

JULY 2006

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FAST 38

F A S T 3 8 A I R B U S T E C H N I C A L M A G A Z I N E



Customer Services

events

Just happened

SPARES, SUPPLIER SUPPORT & WARRANTY SYMPOSIUM **ATHENS, GREECE** **13 - 16 FEBRUARY 2006**

Over 70 customer representatives from Europe and Africa and 30 supplier companies attended the symposium titled 'Working together in partnership'. Airlines, MROs and major suppliers exchanged views on how to optimize maintenance and operational costs. Airbus presented the Airbus Modular Spares Services (AMSS), a fully flexible supply chain services approach, enabling customers to focus on their individual core business. Airbus Supplier monitoring recognized the progress made on supplier performance while continuous improvement initiatives with BFE and engines suppliers were presented to customers.

Airbus Warranty further demonstrated via an on-site classroom the capacities of its all-new on-line services, which enhance efficiency in everyone's operations whilst ensuring protection of customers' rights.

A300/A310 ADVANCED COCKPIT PROGRAMME **TOULOUSE, FRANCE** **22 - 23 MARCH 2006**

A two-day briefing for A300/A310 operators was held in March 2006 in Toulouse to detail this programme which considers aircraft operation until the year 2025 and beyond. With this advanced cockpit, airlines would benefit from a significant reduction in maintenance costs, the FMS2 (Flight Management System) and the new ATM (Air Traffic Management) capabilities will allow trajectory prediction and optimization, resulting in significant fuel saving.

There was also a review of the current in-service requirement for enhancement of the existing Flight Management System memory and data loading characteristics. Though the Advanced Cockpit is the long-term comprehensive solution to this, it was announced that feasibility studies to investigate a shorter term solution are underway, further feedback will be given during the third quarter of 2006.

A330/A340 FAMILY TECHNICAL SYMPOSIUM **SUN CITY, SOUTH AFRICA** **28 MAY - 2 JUNE 2006**

The latest developments in support services from Airbus were explained, including FAIR (an interactive forum for resolution of technical issues), AirN@v and e-Catalogue developments, as well as the new concept for Service Bulletins.

The airline caucus identified issues to be addressed, which were landing gear, design service goal extension and fuel tank contamination. For non-technical issues, vendor management, single source suppliers and AD traceability by part number changes were highlighted. Also requested were more frequent updates outside symposiums.

Operational Excellence awards were presented. Gulf Air was awarded as best operator of a small fleet of six A330s and Korean Air was awarded as top operator of a large fleet of 19 A330s. China Airlines with a fleet of seven A340s and Lufthansa German Airlines with 39 A340s were awarded for their excellence. South African Airways received the award as best A340-600 operator.

HUMAN FACTORS SYMPOSIUM **MOSCOW, RUSSIA** **14 - 16 JUNE 2006**

The 22nd Human Factors Symposium took place with the theme of: 'Human Factors as a core value at Airbus'. The symposium encompassed HF strategy, HF training, operations and threat and error management, ATC and maintenance.

Particular importance was given to the Human Factors Toolkit Project, which is intended to reconcile Human Factors Theory with operational guidance.

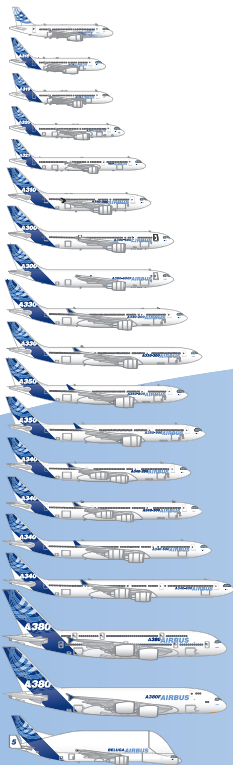
The event was sponsored by ICAO and IAC (Interstate Aviation Committee) of the CIS (Commonwealth of Independent States).

Coming soon

TRAINING SYMPOSIUM, SAN FRANCISCO, USA, 2 - 5 OCTOBER 2006

After an outstanding event in Bangkok in December 2004, Airbus is pleased to announce the eighth dynamic and highly informative forum dedicated to the Airbus international training scene. This two yearly event provides airline training professionals with a unique opportunity.

Whether the focus is on flying, cabin safety or aircraft maintenance, participants will get the latest status of all Airbus training programmes, technologies and perspectives and will share their Airbus training experience with the industry's most senior players. Separate but integrated conference streams covering pilot training, cabin crew training, maintenance training and simulation & training technologies will complement an exhibition featuring the latest developments in these fields. Invitations were sent in June 2006.



FAST

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A I R B U S
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S E R V I C E S

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This issue of FAST has been printed on paper produced without using chlorine, to reduce waste and help conserve natural resources.
Every little helps!

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Performance monitoring of IFE systems

Proposals for the future from Emirates Airline perspective

Today's In Flight Entertainment (IFE) systems installed in many wide body aircraft are undoubtedly some of the most complex systems engineering professionals have ever designed and developed. On average, well over 2,000 Line Replaceable Units (LRUs) are installed and linked by networks onboard the aircraft. These systems have a core hardware platform layer, a network layer, an oper-

ating system layer, a core software layer, an application layer, a BITE (Built-In Test Equipment) reporting layer and a Graphic User Interface (GUI) layer. These are augmented by databases that identify an airlines chosen cabin/seat configuration, overhead display configuration and applicable media storage and reproducing devices (video, audio and games).

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There are many parties involved in the life cycle of IFE development and maintenance. The airlines engineering projects team, which is the focal point within an airline, works with other departments such as in-flight services, catering, IFE media services, maintenance engineering, procurement, spares planning and cabin/IFE maintenance teams. Externally, the projects team interfaces with OEMs (Original Equipment Manufacturers - Airbus or Boeing), IFE vendors, seat vendors, galley vendors, Airshow/ Camera and other third party suppliers. Typically, the development cycle takes well over two years from the kick-off stage to delivery of the first aircraft with operational and certified IFE.

Consider the following scenario: You have worked tirelessly for two years along with other teams to successfully develop and deliver an IFE system, which is fully installed and operational. The responsibility does not stop here. If all goes well, the first revenue flight with passengers is successful. Over a period of several months after entry into service, as is common with complex systems ; you find a certain number of problems. On Monday morning, your Senior Vice President asks your team for input on how the IFE is performing in service. You hastily review the in-service logs, pore over MTBUR/MTBF data, scan and rescan in-service problems organized

according to priority/ criticality, and review technical logs. Moreover, if you are lucky, you may be apprised of the customer's feedback.

In the end, what you have compiled can best be described as a mixed bag of information, and you have come to realize that the report still does not represent how the IFE performed throughout flight. In addition, the compilation process has most probably taken considerable time while the Senior VP is waiting for the information. It is fair to say that this collection and reporting process is more impromptu than organized. Every few weeks or months, you may have to go through a similar exercise, some routine, others requested.

What is missing in the above scenario is a clear and concise method of objectively, qualitatively and quantitatively reporting IFE in-service performance. Such a reporting method would provide the most realistic summary of system performance throughout the flight.

This article puts forward proposals to achieve this objective from Emirates Airline's perspective. Some alternatives are presented. The proposals apply equally to both wide body aircraft and single aisle aircraft equipped with IFE.



Abbreviations:

ACMS	Aircraft Condition Monitoring System
ACARS	Aircraft Communication Addressing and Reporting System
APU	Auxiliary Power Unit
ARINC	Aeronautique Radio Incorporated
ATSU	Air Traffic Service Unit
AVOD	Audio Video On Demand
BGAN	Broad Band
BITE	Built-In-Test Equipment
CMEU	Centralized Memory and Expansion Unit
CMT	Cabin Management Terminal
CPMU	Cabin Passenger Management Unit
CTU	Central Telecommunication Unit
DAR	Direct Access Recorder
DMU	Data Management Unit
EADB	Enhanced Area Distribution Box
EPESC	Enhanced Passenger Entertainment System Controller
FADEC	Full Authority Digital Engine Control
FDIMU	Flight Data Interface and Management Unit
GUI	Graphic User Interface
IFE	In Flight Entertainment
IRM	IFE Report Domain
LRU	Line Replaceable Unit
MCDU	Multipurpose Control and Display Unit
MDDU	Multipurpose Disk Drive Unit
MTBR	Mean Time Between Removals
MTBUR	Mean Time Between Unscheduled Removals
MU	Management Unit
OEM	Original Equipment Manufacturer
SATCOM	Satellite Communication Unit
TOC	Top of Climb
TOD	Top of Descent



Proposal 'A' Link between IFE and ACMS

With the integration of modern, state-of-the-art technology such as fly-by-wire or Full Authority Digital Engine Control (FADEC), the complexity of aircraft systems has led to the development of the Aircraft Condition Monitoring System (ACMS). The ACMS monitors the data supplied by various aircraft systems for trend monitoring to get maintenance relevant data. This data enables the airline to customize their maintenance planning. Long-term trend monitoring of the engines and APU (Auxiliary Power Unit) prevents

expensive, unscheduled maintenance actions outside the main base of the airline. In addition, the ACMS is presently used for various tasks such as hard landing detection, team proficiency monitoring and trouble shooting at the system level. The main objective of ACMS is more preventative in nature.

The ACMS is organized around a DMU (Data Management Unit, on A340-500 the FDIMU - Flight Data Interface and Management Unit), which interfaces with other aircraft systems. Approximately 13,000 parameters from 48 computers (via ARINC 429 data buses) on the aircraft are fed into the DMU.

Based on these parameters, the DMU performs several tasks, the results of which are either found on DAR (Direct Access Recorder) cassettes, floppy disks (via MDDU - Multi Disk Drive Unit), on the MCDU (Multipurpose Control and Display Unit) screen or (if they are downloaded via ACARS - Aircraft Communication Addressing and Reporting System) directly on the ground support computer at the airline ground station. ACMS generates at least 21 reports, which include several standard reports and three user programmable reports.

PROPOSAL 'A' CONSISTS OF THE FOLLOWING ELEMENTS

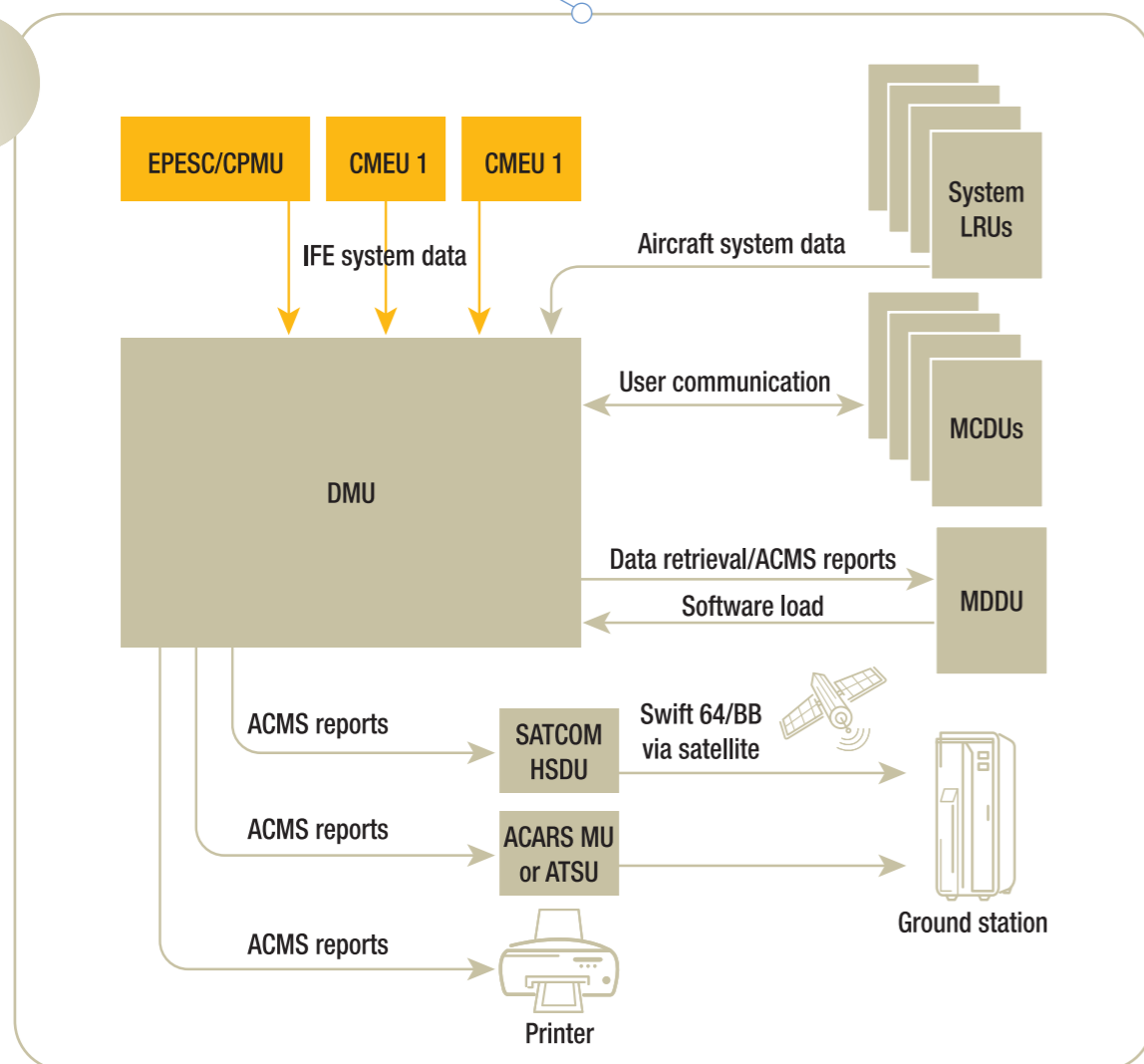
Connect the IFE main servers such as CMEU (Centralized Memory and Expansion Unit) and main processing LRUs (Line Replaceable Units) such as EPESC (Enhanced Passenger Entertainment System Controller) via ARINC 429 bus to the DMU. There shall be at least one bus from CMEU 1 to the DMU, a

second bus from CMEU2 to the DMU and a third bus from the EPESC to the DMU.

The IFE servers shall regularly transmit various data such as seat operational mode (audio, video, interactive modes), seatbox health status, EADB (Enhanced Area Distribution Box) health status, handset operational status, overhead health status, AVOD (Audio Video On Demand) availability status, CMEU availability status, AVOD storage device health status, AVOD server health status, CMT (Cabin Management Terminal) health status, CTU (Central Telecommunication Unit) health status, SATCOM (Satellite Communication Unit) availability status, seat reset status at least once every 30 minutes (this should be customizable to an airline's specific needs) via ARINC 429 buses to the DMU. In addition, software configuration data and database configuration are sent once at the beginning of the flight to the DMU.



ACMS - Data management function for proposal A



The DMU processes all engineering data received from the IFE system and generates IFE performance/stability reports on ground, at takeoff and every hour after take off, at TOC (Top Of Climb), at TOD (Top Of Descent), at touch down and upon arrival at the gate.

These reports are sent as IFE Stability Report <23> either to the printer on arrival, to floppy disks on MDDU or down linked automatically via ACARS, Data-3, swift 64 or BGAN (broad band), whichever is available and selected as the channel of communication by the airline. A sample of such an IFE Stability report <23> is shown below.

In addition to standard report triggers for report <23>, means shall be provided to support user definable triggers via the IFE database. These user definable triggers are used to monitor specific events such as AVOD stream failure, CMEU server failure, and CMT failure to capture the overall cabin IFE health conditions via reports.

In addition, the logic for the report <23> shall provide means to capture all commanded and commanded seat reset data along with pertinent UTC (Universal Time Clock), data and seat location parameters.

CMEU availability status, AVOD storage device health status, AVOD server health status, CMT health status, CTU health status, SATCOM availability status and seat reset status at least once every 30 minutes (this should be customizable to an airline's specific needs) via internal buses to the IRM. In addition, software configuration data and database configuration are sent once at the beginning of the flight to the IRM.

The IRM processes all engineering data received from the IFE system and generates the IFE Stability/Performance report on ground, at takeoff and every hour after take off, at TOC, at TOD, at touch down and upon arrival at the gate. These reports are sent as IFE Stability report <23> either to the printer in flight, to floppy disks on MDDU or down linked automatically via ACARS, Data-3, swift 64 or BGAN whichever is available and selected as the channel of communication by the airline. A sample of such an IFE Stability report <23> is shown previous page.

In addition to standard report triggers for report <23>, means shall be provided to support user



Proposal 'B' Built-in condition monitoring

Instead of connecting the DMU via ARINC 429 data buses to core IFE servers and processing units, this proposal necessitates fully certified software running as part of the CMEU servers 1 and 2. The core certified software is essentially ACMS report <23> IFE Stability/Performance report re-hosted on CMEUs 1 and 2.

The algorithm and implementation is certified as part of the core software by the OEM (Airbus or Boeing as applicable) during the certification process. Once certified, the IFE vendor cannot modify these core algorithms. For further discussions, we shall call this software IRM (IFE Report Domain).

The IFE servers regularly transmit various data such as seat operational mode (audio, video, interactive modes), seatbox health status, EADB health status, handset operational status, overhead health status, AVOD availability status,

Sample user programmable triggers

- (a) IF QMU1 NOT healthy, THEN generate report <23>
- (b) IF Seats availability < or = 95%, THEN generate report <23>
- (c) IF AVOD INOP, THEN generate report <23>

Seat availability explanation

```

A340-500 IFE STABILITY REPORT <23>
ACID DATE UTC FROM TO FLT CNT
H1 A6-ERA 17JUN06 07.33.14 OMD B KJFK EK201XXXX 020
PRV FLT IFE IDENTIFICATION VERSION
H2 EK202XX SYSTEM 3000I PANASONIC 12/42/204 PERF 12.2
SOFTWARE CONFIGURATION SUMMARY
C1 XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
SYSTEM RESET SUMMARY
D1 XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
HEADEND FAILURES
D3 XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
ON GROUND RESET DATA
D5 XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
AVAILABILITY DATA AT TAKEOFF (T) - SEATS IFE
D7 01 AEFK 02 AEFK 03 AEFK
D8 XXYXXYY XXYXXYY XXYXXYY
D9 06 AB EF JK 07 AB EF JK
D10 XXYXXYY XXYXXYY XXYXXYY
D11 08 AB EF JK 09 AB EF JK
D12 XXYXXYY XXYXXYY XXYXXYY
D13 10 AB EF JK 11 AB EF JK
D14 XXYXXYY XXYXXYY XXYXXYY
D15 12 AB EF JK
D16 XXYXXYY XXYXXYY XXYXXYY
D17 15 AB DE G JK
D18 XXYXXYY XXYXXYY
D19 .
D20 .
D21 .
D22 41 AB DE FG JK
D23 XXYXXYY XXYXXYY XXYXXYY
                
```

```

AVAILABILITY DATA AT T + 60 MINS - SEATS IFE
D24 .....
D25 .....
D26 .....
D27 .....
D28 .....
D29 .....

AVAILABILITY DATA AT T + 120 MINS - SEATS IFE
D30 .....
D31 .....
D32 .....
D33 .....
D34 .....
D35 .....

AVAILABILITY DATA AT T + 180 MINS - SEATS IFE
D36 .....
D37 .....
D38 .....
D39 .....
D40 .....
D41 .....

SEAT AVAILABILITY SUMMARY DATA - SEATS IFE
E1 AT T XXX
E2 AT T + 60 MINS XXX
E3 AT T + 120 MINS XXX
E4 AT T + 180 MINS XXX
E5 AT T + 240 MINS XXX
.
E22 AT LANDING XXX
                
```

The status of each seat in the IFE stability report <23> is represented by two hexadecimal digits.

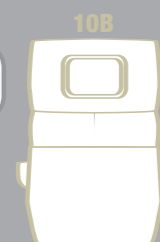
Audio	Video	AVOD	Games	Interactive	Telephone	Airshow	Camera
1	1	1	1	1	1	1	1

1	1	1	1	1	1	0	0
---	---	---	---	---	---	---	---

1 means available, 0 means not available

For example, the seat 10B may have a status of FC, which translates into binary values 1111100 and gives the following IFE availability:

- Audio available
- Video available
- AVOD available
- Games available
- Interactive available
- Telephone available
- Airshow NOT available
- Camera NOT available





Comparison of the two proposals

PROPOSAL 'A' MERITS

Once certified, the ACMS software architecture and its implementation tend to be more stable. It has the added advantage of rigorous control by OEMs. The links to all other peripherals (such a printer, MDDU, ACARS and MCDUs) are already established and implemented as part of the ACMS system configuration.

PROPOSAL 'B' MERITS

No additional wiring between the IFE and DMU is necessary. Implementation is under the control of one vendor without involving the ACMS supplier. Integration and testing are entirely between the IFE vendor and OEM.

About the authors...

Mahmood AMEEN

Mahmood Ameen is currently head of the Cabin, IFE and Avionics Engineering projects section at Emirates Airline where he serves as Vice President of Engineering Projects. In his role, he oversees the development of new IFE and Cabin systems for all of Emirates new fleet of aircraft. He is also responsible for the in-house retrofit and maintenance of cabin and IFE systems in Emirates current fleet. Mr. Ameen holds a Bachelor of Science in Aeronautical Engineering from St Louis University, Missouri, USA and Master of Science in Air Transport Management from Cranfield University, UK.

Vijay RATHNAM

Vijay Rathnam is currently Projects Engineer in Emirates Engineering, Dubai. He serves as a focal engineer for IFE development for Emirates new fleet and also is responsible for the development of enhanced cabin lighting (mood lighting/star lighting) systems. Vijay, a US citizen, has extensive experience in IFE industry and avionics systems (FMS, ACMS) development. He holds a Bachelor of Engineering (Electrical) from the University of Madras, and Master of Science in Computer Science from the University of Texas, USA.



Illustrations provided by Emirates Airline

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definable triggers via the IFE database. These user definable triggers are used to monitor specific events such as AVOD stream failure, CMEU server failure, and CMT failure to capture the overall cabin IFE health conditions via reports.

The logic for the report <23> shall also provide means to capture all commanded and uncommanded seat reset data along with pertinent UTC, data and seat location parameters.

If critical changes have to be installed in the IRM domain, they shall not be down linked by normal down load procedures used by IFE systems. Instead, these changes shall be approved by OEMs prior to controlled installation on the CMEU servers.

Software considerations in airborne systems

Presently, ACMS software is classified as Level D or Level E. Level D is assigned to report generation software and Level E for the data collection software. Report generation software refers to standard reports such as the engine cruise report and cruise performance report, which highly influence engine performance warranty calculations and scheduled maintenance. The IFE Stability report, which is a user definable report, is classified under Level E. All IFE software products onboard are currently classified as Level E systems based on DO-178B classifications.

Conclusion

Although a sample report is provided in this article, it could be further enhanced with additional parameters and formatting as deemed necessary. The interval for the report trigger and parameters to monitor can be further refined.

There are recent developments in the industry to implement health-monitoring systems, which are aimed at remotely collecting and monitoring aircraft data to determine the status of an aircraft's current and future serviceability. There is potential to connect the IFE health

monitoring enhancements proposed above to such systems to provide value added IFE maintainability services both to an airline's maintenance control centre and line maintenance teams

With the enormous complexity of present day IFE systems, it is critical for airlines to have a complete, comprehensive, objective window into the performance of IFE throughout the flight, at take off and at landing. These added tools will provide the necessary mechanism to report with confidence the performance of IFE.

Performance monitoring of IFE systems

Airbus vision for the future

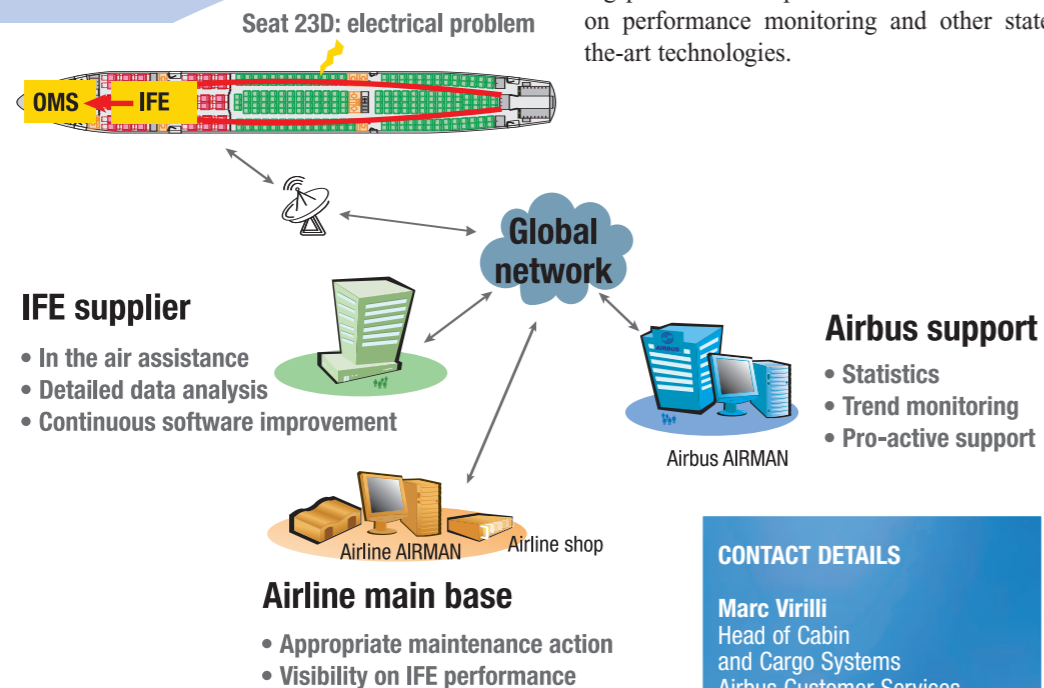
* AIRMAN (Aircraft Maintenance Analysis) is a real-time health monitoring and troubleshooting solution developed by Airbus. AIRMAN constantly analyses the status messages sent by aircraft systems and helps airlines to optimize their maintenance and troubleshoot their aircraft to:

- Better anticipate possible aircraft technical events.
- Improve their aircraft dispatch reliability.
- Cut their maintenance and operational costs.
- Improve their maintenance task efficiency.



Marc Virilli

Aircraft Health Monitoring and Management has been a constant major subject for Airbus for some years now and solutions for both raw OMS (Onboard Maintenance System) data acquisition such as BITE (Build In Test Equipment) and ACMS (Aircraft Condition Monitoring System) plus on-ground processing (AIRMAN*) have been developed and are available on all the Airbus current product line. Enhancements of these systems are implemented at the opportunity of each new aircraft as well as new services aimed at improving pro-active and predictive maintenance based on performance monitoring and other state-of-the-art technologies.



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The A380 maintenance programme is born!

A major success by all involved

On 23 December 2005, Airbus received acceptance of the A380 Maintenance Review Board Report (MRBR) from the European Aviation Safety Agency (EASA). This significant achievement is one major step in the A380 scheduled maintenance activity, but not the first, nor the last.

This article describes the way this milestone was achieved thanks to the very active and dedicated involvement of hundreds of people from operators, authorities, suppliers and Airbus in the MRB process.

Conclusion

This approach is global for all systems installed on Airbus aircraft and includes IFE (In Flight Entertainment) systems. Both proposals in the previous article from Emirates Airline are very valid ones, which in their principle complement investigation paths under study in

Airbus. In the next issue of FAST Magazine, we will share in more detail Airbus vision for the future for IFE Systems trend monitoring and enhanced maintenance processes using the aircraft as a major node of a network as shown above.



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 Director Maintenance Planning & Services
 Airbus Customer Services

For more details on the MRB process and ISC organization see the article in FAST31 December 2002.



The A380 MRBR

APPLICATION FOR THE MAINTENANCE REVIEW BOARD PROCESS

In December 2000, Airbus officially launched the A380 maintenance programme. To meet certification targets, Airbus must comply with the JAR/FAR 25-1529 Instructions for Continued Airworthiness applicable at that time. As the A380 Type Certification (TC) holder, Airbus must prepare, revise as necessary and submit for approval to the relevant airworthiness authorities the initial minimum scheduled maintenance/inspection requirements that are applicable to the A380 aircraft.

Just after the A380 first metal cut (Jan 2002), Airbus officially applied for the Maintenance Review Board (MRB) process to the Joint Airworthiness Authorities (JAA) in June 2002. At this time Airbus initiated an MRB process compliant with:

- JAA OPS Administrative & Guidance Material Section 2-Part 2 – Chapter 16
- FAR 121 AC 121-22A

At the time of application, the applicable Maintenance Steering Group method was MSG3 Rev 2002.1. This is the revision that was used to develop the A380 MRBR.

THE A380 POLICY AND PROCEDURES HANDBOOK

From June to November 2002 Airbus Maintenance Engineering developed the A380 Policy and Procedures Handbook (PPH) which, compared to the MSG3 document, provides additional procedures, details, guidance, interpretation of the rules, maintenance interval selection, form sheets, etc. necessary for analysis. The PPH also provides detailed work steps, responsibilities and scheduling. Between November 2002 and January 2003, Airbus

Maintenance Engineering organized three working sessions with the airworthiness authorities to finalize the preparation of the PPH before submission to the Industry Steering Committee.

The European JAA represented by the GSAC (France), the LBA (Germany), the CAA (UK) and also the FAA (USA) and the CASA (AUS) contributed to the A380 PPH preparation.

FEBRUARY 2003: THE FIRST INDUSTRY STEERING COMMITTEE

From 18 to 20 February 2003, Airbus organized the first A380 Industry Steering Committee (ISC), whose responsibilities were:

- To approve the A380 PPH.
- To monitor the development of the A380 MRBR and the different Maintenance Working Groups (MWG) activities.
- To submit the A380 Maintenance Programme Proposal to the MRBs for approval.

First ISC meeting participants

Organizations

- Air France
- All Nippon Airways
- Cargolux
- Fedex
- Lufthansa
- Lufthansa Technik
- Malaysia Airlines
- Qantas Airlines
- Singapore Airlines
- Virgin Atlantic

Engine manufacturers

- Rolls Royce
- The Engine Alliance

Airworthiness authorities

- Groupement pour la Sécurité (GSAC) - on behalf of the JAA
- Federal Aviation Administration (FAA) - USA
- Groupement pour la Sécurité (GSAC) - France
- Civil Aviation Authority (CAA) - UK
- Civil Aviation Authority (CAA) - Netherlands
- Federal Office for Civil Aviation (FOCA) - Switzerland
- Luftfahrt-Bundesamt (LBA) - Germany
- Civil Aviation Authority of Singapore (CAAS)
- Civil Aviation Safety Authority (CASA) - Australia

Lufthansa Technik was nominated ISC chair by the operators panel, Airbus co-chaired the ISC and GSAC was nominated MRB chair by the JAA.

The ISC also gave the A380 PPH preliminary acceptance and validated the overall planning definition to help the first A380 operator Singapore Airlines to get a CAAS approved Operator Maintenance Programme for EIS (Entry Into Service). As a consequence, the overall MRBR planning highlighted the need for the first MPP submission to the MRBs for approval 12 months before EIS.

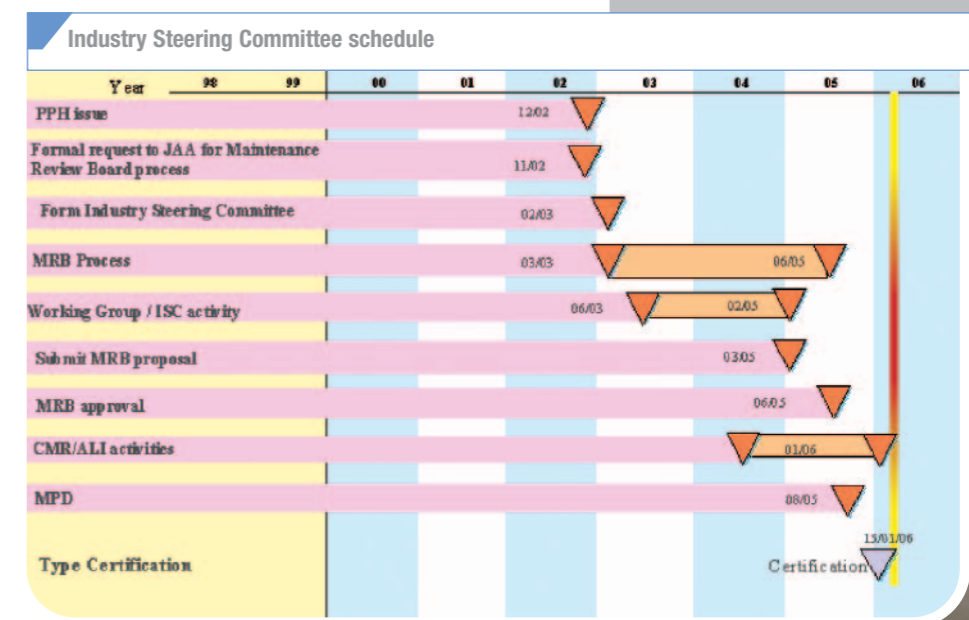
The ISC also defined the organization in charge of the development of the MRBR, relying on nine MWGs.

- MWG 1: Hydraulics and flight controls
- MWG 2: Environmental
- MWG 3: Power Plant APU
- MWG 4: Avionics
- MWG 5: Structures
- MWG 6: Zonal
- MWG 7: Fuel
- MWG 8: Landing gear
- MWG 9: Interior

To ensure an optimized contribution from all ISC/MWG and MRB participants, the ISC also set up an intensive planning for training sessions.

FEBRUARY TO JULY 2003: THE TRAINING SESSIONS AND A380 PPH APPROVAL

From February to July 2003, Airbus Maintenance Engineering organized five one-week training sessions around the world with the support of hosting customers, Airbus Engineering and A380 Programme organizations. All in all, more than 350 people from customers, airworthiness authorities, vendors and suppliers were given a general familiarization of the A380 design and trained on the A380 PPH.



Airbus maintenance training sessions



Policy and Procedure Handbook highlights

Maintenance interval

- Usage parameters chosen over letter intervals
- Each interval is expressed with the most appropriate usage parameter: fh (flight hour), fc (flight cycle) calendar
 - A flexible concept: Planning and maintenance checks can be optimized according to actual aircraft operation

A combined Zonal analysis for

- Standard Zonal Analysis
- Enhanced Zonal Analysis
- Lightning/HIRF Analysis

Ambitious scheduled maintenance threshold/ interval targets

- No scheduled maintenance requirement below 750fh at EIS
- Intermediate maintenance target: 24 months
- Structure inspections: 6Y (6 Year) and 12Y

JUNE 2003: THE PPH APPROVAL

In the mean time, thanks to the lessons learned during the training sessions, the PPH was updated and got its first approval by the ISC and acceptance by the MRBs in June 2003. The major highlights of this PPH are the aircraft yearly utilization for medium/long haul routes.

The A380 PPH becomes the industry benchmark in the opinion of the MRBs and operators who report it as the best they have ever seen.

The MWG activity

From June 2003 to March 2005, the nine MWGs reviewed the MSG3 analyses for A380 systems, structures and zones selecting the most appropriate scheduled maintenance tasks to ensure a safe, reliable and economical aircraft operation.

During this 21 month period, more than 900 MSG3 dossiers prepared by Airbus and major vendors maintenance engineers, representing the equivalent of more than 30,000 MSG3 analysis pages (equivalent) were reviewed during 54 MWG meetings from which close to 1,000 scheduled maintenance tasks were selected.

During Maintenance Working Groups activities

- The A380 rolls out of the final assembly line (May 2004)
- The European Aviation Safety Agency (EASA) takes over from the JAA for MRB processes
- Emirates and Korean Air join the A380 ISC
- The Civil Aviation Department (CAD) (Hong Kong) and the Bermuda authorities join the airworthiness authorities panel

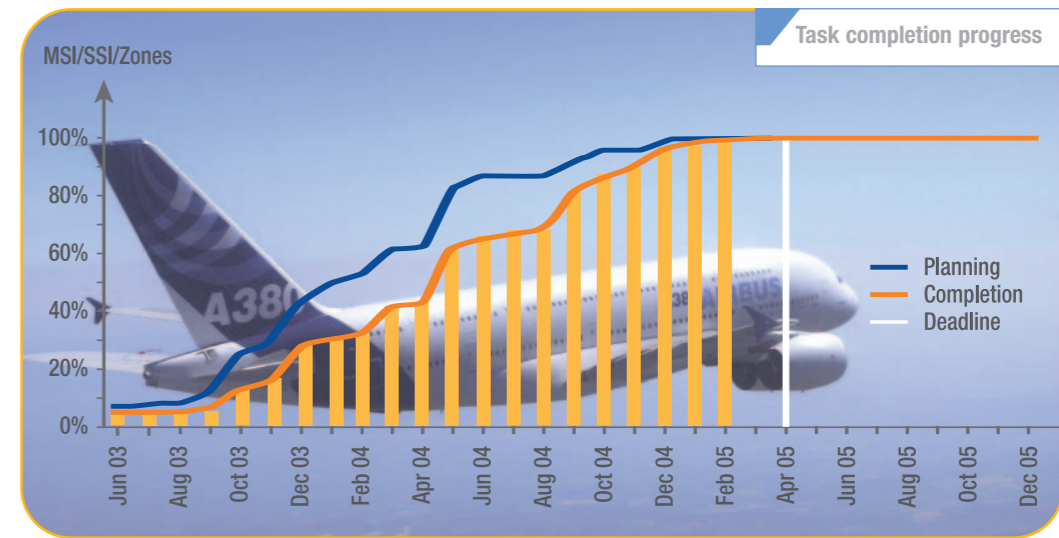
The first A380 Maintenance Programme Proposal (MPP)

Thanks to the efficient MSG3 analyses production and quality monitoring process controlled by the ISC, the initial target was met: **The A380 MPP is ready for review and acceptance by the A380 ISC in March 2005.**

During the tenth meeting in March 2005 the ISC completed review of the MWG results and concluded that the selected scheduled maintenance tasks and associated intervals are the most appropriate ones. The ISC then accepted the compiled MPP.

On 8 April 2005, some days prior to the A380 maiden flight, the first A380 MPP was submitted to the MRBs for acceptance according to the planning set up more than two years earlier. Early involvement in design phases and very active operator involvement were two key issues.

Most of the initial technical objectives were met in the A380 MRBR proposal, particularly the objectives associated with task selection and interval definition.



This was not achieved by chance. First of all, the active involvement of Airbus maintenance engineers in the very early stages of the aircraft design development was essential. The A380 maintenance tasks interval targets had been selected at the beginning of the 'A3XX' story, well before it became the A380. All through the concept and design phases of the A380 programme, Airbus maintenance and design engineers worked together to optimize scheduled and unscheduled maintenance. Their target was to offer an A380 with optimized maintenance costs to operators, while maintaining safety as the primary objective. All design specifications are defined so that the A380 design fulfils the initial MRBR targets and also remains compatible with future maintenance programme evolutions according to in-service experience.

All through the A380 design development and the MRB process, operators, airworthiness authorities and Airbus challenged each other, contributing to the continuous improvement of the overall MRB process with the common objective to offer the A380 with the most appropriate maintenance programme to support a safe, reliable and economical aircraft operation. This led to the development of very thorough MSG3 analyses and the selection of the most appropriate tasks and intervals.

Consequences of the A380 MRBR proposal acceptance versus the MRBR approval

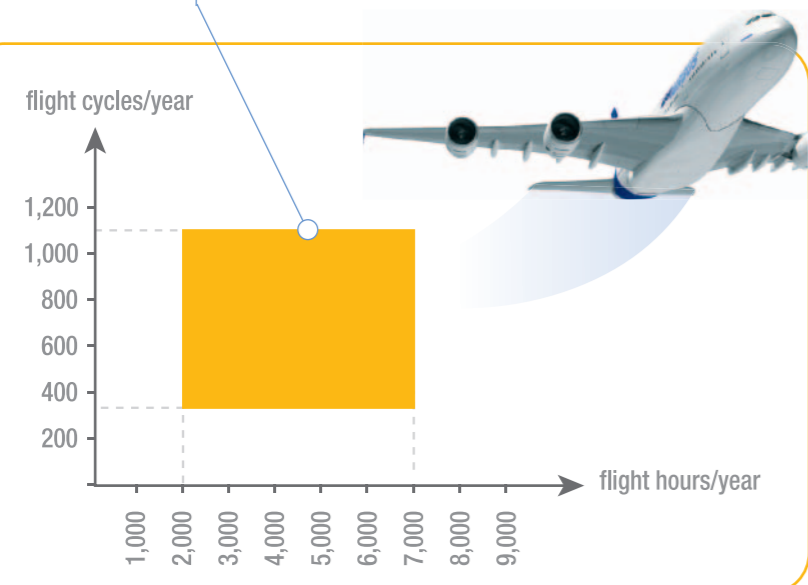
Readers familiar with the MRB Process may wonder why 'MRBR Proposal' acceptance is mentioned instead of 'MRBR approval' in this article.

According to the Instructions for Continued Airworthiness (ICA) JAR/FAR 25-1529, an approved MRBR is required at the latest for aircraft EIS. However, as agreed by the ISC the A380 MRBR planning has been developed in such a way that enough time is provided to the first operator to get approval for its Operator Maintenance Programme (OMP) by its local authorities.

Consequently, review of the MSG3 analyses started in July 2003 based on the design known at that time. Because of this and the numerous design changes that typically happen during the design and flight test phases, the MRBs were not in a position to approve a document covering the aircraft EIS design standard at this time.

In addition, during the development and review of the MSG3 analyses by the MWGs, some

A380 PPH aircraft utilization assumptions





- The 'MRBR Proposal' will be updated according to the changes identified during the March 2005 - June 2006 MWG and ISC meetings and submitted to the MRBs to be approved prior to EIS. This will become the first A380 approved MRBR.
- The first A380 operator, at that time, will only have to integrate the changes in its OMP in order to get approval from its local airworthiness authority.

This agreement offers benefits:

- To the first A380 operator who can anticipate their programme and planning to minimize workload just prior to EIS and limit it to a programme revision.
- To all A380 operators who can prepare in advance their maintenance programme and planning.
- To local authorities who have contributed to the MRB process and can approve their operators OMP more quickly.

assumptions on Flight Manual (FM) and Master Minimum Equipment List (MMEL) are made. These assumptions must be cleared for the MRBR approval. To protect the first A380 operator's interests an agreement is therefore found between operators, MRBs and Airbus:

- The first MRBR will be called 'MRBR proposal' and will not be approved but accepted by the EASA. It will thus be recognized as an acceptable basis by the first operators local airworthiness authority for approval of the first OMP.
- All design changes will be analysed by Airbus maintenance engineering for MSG3 analyses update and review by the relevant MWG prior to submission of the MPP to the MRBR for approval. This process is a standard one that remains applicable throughout the aircraft life in the MRBR revision process.
- All assumptions taken and recorded during review of the MSG3 analyses must be confirmed, if not, MSG3 analyses and MRBR must be reviewed and updated accordingly.

The A380 Maintenance Planning Document

A SCHEDULED MAINTENANCE DATA REPOSITORY

Parallel to the A380 MRB process, Airbus Maintenance Planning organization prepared the A380 Maintenance Planning Document (MPD) with new and enhanced features. The MPD is a single reference for all repetitive tasks recommended by Airbus and is a non-approved document that contains approved and non approved scheduled maintenance requirements from:

- The MRBR
- The Airworthiness Limitation Items document (ALI)
- The Certification Maintenance Requirements document (CMR)

- In-service experience (AD/CN, Service Bulletins (SB), Service Information Letters (SIL), All Operators Telex (AOT)...))

The MPD provides additional information for each scheduled maintenance task such as, access, zones, source data, preparation work, man hours, elapsed time and reference to the associated Aircraft Maintenance Manual (AMM) procedure.

Similar requirements for different sources are consolidated in the MPD at task and/or Threshold/ Interval level.

At this stage of the A380 programme, the MPD contains only data coming from the MRBR proposal.

A SIMPLIFIED MPD WITH NEW FEATURES

Compared to other Airbus programmes, the A380 MPD is simplified. Volume 2 is deleted as:

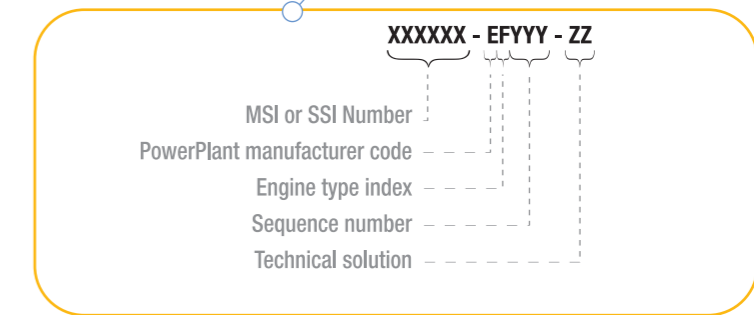
- The zoning and access illustrations previously covered in section 10 and 11 are redundant with AMM Chapter 06 information.
- The illustrations of the Structure Significant Items (SSI) from the MRBR structures section, previously covered in section 12 are now available in the relevant AMM procedures.

With experience gained from other Airbus programmes and in agreement with the A380 ISC, a new task numbering concept was introduced to be self-explanatory and remain compatible with future maintenance programme and planning evolution. To assist operators maintenance planning organizations, a new appendix for maintenance planning is available. In this, all MPD tasks whatever the source, are packaged into maintenance checks according to typical aircraft operations.

Maintenance Planning Document on CD



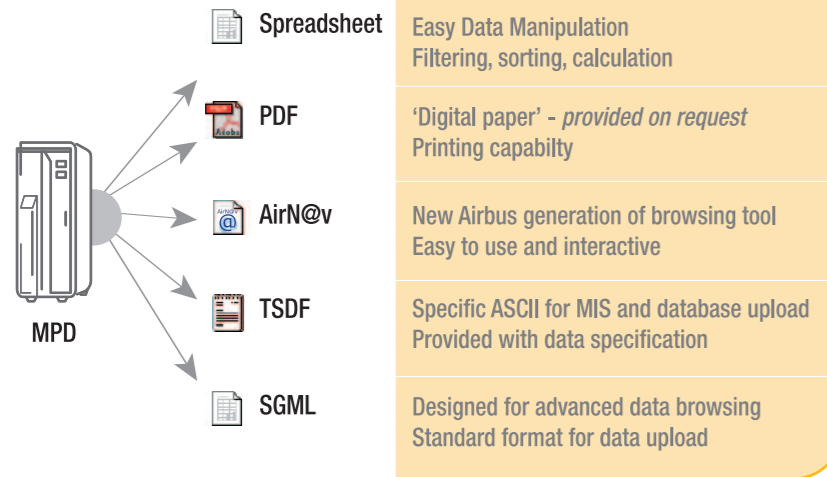
New task numbering concept



New appendix for maintenance planning

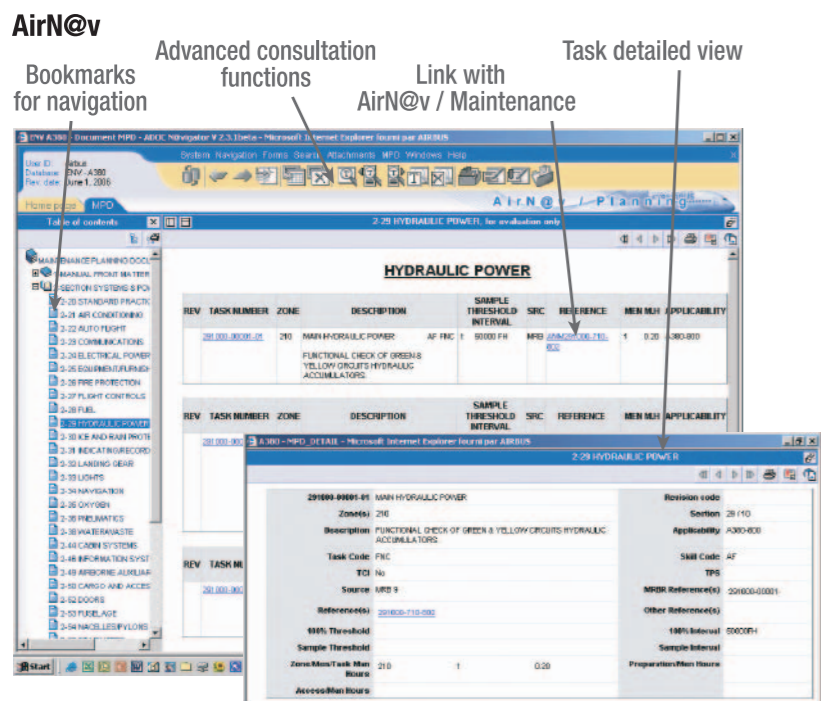
A SIMPLIFIED MPD AVAILABLE IN MULTIPLE FORMATS

The A380 MPD and associated features are available in multiple formats to meet operators expectations and provide an easy interface with their systems.



In particular, the AirN@v module 'AirN@v / Planning' offers the possibility to be 100% compatible with the other AirN@v new generation of technical data browsing tools, which are easy to use and interactive (see article in FAST 35).

AirN@v module 'AirN@v / Planning'



Next steps

As previously mentioned the A380 MRBR Proposal acceptance by EASA is the first major step in the development of the A380 scheduled maintenance documentation. It was not the first one, and it will not be the last.

THE MRB PROCESS

Following ISC, MRBs and Airbus agreement, the A380 MRBR will be updated according to design changes to obtain a formal approval for EIS of the first aircraft. Then, once the A380 becomes an in-service aircraft, the MRBR will follow a standard revision process according to:

- Design changes
- New regulations
- In-service experience feedback

For this, it is essential that from day one, A380 operators collect in appropriate databases the results of the scheduled maintenance tasks (findings and nil findings) to later support MRBR evolution exercises.

THE AIRWORTHINESS LIMITATION ITEM

The Airworthiness Limitation Item (ALI) process has also started with the target to get the A380 ALI document approved for the A380 type certification (compliance to JAR/FAR 25-571).

A380 fatigue and damage tolerance evaluations will be performed and associated scheduled maintenance requirements will be published in the A380 document at type certification. The ALI will later be updated once results from the fatigue test cell are available.

THE CERTIFICATION MAINTENANCE REQUIREMENT

The process has also started. Two Certification Maintenance Coordination Committee meetings have taken place with operators and air-

worthiness authorities to perform the MSG3/SSA (System Safety Assessment) compatibility check that leads to selection of the Certification Maintenance Requirement (CMR) (compliance with JAR/FAR 25-1309). As with the MRBR development process, early involvement of Airbus maintenance engineers during the design phases is essential to reduce the number of CMRs to the minimum.

THE MPD

The A380 MPD will be revised every time one of the source documents is revised. To minimize the burden on operator's maintenance planning organizations, MPD revisions will combine source document revisions as much as possible according to the different planning and document approvals.



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Conclusion

A marvellous experience and a real team spirit. The acceptance of the A380 MRBR proposal by EASA is a major step in the A380 maintenance programme development. This was achieved thanks to a very efficient ISC organization where operators, airworthiness authorities, major suppliers and Airbus joined efforts to give the A380 a maintenance programme at the same level as the aircraft: **A reference in the industry.**

Hundreds of thousands of working hours have been invested in the A380 MRBR, more than 8,000 meeting man-days, more than 30,000 equivalent pages of documents prepared, reviewed and validated by hundreds of people. All this was performed in a very professional and very friendly atmosphere.

The result is that the A380 has a maintenance programme ready for implementation. The MPD provides the tools to help operators develop their maintenance programme (OMP) get it approved by their local airworthiness authority and prepare the associated A380 maintenance schedule. Airbus Maintenance Planning Organization offers customized services to help operators in these activities.

The A380 has not yet been delivered to its first customer but the MRBR and the MPD have already switched from the development to the revision phase.

Airbus Maintenance Planning organization has developed a specific assistance for the Flight Test department. The A380 flight test aircraft scheduled maintenance is already performed according to the A380 MPD, customized to the aircraft definition and operation.

- A very efficient result**
- First technical evaluations of the A380 maintenance programme, based on standard aircraft operation confirms that the initial MRBR targets are met:
- An equivalent A check can be scheduled every 750fh
 - An equivalent C check can be scheduled every 24 months/6,000fh
 - Structure inspections can be scheduled every 6 and 12 years

This leads to significant maintenance man-hours and maintenance cost savings compared to aircraft with similar operations.



Hypoxia

An invisible enemy

Cabin depressurization effects on human physiology

DEFINITIONS OF HYPOXIA

Hypoxia is separated into four types:

- *Hypoxic hypoxia* is a condition caused by reduced barometric pressure, affecting the body's ability to transfer oxygen from the lungs to the bloodstream.
- *Histotoxic hypoxia* can be induced by the introduction of substances like alcohol or drugs into tissue, reducing its ability to accept oxygen from the bloodstream.
- *Hypaemic hypoxia* (or *anaemic hypoxia*) is a result of the blood being unable to carry oxygen, e.g. caused by exposure to carbon monoxide.
- *Stagnant hypoxia* results from the body's inability to carry oxygen to the brain, which can result from high gravity-forces causing blood to pool in the lower extremities of the body.

When public air transportation first became commonly available, flights did not reach altitudes that represented a significant risk of reduced oxygen supply - called hypoxia - to either passengers or crew. However, in the late 1940s and 1950s aircraft were developed that allowed safe transport of the flying public at altitudes around 40,000ft, which have remained relatively constant since then.



Hartwig Asshauer
Certification Manager
Hydro-Mechanical & Air Systems
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Operating at high altitude without adequate understanding, training or equipment protection can be dangerous as shown by the following extracts from two accident reports:

'One of the first encounters with the dangers of high altitude flight was reported in 1862 when a balloon flight was made to study the effects of low ambient pressure. The balloon ascended to approximately 29,000ft and during the flight a series of "strange" symptoms, notably loss of visual and hearing capability, paralysis of arms and legs, and finally, unconsciousness occurred. The team could have been lost, but was saved by one member pulling the balloon valve rope with his teeth (his arms were already paralysed), to descend the balloon. The team recovered as the balloon descended, but this marked for the first time the risk of low ambient pressure.'

'In 1998 a decompression incident occurred on an aircraft at 35,000ft. Both the captain and the first officer had received altitude-chamber training during their previous military careers and knew about the effects of low cabin pressure. The first officer attempted to control the cabin rate of climb by switching to the standby pressurization system. When use of the standby system failed to improve the situation, he donned his oxygen mask. The captain, who had been talking with a passenger who was visiting the flight deck, attempted to don his oxygen mask too, but in doing so he knocked his glasses to the floor. When trying to retrieve them he lost consciousness and slumped forward. The first officer attempted to help the captain but was unable to do this, so initiated a descent to 25,000ft. A short time later the first officer asked the senior flight attendant to assist the captain. To enter the flight deck the flight attendant had to remove her oxygen mask connected to the fixed cabin oxygen

system. She decided not to use the portable oxygen equipment and went straight to the flight deck. Before being able to assist the captain she collapsed onto the floor. Once again, the first officer attempted to put on the oxygen mask for the captain, this time successfully. Soon afterward, the captain regained consciousness and was unaware he had been unconscious, which is a typical reaction from a victim of hypoxia.'

The hypoxia effects of a quick cabin depressurization

During a quick depressurization the partial pressure of oxygen in the lungs/alveolae reduces rapidly with the effect of reverse diffusion. This means that once the oxygen partial pressure in the alveolae has reached a level that is below the level in the blood, the blood oxygen moves out of the body back into the ambient air. This effect of reverse diffusion unfortunately further reduces the already very limited oxygen storing capability of blood and supports hypoxia effects. Holding of breath cannot stop the reverse flow since the pulmonary gas expansion would lead to serious lung injury.

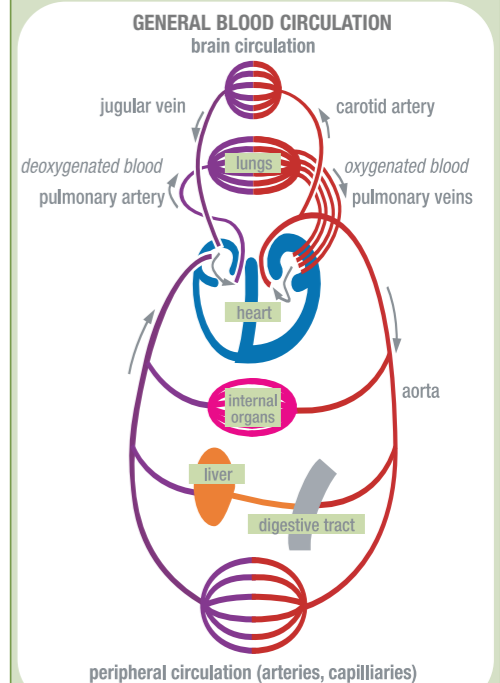
Severe hypoxia caused by a significant reduction in cabin pressure is very dangerous for flight crew because:

- The victims of hypoxia rarely notice that they are about to pass out.
- Usually there is quickly a loss of critical judgment
- Most victims often experience a mildly euphoric state
- Thinking is slowed, muscular coordination is impaired

The only effective means of protection is the quick donning of oxygen masks as the first action - before troubleshooting!

Human physiology

Within the lungs the alveola provide the interface between air and blood. The blood which is returned from the body tissue into the alveolae has given away most of its oxygen so that the oxygen partial pressure in the lungs is higher than in the arriving blood. A process of diffusion then drives oxygen through the thin alveolar wall into the blood.



The most important parameters for the oxygen diffusion process are the oxygen percentage and barometric ambient pressure. Changing these parameters changes immediately the oxygen saturation level in blood and with it the oxygen supply to the body tissue. Unfortunately, there is no significant storage of oxygen in the human body, unlike many other chemical substances necessary to maintain life. The blood is the only storehouse for oxygen, and its capacity is very limited. Hence, the human body lives only a hand-to-mouth existence with its oxygen supply.

As the pressure of air in the atmosphere decreases with increasing altitude, the partial pressure of oxygen in the air reduces and with it the diffusion of oxygen into the body. Reduction of oxygen availability in the body results in loss of functions ranging from slight impairment up to death. It is the nervous system, in particular in the higher centres of the brain, and the eyes which have a high metabolism with no oxygen reserve. These are most sensitive to oxygen depletion and therefore are the first to be affected by a reduced oxygen supply.

For healthy persons altitude exposure up to 15,000ft is usually not hazardous since cardiovascular and respiratory compensatory mechanisms (faster breathing and increased pulse rate/blood circulation) act to maintain adequate oxygenation at the cellular level.

The effects of reduced oxygen supply to the body (hypoxia) vary between persons, depending on health, physical fitness, age, activity level and statistical scatter with the population. Pilots and flight attendants usually require more oxygen during an emergency than healthy, seated passengers and might therefore suffer earlier from hypoxia effects.

*** Dalton's Law**
(1766 -1844)

In 1801, the English astronomer and chemist, John Dalton, discovered the pressure relationship among gases in a mixture. Dalton's Law states that the pressure exerted by a mixture of gases is equal to the sum of the pressures that each would exert if it alone occupied the space filled by the mixture.

Oxygen partial pressure

The concentration of oxygen in the atmosphere is constant at 20.95% at altitudes up to 100,000ft, which means that according to Dalton's Law* the oxygen partial pressure at sea level is 212mbar (20.95% of 1013mbar where 1013mbar is the standard atmospheric pressure at sea level).

As altitude increases above sea level the partial pressure of the component gases decreases consistent with the decrease in total atmospheric pressure. For example, the partial pressure of oxygen at 40,000ft is reduced to 39mbar only, which is far too inadequate to support human metabolism.

One means to increase oxygen partial pressure is to increase the oxygen concentration in breathing air. At 40,000ft cabin altitude an oxygen partial pressure of maximum 188mbar can be achieved by breathing pure oxygen (100% oxygen concentration without overpressure).

Another additional means for hypoxia protection is positive pressure breathing, which is usually found in modern crew oxygen masks and means the delivery of pure oxygen under pressure into the respiratory tract. For civil applications positive pressure breathing is able to increase additionally the oxygen partial pressure by around 20 to 30mbar provided that the overpressure condition is limited to some minutes only. This means that at 40,000ft it requires 100% oxygen concentration of the breathing gas combined with positive pressure breathing to achieve sea level equivalent conditions. Positive pressure breathing requires some training and is tiring and inconvenient, which is the rationale for having so far provided this protection feature to flight crew only (for short time use only).

Time of Useful Consciousness

In the 'World of Hypoxia' the Time of Useful Consciousness (TUC) is a very important parameter. For low ambient pressure conditions it indicates the time available to perform purposeful activities, such as oxygen mask donning or aircraft control. Beyond this time frame mental and physical capabilities are dangerously impaired and finally result in unconsciousness and potentially death.

As shown in the table on the right, TUC is negatively correlated with altitude. It is important to note that even if activities are performed within the TUC time frame there is a significant deterioration of work rate and mental capability, which is correlated with the time spent at low pressure conditions (at the end of the TUC time frame, performance is much lower than at the beginning).

The TUC is the 'Window of Opportunity' for donning an oxygen mask and can be very limited so must take overriding precedence over any other activities.

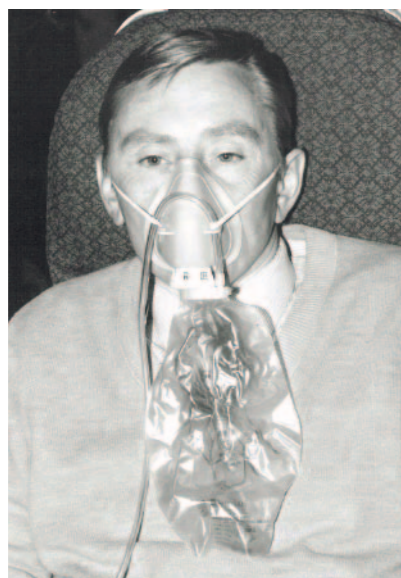
Time of Safe Unconsciousness

Some experts believe that for passengers - in contradiction to the flight crew - a short period of unconsciousness during cabin depressurization can be tolerated since they are not performing an operational task. Unconsciousness is a clear sign of insufficient oxygen supply to the brain and it is obvious that this time can only be very short before permanent brain damage occurs. So far, it has not been possible to associate a specific time frame for the safe time of unconsciousness.

The uncertainties in extrapolation of animal data and the wide variability in individual tolerances have so far prevented determination of a commonly agreed value for Time of Safe Unconsciousness (TSU) among human physiology experts. It is believed that a safe time of unconsciousness is somewhere between 90 seconds and 4 minutes.

Time of Useful Consciousness	
20,000ft	All unacclimatized persons lose useful consciousness within 10 minutes
25,000ft	Useful consciousness is lost after 2.5 minutes or less
30,000ft	TUC: approx. 30 seconds
37,000ft	TUC: approx. 18 seconds
45,000ft	TUC: approx. 15 seconds

These data on TUC are averaged values based on tests with healthy individuals when breathing ambient air (no supplemental oxygen provided). A large individual variation in the effects of hypoxia has been found. There is evidence that TUC is shorter for people exposed to stress conditions.



← Early type of shaped oxygen mask for passengers



↙ Current oxygen mask for passengers



↓ Mask straps inflated



↓ Mask in place



↑ Flight crew oxygen mask *
* Manufacturer EROS

Effect on human physiology of moderate cabin altitude

Very large numbers of aircrew and passengers have been exposed to breathing air at cabin altitudes up to 8,000ft over the last 60 years without significant deleterious effects. Although exposure to this altitude reduces the oxygen partial pressure in the pulmonary tract the tissues of the body are maintained well above the required level.

Some airlines still allow smoking in the aircraft cabin, which results in carbon monoxide inhalation with the smoke. Carbon monoxide has a 240-times greater tendency than oxygen to attach to red blood haemoglobin, thus inactivating a large amount of haemoglobin as an oxygen carrier. It has been found that the hypoxia effects from carbon monoxide and altitude are additive; hence chronic smokers are at a higher equivalent altitude than non-smokers in terms of blood oxygen supply.

Also, alcohol poisons body tissues in such a manner that they cannot use oxygen properly. Usually, it is noticed by passengers that the physiological effect of alcohol consumed during flight is more intense than at sea level, which is due to the additive hypoxia effects of alcohol and altitude.

Oxygen equipment on civil aircraft

On modern aircraft oxygen equipment is installed to provide adequate protection against the damaging effects of hypoxia in case of cabin depressurization:

For flight crew there are usually quick donning oxygen masks installed, which can be donned with one hand in less than 5 seconds. The mask straps are combined with elastic tubes that inflate and stiffen when the mask is taken from its stowage, allowing the mask to be easily put over the head with one hand. Once the grip on the mask is released, the tubes deflate and their elastic characteristics ensure a perfect fit. The required oxygen concentration of the breathing air is automatically adapted to the cabin pressure.

For the passenger oxygen supply the continuous flow concept is used on all Airbus aircraft. Oxygen is delivered continuously to an expandable oxygen bag where it is conserved during exhalation, so it is available during the next inhalation to supplement the steady oxygen flow.

It was decided at an early stage in passenger oxygen mask development that the untrained civilian population should not be expected to recognize the correct orientation for a shaped mask, and it was required that a mask should be operable in any position in which it might be donned by the user. A second basic requirement was a universal size, which finally defined the well-known cylindrical mask body.

Airworthiness requirements

The Airworthiness authorities have identified the risk of hypoxia and have created requirements (see table on the left).

Also, after an accident in the USA the FAA initiated a Special Certification Review (SCR) on pressurization systems. The SCR recommends that the aircraft flight manual (for aircraft certified for flights above 25,000ft) require in the emergency procedures the donning of oxygen masks as the first crew action after a cabin altitude warning.

This highlights again the importance of immediate donning of oxygen masks when cabin depressurization occurs.

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**Conclusion**

The first step for any flight crew member faced with cabin depressurization should be the immediate donning of an oxygen mask. Any delay in donning a mask will significantly increase the risk of losing consciousness before cabin pressure is regained. Severe hypoxia leads usually to the loss of critical judgement combined with a mildly euphoric state, which makes hypoxia very dangerous for flight crew. This is highlighted also in the FAA Special Certification Review that was issued some years ago on the effects of cabin depressurization.

Moreover, in case of rapid cabin depressurization a quickly accomplished emergency descent is often the only means of fast re-oxygenation of

passengers that were unable to protect themselves against hypoxia by using the passenger oxygen masks provided. Severe hypoxia is very dangerous for unprotected passengers and requires a quick return to an adequate cabin pressure or where not possible (above high terrain), it requires a check by the flight attendants that the passenger oxygen masks are correctly used.

For a long time transport aircraft have been equipped with oxygen systems for flight crew and passengers that provide an adequate protection against hypoxia. As long as these oxygen systems are used according to their simple procedures the invisible enemy hypoxia poses little danger to flight crews and passengers.

Extract of the prime requirements**GENERAL**

- CS/FAR 25.841 (a): Maximum cabin pressure altitude under normal operation: 8,000ft
- CS/FAR 25.841 (a): Maximum cabin pressure altitude after any probable failure condition in the pressurization system: 15,000ft
- FAR 25.841 (a) (2) (i): Maximum exposure time to cabin pressure altitude exceeding 25,000ft: 2 minutes
- FAR 25.841 (a) (2) (ii): Exposure to cabin pressure altitude that exceeds 40,000ft: Not allowed

CABIN OCCUPANTS

- CS/FAR 25.1443 (c): Provides oxygen system performance data on oxygen flow and required partial pressure of oxygen
- CS/FAR 25.1447 (c) (1): The total number of masks in the cabin must exceed the number of seats by at least 10%
- CS/FAR 25.1443 (d): Defines oxygen flow for first-aid oxygen equipment (for cabin depressurization treatment)
- JAR OPS 1.760/FAR 121.333 (e) (3): Requires first-aid oxygen for at least 2% of passengers
- JAR OPS 1.770 (b) (2) (i)/FAR 121.329 (c): Defines the percentage of passengers that need to be provided with supplemental oxygen (cabin pressure altitude dependent)

FLIGHT CREW

- CS/FAR 25.1443 (a) & (b): Provides oxygen system performance data on oxygen flow and required partial pressure of oxygen
- CS/FAR 25.1447 (c) (2) (i): For aircraft operating above 25,000ft quick donning oxygen masks are required for the flight crew which can be donned with one hand within 5 seconds
- FAR 121.333 (c) (2) (i) (A): One flight crew member needs to wear permanently his oxygen mask when the aircraft is operated above FL410
- FAR 121.333 (c) (3): In case one flight crew member leaves the controls the remaining pilot needs to use his oxygen mask when the aircraft is operated above 25,000ft



Fuel contamination Prevention and maintenance actions

Airbus continues to focus on optimizing aircraft availability and a key issue is the availability of the Aircraft Fuel Quantity Indication System (FQIS). Within the industry the major threat to the FQIS availability is microbiological contamination of the fuel. Such contamination will impact the FQIS readings, typically driving the FQIS probe readings out of limit. If left untreated, contamination can also generate acids in the fuel tanks, which may attack the wing tank structure.

Airbus has for many years worked with our partners in IATA (International Air Transport Association) on this issue. This work culminated in publication of the IATA Guidance Material on Fuel Contamination, which summarized the science behind contamination and collated the best recommendations from the OEMs (Original Equipment Manufacturers), operators and microbiologists.

Airbus continues to develop recommendations based on operator feedback and this article summarizes current knowledge on prevention and maintenance actions.



Christopher McGregor
Group Manager Fuel Systems
Airbus Customer Services

Fuel Quantity Indication System

The Fuel Quantity Indication System (FQIS) measures the quantity of fuel in each of the aircraft fuel tanks. The FQIS provides this information to the flight deck providing a display of the Fuel on Board (FOB) and, via the ECAM (Electronic Centralized Aircraft Monitor) systems page, the individual tank quantities. On the A300/A310 and A330/A340 fleets the data is used in the auto-transfer functions e.g. CG (Centre of Gravity) control.

Airbus aircraft utilize capacitance to measure the level (volume) of fuel within the aircraft fuel tanks. Vertical probes located throughout the tanks measure the fuel level in the tanks. Each probe has two concentric aluminium tubes. The open ends of the tubes allow the fuel to move freely up and between the tubes. The capacitance value of the probe changes in proportion to the depth of fuel within the tank. When the probe is dry the capacitance value is low, but as fuel moves up the probe the capacitance value increases. Fuel density is measured for example using the fuel dielectric value or variations with the speed of sound. The FQIS uses the volume and density values to calculate the mass (kg or lb).

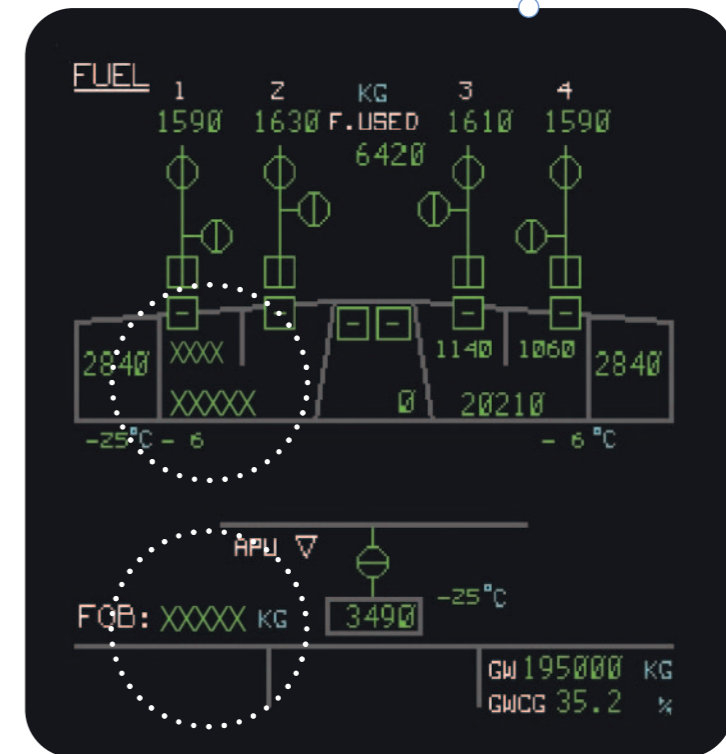
The effect of microbiological contamination on an aircraft FQIS

The probes and downstream calculations are calibrated for use in jet fuel. The probes measure from 'unusable' to full tank capacity. However, when the fuel is contaminated the fuel characteristics change. The probes may also become contaminated. Typically, the probes will now read a higher capacitance level than the real fuel

level. In some cases the probe will over-read or 'disagree' with a neighbouring reading.

At aircraft level on the flight deck a key symptom of severe fuel contamination is FQI fluctuation during flight, or degraded FQI indication.

Degraded indication on the ECAM



In some cases aircraft dispatch may be limited by the status of the FQI display (please refer to the MMEL).

Symptoms and prevention

Operators are encouraged to focus on prevention of microbiological fuel contamination to avoid the penalties associated with occurrences. The bacteria causing such contamination live within the water/fuel interface and these living organisms enter either via the fuel supply or are airborne. However, to live and develop within the tank the bacteria require water (for oxygen). Therefore, the first consideration in prevention is minimizing water content in the

fuel tank system. All modern civil aircraft incorporate water drainage and/or scavenge systems to help achieve this. The Airbus wing design ensures water is maintained in suspension and fed to the engines; any remaining water is then drained at regular intervals via the water drain valves. The water drainage interval for each Airbus aircraft programme is detailed in its Maintenance Planning Document (MPD).

A second key element of prevention is monitoring. Often overlooked is the need to visually inspect any water resulting from the MPD water drain task. Drained water and fuel will separate within the container with the water settling to the bottom. Both should be clear with no particulates

evident to the naked eye. Any 'cloudiness' in either fluid indicates possible contamination and action is required.

Currently, Airbus recommends an annual analysis of fuel from each aircraft to test for fuel/water contamination, which should be considered a minimum for all operators. However, each individual operator needs to assess their risk levels, especially their experience at aircraft and fuel supply level and define their testing requirements accordingly as an annual test may not be sufficient in some circumstances.

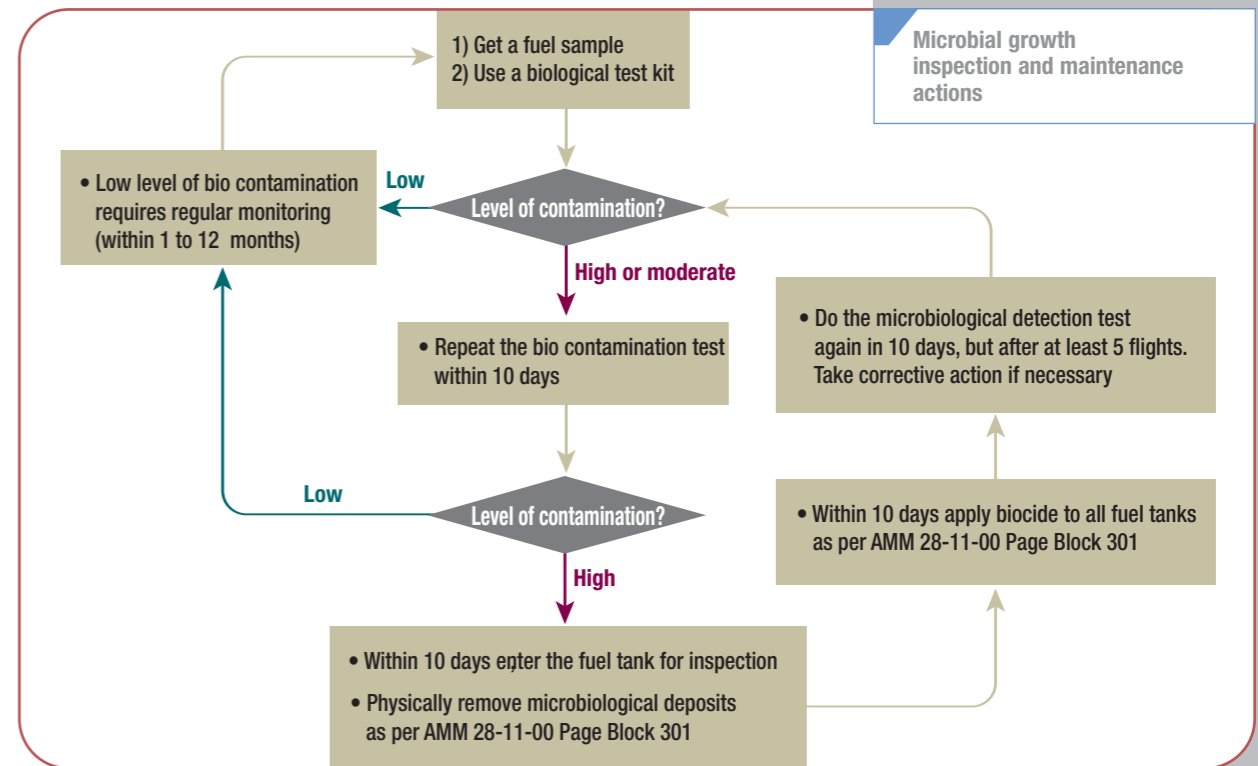
There are a number of fuel contamination test kits available in the market place, each with advantages and disadvantages. The main issue with all test kits is that they cannot be used as a single snapshot to provide a detailed analysis of tank conditions. However, they can be used effectively to create a baseline for operation from which an increase in contamination can be observed and the appropriate action taken.

In summary, the key indicators of fuel contamination are particulates observed in drained water, results from the fuel analysis or FQI fluctuations, or degradation observed on the flight deck. If no action is taken and these symptoms are ignored engine main filter clog events can be anticipated.

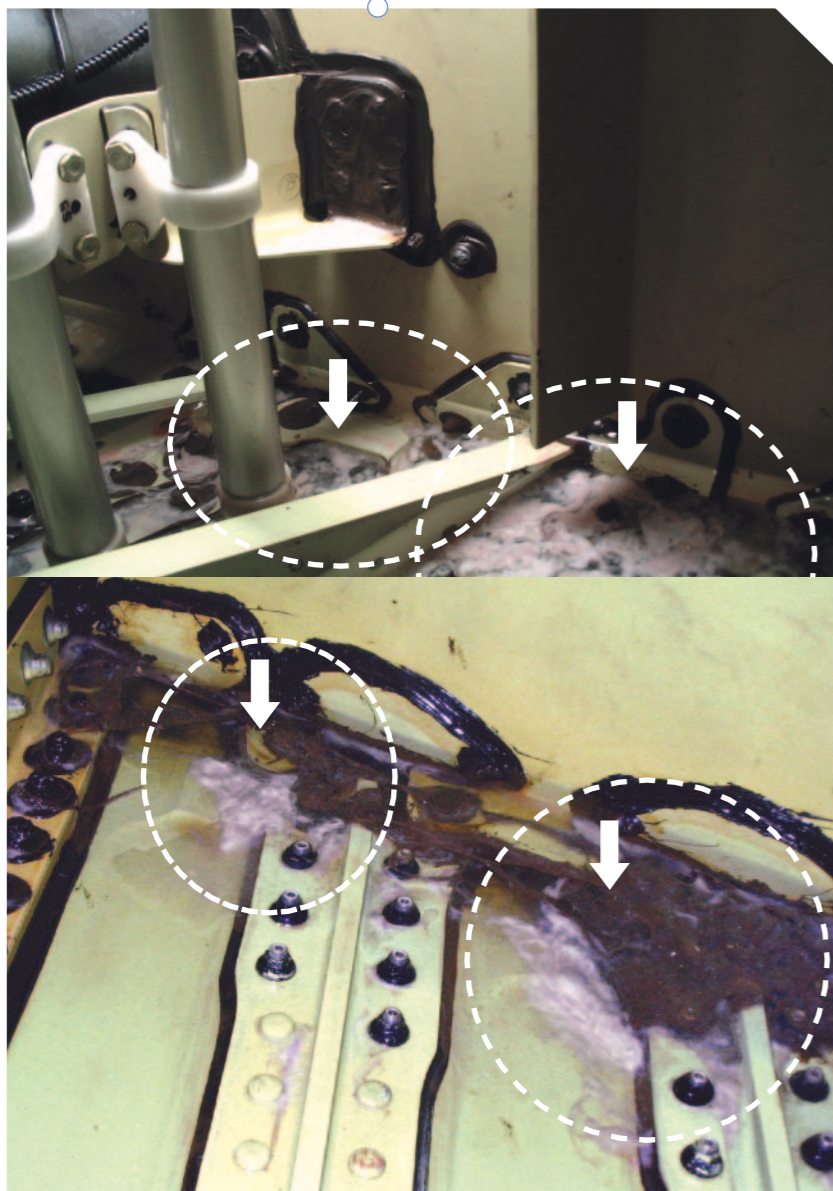
Maintenance actions

In all cases operators are recommended to include contamination prevention in their maintenance programme. Based on the previous explanation the most important tasks are water drainage and fuel monitoring.

Another possibility is sharing the common objective of prevention with an operators fuel supply company. Currently there are no requirements for fuel supply com-



In-tank observation of microbiological fuel contamination: fuel contamination attached to the tank structure



panies or distributors to test for microbiological fuel contamination.

In these discussions we refer operators to the JIG (Joint Inspection Group). Under the IATA umbrella airport facilities are audited and actions taken to maintain the quality of the fuel supply.

If fuel contamination is detected, the industry has developed the following guidance and recommendations. This flow-chart will be integrated into all Airbus aircraft AMMs (Aircraft Maintenance Manuals). It is difficult to provide a single recommendation to cover all scenarios but the flow-chart does summarize very well the thought process and objective of avoiding fuel tank entry if at all possible.

Currently within the industry two biocides are approved for aviation use. The maximum concentrations are defined in the Airbus AMMs and are a compromise between the effectiveness of the biocide and the maximum concentration allowed by the engine and APU (Auxiliary Power Unit) manufacturers. These concentrations allow treated fuel

to be burnt by the engines and avoid operators disposing of the treated fuel.

Airbus recommends metered injection of the biocides to ensure adequate mixing within the fuel. The biocides are not effective at low temperatures hence the soak time defined in the AMM cannot include flight time.

If tank contamination is severe the biocides will only kill the outer layer of bacteria attached to the tank and probe surfaces. Therefore, as per the flowchart, tank entry and cleaning is recommended to remove all visible traces of contamination. The time, schedule disruption and cost of tank entry is well understood and appreciated by Airbus. Hence, the need to focus on prevention to avoid this financial impact is crucial. If a decision is taken to enter a tank, Airbus recommends a thorough cleaning of it. The pressure to return an aircraft to service is well understood, but if a tank is not thoroughly cleaned there is a significant risk of contamination developing again requiring additional future maintenance action.





Developments

The current recommendations on prevention and maintenance tasks have taken many years to develop and Airbus recognizes the efforts and expertise of our partners in IATA. As a result, today there is much more advice and guidance available at aircraft and fuel supply level than ever before.

For the future Airbus will continue to look at ways of reducing the associated maintenance burden.

For the A320 and A330/A340 families of aircraft engineering action has been launched to further develop the water management systems within the aircraft. The objective is to enhance the water scavenge efficiency and at a later date extend the water drainage interval; this is a MRBR (Maintenance Review Board

Report) entry and hence changes require airworthiness authority input and approval.

For the A330/A340 Family an activity is launched to study reducing the impact of contamination on the FQI.

Airbus also intends to study new and more effective biocides, which are available in the market place, but not currently approved within the aviation industry. Biocide approval however is a long lead-time item requiring primarily engine manufacturer approval. There are also significant health and safety issues to consider. Further information on this initiative will be announced when available.

FURTHER READING

Airbus Documentation
 SIL 28-079 • AMM 12-32-28 • AMM 28-11-00 • MPD 28-11-00

Key partners
ECHA MICROBIOLOGY www.echamicrobiology.co.uk
CONIDIABIOSCIENCE www.conidia.com
MERCK www.microbiology.merck.de
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Conclusion

Prevention is the key to avoiding microbiological fuel contamination. Water drainage and fuel sample analysis are the critical tasks at aircraft level. All fuel contains a background level of bacteria, so minimizing water content within the aircraft fuel tanks will significantly reduce the risk of contamination developing within the tanks. In the long term, preventing contamination will reduce the future potential for structural corrosion and damage to in-tank components. Again, the key indicators of fuel contamination are particulates observed in drained water, results from the fuel

analysis or FQI fluctuations or degradation observed on the flight deck.

Operators are recommended to consult the IATA Guidance Material on Microbiological Contamination in Aircraft Fuel Tanks for assistance in planning contamination prevention tasks. In addition please consult Airbus Service Information Letter 28-079. Success against contamination requires long-term industrial co-operation. Within the IATA framework Airbus will continue to work with industry partners to combat fuel contamination and optimize prevention and maintenance practices.

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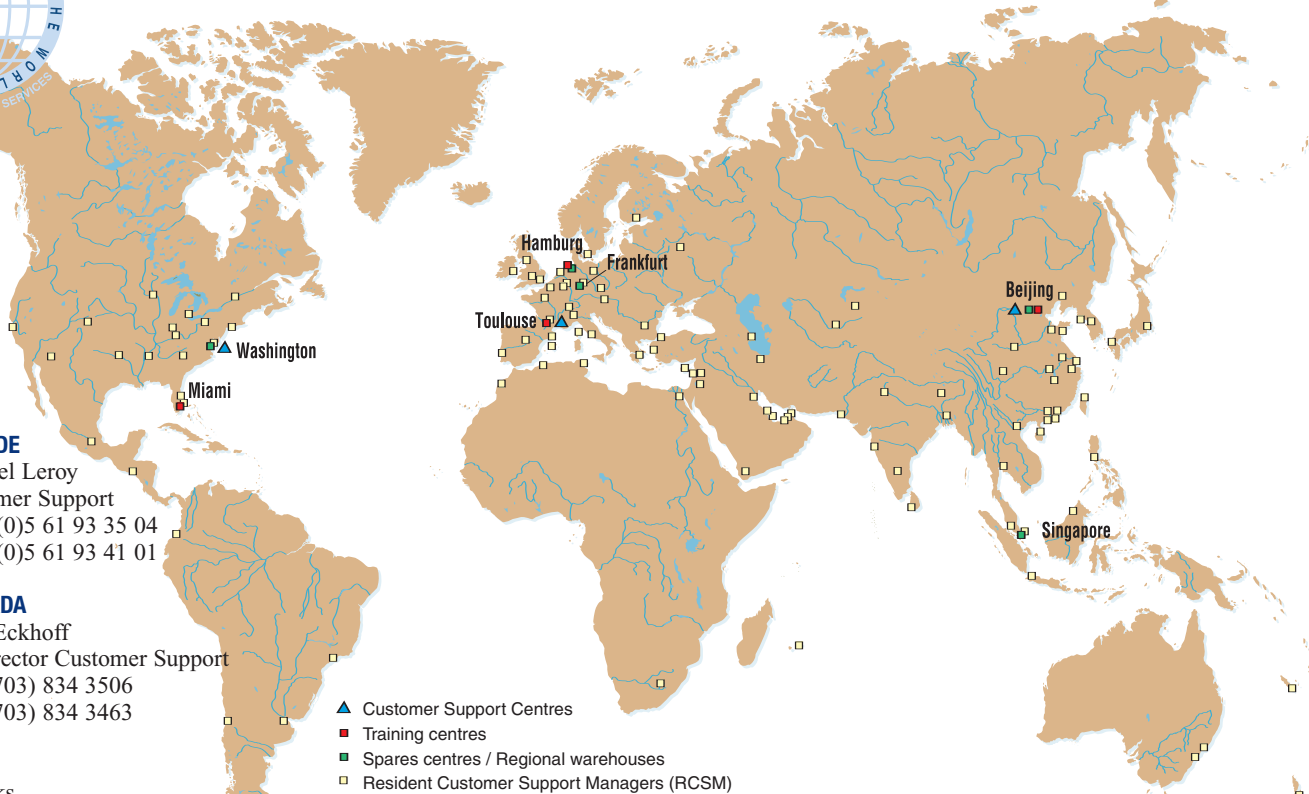
Fuel contamination

Part II

In the good old days refueling aircraft was not as organized and efficient as it is today, with the consequent increased risk of contamination of the fuel.



Refueling an aircraft of the German air police officer's training school, probably just after the First World War.



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