incompatibility of the operator's task cards with the MRO job card system* • The MRO may omit to carry out a required task related to the status of the aircraft; ➨ *S4: Standardization of the task cards including specific tags to introduce operator's specific tasks and requirements may help MROs to pay attention to such data* • The MRO may omit to carry out an additional task related to the local conditions of operation of the aircraft; ➨ *S4: Standardization of the task cards including specific tags to introduce operator's specific tasks and requirements may help MROs to pay attention to such data*

Table E 3: Risks related to scenarios 5 & 6 between operators and MROs

	Scenario 5: The MRO prints the task cards from the operator's AMM	**Scenario 6: The MRO uses the operator's task cards**
Financial risks for the MRO	• Significant extra cost may result for the MRO when the operator's task cards (derived from the manufacturer's task cards) are not suitable for the MRO processes (e.g. production control) or the MRO qualification structure; ➨ *S6: Standardization of the manufacturer's task cards including Part-145 requirements may compensate for the operator's lack of experience as concerns maintenance processes and procedures*	• Significant extra cost may result from the planning process for the MRO, when the operator's task cards are not suitable for the MRO processes (e.g. production control) or the MRO qualification structure; ➨ *S5: Standardization of the task cards including Part-145 requirements may help to prevent an incompatibility of the operator's task cards with the MRO job card system*
Organisational risks for the MRO	• Significant extra time may result for the MRO when the task cards are not suitable for the MRO processes (e.g. production control) or the MRO qualification structure; ➨ *S6: Standardization of the manufacturer's task cards including Part-145 requirements may compensate for the operator's lack of experience as concerns maintenance processes and procedures*	• Significant extra time may result from the planning process for the MRO, when the operator's task cards are not suitable for the MRO processes (e.g. production control) or the MRO qualification structure; ➨ *S5: Standardization of the task cards including Part-145 requirements may help to prevent an incompatibility of the operator's task cards with the MRO job card system*
Safety risks on the operator's side	• The operator may not feel competent to train the MRO on its documentation when it is derived from the manufacturer's documentation; ➨ *S6: Standardization of the manufacturer's task cards including Part-145 requirements may compensate for the operator's lack of experience as concerns maintenance processes and procedures*	• The operator may not have the required experience to adapt its job card system in accordance with maintenance processes and procedures; ➨ *S6: Standardization of the manufacturer's task cards including Part-145 requirements may compensate for the operator's lack of experience as concerns maintenance processes and procedures* • The operator may not feel competent to train the MRO on its job card system (as it is often produced from the manufacturer's documentation); ➨ *S6: Standardization of the manufacturer's task cards including Part-145 requirements may compensate for the operator's lack of experience as concerns maintenance processes and procedures*

	Scenario 5: The MRO prints the task cards from the operator's AMM	**Scenario 6: The MRO uses the operator's task cards**
Safety risks on the MRO's side	• The MRO workers may feel disturbed because they have to cope simultaneously with many different layouts; ➨ *S1: Standardization of the task cards and of procedures on how to fill them may help MRO workers when performing the tasks* • The MRO workers may not be familiar with the manufacturer's documentation; ➨ *S6: Standardization of the manufacturer's task cards including Part-145 requirements may compensate for the MRO workers' lack of experience as concerns some manufacturer's documents* • The MRO may omit to carry out a required task related to the status of the aircraft; ➨ *S4: Standardization of the task cards including specific tags to introduce operator's specific tasks and requirements may help MROs to pay attention to such data* • An error may occur during the implementation of the task cards as manufacturer's task cards never fulfil the how-to-do requirement; ➨ *S6: Standardization of the manufacturer's task cards including Part-145 requirements may address the how-to-do requirement*	• The MRO workers may feel disturbed because they have to cope simultaneously with many different layouts; ➨ *S1: Standardization of the task cards and of procedures on how to fill them may help MRO workers when performing the tasks* • An error may occur during the implementation of the operator's task cards as the MRO has a limited knowledge of the operator's job card system; ➨ *S1: Standardization of the task cards and of procedures on how to fill them may compensate for the MRO' lack of experience as concerns some operator's documents*

Table E 4: Risks related to Options 2, 3 & 4 of the Rulemaking Task n°145.20

	Option 2: **the operator provides the MRO with a job card system**	**Option 3:** **the MRO uses only its internal job card system**	**Option 4:** **a difference is made between line and base maintenance**
Financial risks for the operator	• Significant extra cost may result for the operator to get the experience needed to create and maintain a job card system that meets the Part-145 requirements; ➧ *S6: Standardization of the manufacturer's task cards including Part-145 requirements may compensate for the operator's lack of experience as concerns maintenance processes and procedures* • Significant extra cost may result for a small operator to get the experience needed to adapt its job card system in accordance with the status of the aircraft or with the local conditions of operation; ➧ *S8: Other commercial arrangements should be allowed between the operator and an MRO*	• Significant extra cost may result for the operator to check completeness of various maintenance package with different layouts; ➧ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when controlling the correct completion of the tasks*	• Significant extra cost may result for the operator to check completeness of various maintenance package with different layouts; ➧ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when controlling the correct completion of the tasks*

	Option 2: the operator provides the MRO with a job card system	Option 3: the MRO uses only its internal job card system	Option 4: a difference is made between line and base maintenance
Financial risks for the MRO	• Significant extra cost may result for the MRO to adapt the operator's task cards in accordance with the specific processes described in its MOE; ➧ *S5: Standardization of the task cards including Part-145 requirements may help MROs to introduce (under specific tags) specific tasks and requirements related to their processes and procedures*	• Significant extra cost may result for the MRO to introduce specific operator's tasks in its job card system in accordance with the status of the aircraft or with the local conditions of operation; ➧ *S7: Standardization of documents related to the status of the aircraft and to the local conditions of operation may help the MRO to add operator's specific tasks and requirements* • Significant extra cost may result for the MRO when additional manufacturer's documentation must be searched; ➧ *S8: Other commercial arrangements should be allowed between the operator and the MRO*	• Significant extra cost may result for the MRO to introduce specific operator's tasks in its job card system in accordance with the status of the aircraft or with the local conditions of operation; ➧ *S7: Standardization of documents related to the status of the aircraft and to the local conditions of operation may help the MRO to add operator's specific tasks and requirements* • As concerns base maintenance, significant extra cost may result for the MRO when additional manufacturer's documentation must be searched; ➧ *S8: Other commercial arrangements should be allowed between the operator and the MRO*

	Option 2: the operator provides the MRO with a job card system	**Option 3: the MRO uses only its internal job card system**	**Option 4: a difference is made between line and base maintenance**
Organisational risks for the operator	• Significant extra time may result for the operator to develop and maintain a job card system that meets the Part-145 requirements; ➨ *S6: Standardization of the manufacturer's task cards including Part-145 requirements may compensate for the operator's lack of experience as concerns maintenance processes and procedures* • Significant extra cost may result for a small operator to get the experience needed to adapt its job card system in accordance with the status of the aircraft or with the local conditions of operation; ➨ *S8: Other commercial arrangements should be allowed between the operator and an MRO*	• Significant extra time may result for the operator to check completeness of various maintenance package with different layouts; ➨ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when controlling the correct completion of the tasks*	• Significant extra time may result for the operator to check completeness of various maintenance package with different layouts; ➨ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when controlling the correct completion of the tasks*

	Option 2: the operator provides the MRO with a job card system	Option 3: the MRO uses only its internal job card system	Option 4: a difference is made between line and base maintenance
Organisational risks for the MRO	• Significant extra time may result for the MRO to adapt the operator's task cards in accordance with the specific processes described in its MOE; *S5: Standardization of the task cards including Part-145 requirements may help MROs to introduce (under specific tags) specific tasks and requirements related to their processes and procedures*	• Significant extra time may result for the MRO to introduce specific operator's tasks in its job card system in accordance with the status of the aircraft or the local conditions of operation; *S7: Standardization of documents related to the status of the aircraft and to the local conditions of operation may help the MRO to add operator's specific tasks and requirements* • Significant extra time may result for the MRO when additional manufacturer's documentation must be searched; *S8: Other commercial arrangements should be allowed between the operator and the MRO*	• Significant extra time may result for the MRO to introduce specific operator's tasks in its job card system in accordance with the status of the aircraft or the local conditions of operation; *S7: Standardization of documents related to the status of the aircraft and to the local conditions of operation may help the MRO to add operator's specific tasks and requirements* • As concerns base maintenance, significant extra time may result for the MRO when additional manufacturer's documentation must be searched; *S8: Other commercial arrangements should be allowed between the operator and the MRO*

	Option 2: **the operator provides the MRO with a job card system**	**Option 3:** **the MRO uses only its internal job card system**	**Option 4:** **a difference is made between line and base maintenance**
Safety risks on the operator's side	• The operator may not have the required experience to adapt its job card system in accordance with maintenance processes and procedures; ➨ *S6: Standardization of the manufacturer's task cards including Part-145 requirements may compensate for the operator's lack of experience as concerns maintenance processes and procedures* • A small operator may not have the required knowledge to adapt its job card system in accordance with the status of the aircraft or with the local conditions of operation; ➨ *S7: Standardization of documents related to the status of the aircraft and to the local conditions of operation may help the operator to manage specific tasks and requirements*	• The operator may face difficulties to record several different MRO's work cards which layouts are different; ➨ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when recording the completion of the tasks* • The operator may face difficulties to ensure that the maintenance package is complete, including all relevant mandatory tasks and inspections; ➨ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when controlling the correct completion of the tasks* • A transcription error may occur when transferring maintenance data feedback into the operator's records system; ➨ *S1: Standardization of the task cards and of procedures on how to fill them may prevent operators from error when recording the completion of the tasks*	• The operator may face difficulties to record several different MRO's work cards which layouts are different; ➨ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when recording the completion of the tasks* • As concerns base maintenance, the operator may face difficulties to ensure that the maintenance package is complete, including all relevant mandatory tasks and inspections; ➨ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when controlling the correct completion of the tasks* • As concerns base maintenance, a transcription error may occur when transferring maintenance data feedback into the operator's records system; ➨ *S1: Standardization of the task cards and of procedures on how to fill them may help operators when controlling the correct completion of the tasks*

	Option 2: the operator provides the MRO with a job card system	Option 3: the MRO uses only its internal job card system	Option 4: a difference is made between line and base maintenance
Safety risks on the MRO's side	• The MRO workers may feel disturbed because they have to cope simultaneously with many different layouts; ➨ *S1: Standardization of the task cards and of procedures on how to fill them may help MRO workers when performing the tasks*	• The MRO may not have the required knowledge to adapt its job card system in accordance with the status of the aircraft or with the local conditions of operation; ➨ *S7: Standardization of documents related to the status of the aircraft and to the local conditions of operation may help the MRO to add operator's specific tasks and requirements* • The MRO may omit to carry out a required task related to the status of the aircraft; ➨ *S4: Standardization of the task cards including specific tags to introduce operator's specific tasks and requirements may help MROs to pay attention to such data* • The MRO may omit to carry out an additional task related to the local conditions of operation of the aircraft; ➨ *S4: Standardization of the task cards including specific tags to introduce operator's specific tasks and requirements may help MROs to pay attention to such data*	• The MRO workers may feel disturbed because of differences between line and base maintenance task cards; ➨ *S1: Standardization of the task cards and of procedures on how to fill them may help MRO workers when performing the tasks* • For base maintenance, the MRO may not have the required knowledge to adapt its job card system in accordance with the status of the aircraft or with the local conditions of operation; ➨ *S6: Standardization of the manufacturer's task cards including Part-145 requirements may compensate for the operator's lack of experience as concerns maintenance processes and procedures* • For base maintenance, the MRO may omit to carry out a required task related to the status of the aircraft or to the local conditions of operation of the aircraft; ➨ *S4: Standardization of the task cards including specific tags to introduce operator's specific tasks and requirements may help MROs to pay attention to such data*

This assessment shows the eight following solutions:

- S1: Standardization of the task cards and of procedures on how to fill them
- S2: Standardization of the interpretation of the regulatory text that is allowed by the supervision authorities
- S3: Raising consciousness on risks related to complacency during continuous human factors training
- S4: Standardization of the task cards including specific tags to introduce operator's specific tasks and requirements
- S5: Standardization of the task cards including Part-145 requirements
- S6: Standardization of the manufacturer's task cards including Part-145 requirements
- S7: Standardization of documents related to the status of the aircraft and to the local conditions of operation
- S8: Other commercial arrangements should be allowed between the operator and an MRO

For economical, organisational and safety reasons, the eighth solution S8 should be allowed, which belies Options 2, 3 and 4 of the Rulemaking Task n°145.020. Thus, BUREAU VERITAS considers that Options 2, 3 and 4 of the Rulemaking Task do not satisfy the Agency's objective to enhance aviation safety throughout Europe.

Considering Option 1 (of the Rulemaking Task n°145.020), it is acceptable on the condition that solutions S1 to S6 are implemented. Those solutions can be regrouped into three broad solutions that are discussed in § **4 Data Analysis**:

- **Solution A** (grouping solutions S1, S4, S5, and S6):
  Standardization of the task cards and of procedures on how to fill them, including:
  - Part-145 requirements;
  - Specific tags to introduce operator's specific tasks and requirements related to the status of the aircraft and to the local conditions of operation;
  - Specific tags to introduce specific tasks and requirements related to the MRO's processes and procedures.
- **Solution B** (corresponding to solution S2):
  Standardization of the interpretation of the regulatory text that is allowed by the supervision authorities
- **Solution C** (corresponding to solution S3):
  Raising consciousness on risks related to complacency during continuous human factors training

Annex F

Model to implement a safety process in a maintenance organisation

BUREAU VERITAS proposed the following model to implement the safety process in the maintenance organisations, in the purpose of obtaining more positive results and decrease of errors particularly in documentation.

♦ General approach

Detection and correction of maintenance errors are essential elements contributing to the improvement of safety in the aeronautical field. Recent statistics show that 70 % up to 80 % aircraft accidents are due to human factors, and in a significant part, a maintenance error is one of the main causes or a contributing factor at least.

The Henrich ratio or "iceberg scheme" demonstrates that we only see what is visible. In fact for 1 fatal accident there are 10 accidents, and we never see the 30 reportable incidents and 600 incidents.

"The cause of an accident is to be found in whatever it was that interfered with the aviation maintenance specialist's performance at a critical moment, the outcome of which was a maintenance error."

The common errors in maintenance are:

- Omission—forget a step, a part, etc. **56%**
- Incorrect installation **30%**
- Wrong part **8%**
- Other (ground handling, etc.) **6%**

Source: ICAO Human Factors Circular 12 - *Human Factors in Aircraft Maintenance Digest*

The information exchange enables to reduce or even avoid the causes of incidents and accidents. To take human factors into account is essential, as to develop the "safety net" which includes the "Awareness, Knowledge and Resources".

♦ Objectives

The objective is to identify the factors contributing to these events by estimating all the known information, while implicating and encouraging the personnel to spontaneously report, in due time, the potential causes of errors they are involved or witnessed to. This in order to avoid the risk of error and in order the system be resistant to similar errors.

♦ Sources of information and means of detection

- Results of scheduled and non scheduled audits,
- Reports of Authorities, external audits, contracted operators, etc.…
- Analysis of reports relative to ground, flight incidents, flight and ground U turns, delays, Technical Log Book etc.
- Failures found during maintenance : ("Material Incident Report" §2.18 MOE)
- An error observed by the personnel: «EVENT REPORT» (see part 5 of MOE).
- Other sources.

♦ Internal report of an internal event

Any personnel who, through his position in the Maintenance Organization, can find or is implicated to an event likely to affect the safety, is compelled to mention it with regard to the professional and moral ethics.

In order to encourage him to do so, he can fulfil a form entitled « EVENT REPORT» and send it as soon as possible to the Quality Division, to the attention of Maintenance Safety Department. It is possible to mention, at the bottom of this form, proposals of improvement of safety or quality.

The way of writing or spelling is not important; the most important is to notify the event in due time in order to start the necessary corrective action and in order to avoid the incident and the reproduction of such cases.

The Maintenance Organization is committed not to inappropriately sanction any person spontaneously declaring an error on due time.

The Organization is committed to guarantee anonymity and immunity for any person spontaneously declaring an error.

Means:

The Maintenance Safety Department holds at disposal:

Forms entitled: **«EVENT REPORT»**

Letter-boxes set at level of the different activities on base and of the e-maintenance sites are identified: **«EVENT REPORT BOX».**

♦ Report analysis

From the information collected in the individual notifications, the control reports, audit reports, incident and delay reports, and any other source, the Maintenance Safety Department deals with the event on the form «Event Handling Form»:

- Analyses, classifies and determines the errors origins and the factors contributing to.
- Requests or recommends to the concerned entity, the corrective action to be done.
- Will value the efficiency of the corrective action and will proceed to the closure of the form.

♦ Acquisition of the collected information

A status is established and followed by the Maintenance Safety Manager (MSM) in order to enable the collected information management.

The MSM can delegate the management of this follow-up status. The MSM's role is mentioned in chapter 1.4.4.of the MOE. If needed, the interim can be performed by a «maintenance safety» referring member who is appointed by the MSM.

A list of the referring members is validated by the Managing Director and is updated by the MSM.

♦ Investigations

In accordance with the urgency and the nature of the collected information, the necessary and sufficient investigations can be performed either only with the «Event Handling Form», or with the «Investigations Report» as a complement. The «Investigations Report» form is in part 5 of the MOE.

With sole purpose of investigations, the use of the safety form (for example: «MEDA», *Maintenance Error Decision Aid*, developed by the manufacturer Boeing) enables the "maintenance safety" referring members (safety investigator) to remain objective, independent and impartial.

♦ "Maintenance safety" evaluation and review of undertaken actions

Directing reviews of the Maintenance Organization are released by the Managing Director, during which a review of accidents, incidents, events linked to the maintenance safety will be performed.

Conclusions of the directing reviews and any other investigation can be used by the MSM to release "safety" evaluations. For this purpose, he will designate one or some "maintenance safety" referring member(s) not involved in the evaluated field.

♦ Distribution of conclusions

The maintenance safety department will send, according to the case, an Event Bulletin relating conclusions relative to the recorded event, to the concerned people and generally within the Organization.

♦ Feedback

These bulletins are transmitted by the Maintenance Safety Department to the Training Department in order to be integrated in the framework of the continuous training upon the Maintenance Organization procedures and upon human factors. (MOE §3.4, §3.13 and §3.14).

♦ Disciplinary policy

Errors are either deliberate acts called violations, or unintentional acts called human errors. The latter are of two types: errors of intention (mistakes) and errors of execution (slips, lapses).

Violations need to be punished to avoid the spread of undesirable practices. The disciplinary policy must both provide fair disciplinary sanctions depending on the gravity of each violation act, and offer immunity to persons who spontaneously declare errors. Such policy establishes a so-called just culture, which is recalled by the Part 145 regulation as follows: *"An occurrence reporting 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."* AMC 145.A.60(b)(2) Occurrence reporting

The internal policy must include a disciplinary policy that clearly describes the sanctions and the related cases of application, together with conditions to be granted immunity. This policy must be well-known by each employee.

Any proposal of disciplinary sanction, administrative or else, is compulsorily submitted to the MSM's opinion. This one performs an analysis of standards, system and facts on the basis of human factors and safety form like MEDA or other. The MSM makes a recommendation to the Managing Director and to the proposal emitter.

The violation act, together with the applied sanction, shall be displayed as a recall of the existence of the disciplinary policy. Moreover, any proposal of sanction can be dealt with by the MSM as a source of information to start the process described in the present procedure.

When implementing a disciplinary policy, the Managing Director must decide:

- <u>To establish the truly "blame-free" system</u>, telling the employees that unless they intended the damage (e.g. as an answer to pressure from superior management), no disciplinary action will be taken against them if they report their error (spontaneously and within reasonable delays) and participate to its investigation;
- <u>Not to continue with punitive systems</u>. Those systems essentially outlaw human error, leading to resign oneself to the fact that employees will never self-report, and to restrict one's learning to only those errors that cannot be hidden;
- While creating confidential reporting systems to collect error data, not to leave the employees to fend for themselves under punitive disciplinary policies;
- Not to draw a line in the sand, educating the workforce to know where the line is and ask for reporting by those who have not crossed the line.

♦ Conclusion

In an organization, individual attitude of each member of the staff is influenced by the structure of this organization.
In a system, consequences of an error are determined by the hardness of this system.
Procedures and culture of an organization determine the level of safety of this organization.
Security of an organization is directly linked with capacity to implemented relevant rule.

♦ Profiles and duties

<u>Note</u>: In the future, a "Maintenance Safety Officer" will be appointed. He will have to meet, in particular, the profile of the dedicated personnel and to have a specific role with the MRO Accountable Manager and Quality manager. Its independence will have to be demonstrated. The Maintenance Safety Officer is the key man for internal and external Safety and Human Factors matters.

❖ *<u>Profile of Human Factors trainers</u>.*

- Qualified trainer with 3 years experience,
- Employed in a Maintenance Organization at least 3 years,
- Basic human factors Knowledge,
- Really recognized in the company and to hold a certain legitimacy,

- Volunteer,
- Motivated,
- Independent from trainees working activities.

❖ *Duties of Human Factors trainers*.

The trainer is the leader in the success of the implementation of the company human factors process. He must:

- Be convinced in the interest of HF approach for a good transfer of know-how,
- Analyse specific events (incidents/accidents) related to maintenance errors,
- Change the approach and the behaviour of individuals within the organisation more than to transmit detailed knowledge on a given field,
- Be involved in the subject, credible, respected, to recognize its own limits and its own errors,
- Inculcate the Human Factors concept to the personnel by persuading them that an individual, voluntary and continue participation will allow a strong contribution to the improvement of the safety,
- Be sensitive to trainees' request,
- Be aware of any events (incidents/accidents) arising in the organization regarding HF,
- Be familiar with the training needs of each individual in this matter.

❖ *Profile of Human Factors dedicated personnel.*

- Managers (line station, maintenance base, workshops,….) or skilled personnel. They must:
- Be really "notorious" in the Organisation and hold certain legitimacy,
- Have basic knowledge about HF and safety policy,
- Be impartial and neutral,
- Have appropriate skills in communication, interview as well as collection, analysis and compilation of information,
- Be volunteer,
- Have a personal motivation and involvement.

❖ *Duties of Safety Policy/Human Factors dedicated personnel*.

- Focal point of management of major safety events (follow up, investigation,…),
- Risks analysis,
- HF concept coordination and follow up,
- Feedback information of safety events to the Accountable Manager,
- Promote the Safety Policy within the organization,
- Field management of events related to Safety,
- Be familiar with the training needs of each individual in this matter,
- Be aware of any events (incidents/accidents) arising in the organization regarding HF,
- Be allowed to meet any individual at any time within the organisation,
- Get access to any documents needed for events investigation,
- Have enough skills to understand aircraft systems, related technical documentation and the maintenance procedures in force in the organisation,
- Be appointed for the analysis or participation of the analysis of maintenance errors.