## Abbreviations used in this issue of FAST

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACARS</td>
<td>Aircraft Communication Addressing and Reporting System</td>
</tr>
<tr>
<td>ADF</td>
<td>Automatic Direction Finding</td>
</tr>
<tr>
<td>AFS</td>
<td>Automatic Flight System</td>
</tr>
<tr>
<td>APU</td>
<td>Auxiliary Power Unit</td>
</tr>
<tr>
<td>ARINC</td>
<td>Aeronautical Radio Inc.</td>
</tr>
<tr>
<td>ATA</td>
<td>Air Transport Association</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>BITE</td>
<td>Built-In Test Equipment</td>
</tr>
<tr>
<td>CASP</td>
<td>Canadian Atlantic Storms Program</td>
</tr>
<tr>
<td>CFDS</td>
<td>Centralised Fault Display System</td>
</tr>
<tr>
<td>CFDIU</td>
<td>Centralised Fault Display Interface Unit</td>
</tr>
<tr>
<td>CMC</td>
<td>Central Maintenance Computer</td>
</tr>
<tr>
<td>CMS</td>
<td>Central Maintenance System</td>
</tr>
<tr>
<td>DME</td>
<td>Distance Measuring Equipment</td>
</tr>
<tr>
<td>ECAM</td>
<td>Electronic Centralised Aircraft Monitor</td>
</tr>
<tr>
<td>EFIS</td>
<td>Electronic Flight Instrument System</td>
</tr>
<tr>
<td>EFCS</td>
<td>Electronic Flight Control System</td>
</tr>
<tr>
<td>eg</td>
<td>For example</td>
</tr>
<tr>
<td>EGT</td>
<td>Exhaust Gas Temperature</td>
</tr>
<tr>
<td>ETOPS</td>
<td>Extended Range Twin Engine Operations</td>
</tr>
<tr>
<td>FIM</td>
<td>Fault Isolation Document</td>
</tr>
<tr>
<td>FIN</td>
<td>Functional Item Number</td>
</tr>
<tr>
<td>FL</td>
<td>Flight Level</td>
</tr>
<tr>
<td>FMS</td>
<td>Flight Management System</td>
</tr>
<tr>
<td>FWC</td>
<td>Flight Warning Computer</td>
</tr>
<tr>
<td>GCPU</td>
<td>Ground Power Control Unit</td>
</tr>
<tr>
<td>I-CMS</td>
<td>Index of CMS fault messages</td>
</tr>
<tr>
<td>I-EFIS</td>
<td>Index of EFIS, ND and PFD fault messages</td>
</tr>
<tr>
<td>I-LOCAL</td>
<td>Index of local warnings</td>
</tr>
<tr>
<td>I-OBSV</td>
<td>Index of crew and maintenance observations</td>
</tr>
<tr>
<td>I-WM</td>
<td>Index of warnings and malfunctions</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
</tr>
<tr>
<td>IDG</td>
<td>Integrated Drive Generator</td>
</tr>
<tr>
<td>ISO</td>
<td>International Standardisation Organisation</td>
</tr>
<tr>
<td>JAA</td>
<td>Joint Airworthiness Authorities (European)</td>
</tr>
<tr>
<td>kt</td>
<td>Knots</td>
</tr>
<tr>
<td>LRU</td>
<td>Line Replaceable Unit</td>
</tr>
<tr>
<td>MCDU</td>
<td>Multi-purpose Control and Display Unit</td>
</tr>
<tr>
<td>MDDU</td>
<td>Multi-purpose Disc Drive Unit</td>
</tr>
<tr>
<td>MMEL</td>
<td>Master Minimum Equipment List</td>
</tr>
<tr>
<td>MU</td>
<td>Management Unit</td>
</tr>
<tr>
<td>ND</td>
<td>Navigation Display</td>
</tr>
<tr>
<td>nm</td>
<td>Nautical miles</td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer</td>
</tr>
<tr>
<td>PFD</td>
<td>Primary Flight Display</td>
</tr>
<tr>
<td>PFR</td>
<td>Post Flight Report</td>
</tr>
<tr>
<td>P/N</td>
<td>Part Number</td>
</tr>
<tr>
<td>SD</td>
<td>System Display</td>
</tr>
<tr>
<td>SGML</td>
<td>Standardised General Mark-up Language</td>
</tr>
<tr>
<td>SLW</td>
<td>Supercooled Liquid Water</td>
</tr>
<tr>
<td>SLWC</td>
<td>Supercooled Liquid Water Content</td>
</tr>
<tr>
<td>TSM</td>
<td>Trouble Shooting Manual</td>
</tr>
<tr>
<td>UTC</td>
<td>Universal Coordinated Time</td>
</tr>
<tr>
<td>VHF</td>
<td>Very High Frequency</td>
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A330/A340 CENTRAL MAINTENANCE SYSTEM
MARC VIRILLI

EVOLUTION OF THE TROUBLE SHOOTING MANUAL ON THE A319/A320/A321/A330/A340
KENNETH JOHNSON

A330/A340 RAMP HANDLING
DAVID SAXTON

ACCELERATED ETOPS FOR THE A330
ANDRE QUET AND THE ETOPS GROUP

ETOPS CONFERENCE

UNDERSTANDING THE PROCESS OF ICE ACCRETION
CLAUDIUS LA BURTHE

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RAMP HANDLING - PART II

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A330/A340
CENTRAL MAINTENANCE SYSTEM

by Marc Virilli
Group Leader, Maintenance and Trouble Shooting Systems
Airbus Product Support

The A330/A340 Central Maintenance System (CMS) is a development of the A320 Centralised Fault Display System (CFDS) which was the first of a new generation of maintenance tools. This article describes the design features of the CMS, how it integrates with the rest of the aircraft, and its role in the global A330/A340 trouble shooting concept. This is an updated version of the article which appeared in the Airline magazine, Plane Talk, in June 1992.
On Airbus aircraft, centralised maintenance experience started with the design of the A300. In 1974, the Auto Flight System consisted of 20 computers, two of which were dedicated to help maintain the system. The entry into service of the glass cockpit A310 in 1983 was the beginning of a new era from the aircraft technology point of view, and also for line maintenance activities.

Taking advantage of the performance of new digital technology, the fault isolation devices were integrated into the basic system design. The best examples are the A310 Auto Flight System (AFS), the Flight Management System (FMS), the Electronic Flight Instrument System (EFIS) and the Electronic Centralised Aircraft Monitoring (ECAM). These systems were the first to provide automatic troubleshooting and test procedures, and were the first to introduce plain English for the identification of faulty Line Replaceable Units (LRU) (Figure 1).

Although these systems provided many benefits for maintenance personnel, more development was necessary to provide more maintenance data and wider fault isolation coverage. This is why in 1988, when the A320 entered service, the CFDS was one of the features of this aircraft. This system resulted from a common position taken by the major airframe manufacturers. They identified the need within the airline world for a system that concentrates maintenance data into one location and provides maintenance personnel with clear information needing little interpretation. The guidelines for the design of such a system materialized in the ARINC Report 604, Guidelines for design and use of Built-In Test Equipment (BITE).

The A320 CFDS is in fact a man/machine interface for maintenance purposes, which allows the display of fault messages in plain English, to interrogate the BITE of various electronic systems and to initiate system tests from a central point located in the cockpit: the MCDU (Multipurpose Control and Display Unit). The architecture of the A320 CFDS is of the distributed type, compared to the centralised type chosen by another aircraft manufacturer. This means that the intelligence required for identifying the faults, processing the maintenance data and formatting the failure messages is included in the BITE of each individual avionics component.

The main advantage of this architecture is that all conditions for generating a message depend on one system only: the originator of the message, thus making information more reliable and easier to manage. It is important to note that this approach does not prevent the Centralised Fault Display Interface Unit (CFDIU) from automatically correlating events, thereby minimizing the number of messages. This is an advantage shared with the centralised architecture.

**A330/A340 ARCHITECTURE**

The A330/A340 CMS architecture includes two fully redundant Central Maintenance Computers (CMC), instead of one on the A320, the CMC2 being a hot spare. Four user interfaces are also defined: three MCDUs, the printer, the Aircraft Communication Addressing and Reporting System (ACARS) Management Unit (MU) and the Multipurpose Disk Drive Unit (MDDU), the last two being optional.

This variety of interfaces is aimed to answer all airline needs in terms of efficiency of operation of their aircraft:
- the printer (A4 size) and MCDU on-board use,
- the ACARS MU for preparation of the work during next transit,
- the MDDU for downloading data for further analysis.

Both CMCs are directly connected to 48 basic systems plus 11 optional ones, which represent 91 reporting units expandable to 102 reporting units with options. The systems which are connected to the CMCs have been divided into 3 types:
- **Type 1 systems** are characterized by an input/output interface of the ARINC 429 bus type (there are 34 basic and 9 optional systems for a total of 75 units),
- **Type 2 systems** are characterized by a discrete input from the CMC and an ARINC 429 bus output (there are 10 basic and optional systems for a total of 19 units),
- **Type 3 systems** have an input/output interface of discrete type (there are 4 basic and 1 optional system for a total of 8 units).

**Figure 1**

Easier access to maintenance data on A320 family, A330 and A340

On A320, A330 and A340,
- single location (MCDU in the cockpit)
- alphanumeric display
- menu driven procedure

On previous generation aircraft: difficult access to maintenance data,
- various locations (avionic compartment, cockpit)
- different types of display
- operating procedure varies from system to system
Each member system memorizes the failure messages detected by its BITE and transmits them in clear English to the CMC. The CMS architecture is shown in Figure 2.

**MODE OF OPERATION**

**Reporting mode**

In the reporting mode, the units connected to the CMC automatically and permanently transmit the failures affecting them. These failures can be either of internal or external origin, that is to say affecting LRUs belonging to the system or LRUs external to the system. These failures are also divided into three classes depending on their impact on the current flight (Figure 3):

- **Class 1 failures** are indicated to the crew by means of warnings and flags,
- **Class 2 failures** are indicated to the crew on the ground only but have no impact on the current flight,
- **Class 3 failures** are not indicated to the crew at all, are available on request only and are checked at the next scheduled maintenance check.

As mentioned previously, the maintenance messages are transmitted to the CMC in plain English using ISO 5 coding. As A320 experience had shown that some messages could be interpreted in different ways, the rules for writing maintenance messages have been further refined and are requested to be strictly followed by each computer designer (computer supplier).

The CMC compiles a *Post Flight Report* (PFR) by merging
all class 1 and 2 messages received from all computers as well as all Flight Deck Effects received from the Flight Warning Computer and Data Management Computer. This report allows the maintenance personnel to have an overall view of what occurred during the last flight leg. It is an important complement to the Flight Log.

Although the system architecture is of the distributed type, the CMC performs an event correlation. For a given failure, only one failure message is printed on the PFR. The systems which have reacted to this primary failure are mentioned on the PFR as "identifiers". If the unit which is affected is able to transmit a message, it is this message (internal) which will be mentioned, the other messages (external) appearing as "identifiers" (Figure 4). If the unit affected by the failure is not able to transmit anything to the CMC, the first message reported by its peripherals will be printed in the PFR, the others being "identifiers". In all cases the detail of each detected failure is memorized in each individual unit’s BITE, and is accessible in interactive mode.

This CMC function is based on the ATA chapter associated with each failure message and which corresponds to the LRU incriminated.

In reporting mode the CMC compiles a Class 3 Report which contains all class 3 failures that occurred during the last flight leg as a complement to the PFR.

Finally the Avionics Status gives in real time the list of units which are affected at least by one failure in either class 1, 2 or 3. This report provides a quick overview of the status of the various computers of the aircraft. It also makes it possible to check that all computers have correctly satisfied the power-up tests.

**Interactive Mode**

The interactive mode or menu mode, for type 1 systems, is a mode which allows the connection of the BITE of any unit via the MCDUs, in order to display the data memorized and formatted by each member system. This mode can be activated on the ground only and one of its important purposes is to ease activation of system tests. The reason why this mode is sometimes called "menu mode" is because the users are guided by menus. Some of these menus are generated by the CMC, and others are generated and transmitted by the concerned units for display on the MCDUs.

In order to have a man/machine interface as user-friendly as possible and to break oneself from the distributed architecture while keeping its advantages, all MCDU screens sent by the systems have been normalized to a standard format (Figure 5). In practice these various items of CMS menu can be illustrated using the following Electronic Flight Control System (EFCS)
and GPCU (Ground Power Control Unit) examples (Figures 6 and 7).

The Tests, divided into three groups, ensure that at least one test can always be activated at the ramp by a mechanic:
- **The System tests** are mandatory for each system and normally used as Aircraft Maintenance Manual (AMM) removal/installation tests. Their aim is to cover the integrity of the computer.
- **The complementary tests** send some stimuli to various components such as valves, actuators, etc. For that reason, cautions are displayed on the MCDUs before activating them (Figure 6), the safety procedures themselves being in the AMM.
- **The guided tests** are those where all the requested actions are clearly mentioned on the MCDUs, along with questions about the results of the actions.

The complementary tests and the guided tests increase the coverage level of the system tests when it is useful and possible. In both tests, all initial conditions necessary for successful accomplishment of the test are written on the MCDUs, no documentation is required for test activation, although they are duplicated in the AMM for checking the correct overall functioning of a system.

The information available on the GPCU (Figure 7d) is as follows:

1. **The Last Leg Report** is a simplified back-up to the PFR.
2. **The Previous Legs Report** records the maintenance and warning messages which occurred during previous flights (limited to 64) and will be mainly used in case of intermittent
failures which have to be tracked on several flights.

3L. The LRU Identification function displays on the ground the Part Number of the computers of the selected system and possibly their Serial Numbers. It is a configuration management aid.

4L. The Ground Scanning enables fault trouble shooting based on ground activation by the operators of functions normally performed during a flight. The mechanic decides what type of action has to be performed, depending on the problem to be investigated (which may include control surface movement, for example).

5L. The Trouble Shooting Data consist of primary and coded data, to be used in case of events which do not result from effective component failure.

18. The Class 3 Faults report contains messages which are not shown on the PFR and to which attention can wait until the next maintenance opportunity.

56. The Ground Report has the same usefulness as a PFR but it concerns new faults detected on the ground since the last flight.

**CMS OPTIONAL FUNCTIONS**

In order to complete the basic CMS, a set of additional functions have been developed jointly with our customers and are proposed as an option. These other CMS features are the Service Report, the Aircraft Configuration Report, the Flag and Advisory recording function and the Downloading function.

**Service report**

This report, which is still under development, will gather different parameters involved in periodic checks which might lead to a servicing action. The parameters which compose the Service Report are taken from the following systems:

- Engines
- IDG
- APU
- Hydraulic
- Fuel
- Landing Gear
- Oxygen
- Door and Slide bottles
- Water/Waste
- Air conditioning

The Service Report will be programmable like the PFR for automatic print-out in the cockpit, downloading to a diskette or transmission to a ground station through ACARS, and will be available in either case 15 minutes after last engine shut down. An example of this report is shown on Figure 8. It will also be possible for operators to customize the servicing thresholds, using a Personal Computer (PC), thus allowing them to get a report with parameters which need a servicing.

---

**Figure 8**

Example of Service Report

| AIRCRAFT IDENTIFICATION : F - GGEA |
| CAPT BAUD |
| F/O WARNER |
| DATE : 1101 |
| FLIGHT NUMBER : A/B |
|  |
| GATE IN / GATE OUT | 1050 / 1840 |
| TAKE OFF / LANDING ON | 1034 / 1834 |
| BLOCK TIME | 0910 |
| FROM / TO | LFET / KATL |
| START OF LEG / END OF LEG | 1032 / 1836 |

**MAINTENANCE REPORT**

- LANDING GEAR
- TIRE PRESSURE (PSI): 170/180, 158/183, 167/177, 166/181
- MAX BRAKE TEMPERATURE (°C): 156/171, 174/180, 158/178, 145/178
- TIRE PRESSURE (PSI): 156/188

**OXYGEN**

- CREW OXYGEN BOTTLE PRESSURE: 1800 PSI
- CREW OXYGEN SUPPLEMENTARY BOTTLE PRESSURE: 1806 PSI
- PAX OXYGEN BOTTLE PRESSURE: 1808 PSI

**WATER/WASTE**

- POTABLE WATER
  - FORWARD TANK WATER LEVEL: 060%
  - AFT TANK WATER LEVEL: 060%
- WASTE WATER TANK NOT EMPTY
  - LEFT TANK LEVEL: 000%
  - RIGHT TANK LEVEL: 000%

- Uploaded free text information prepared on a PC

**END OF REPORT**
action based on their airline practices. In that case only a summary of the service report is obtained, associated with servicing item coupons for parameters which actually need a check (Figure 9).

Finally in both cases (full service report or summarized report with coupons), the operator can add free text information. This information will be defined on a PC and uploaded into the CMC using a data loader.

**The Aircraft Configuration Report**

Two reports will be available, one called the Equipment Configuration Report and the other called the Software Loadable Equipment Configuration Report. Both are accessible through the Avionics Configuration Report item of the maintenance menu (Figure 10).

**2L The Equipment Configuration Report** presents each equipment name with its ATA reference, Functional Item Number (FIN), Part Number (P/N) and if any, Serial Number, database 1 reference and database 2 reference.

**4L The Software Loadable Equipment Configuration Report** makes it easier to manage the configuration of the software loadable equipment and associated diskettes. The list of equipment included in this second report is uploaded in the CMC, and a PC is used for the definition of the list. This report reflects the following parameters: Disk number, Equipment
The list of advisories and flags is shown in the previous table and they will be represented on the PFR as mentioned below, with the associated Universal Coordinated time (i.e. GMT) and flight phase:

<table>
<thead>
<tr>
<th>ATA</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1226</td>
<td>00</td>
<td>CRUISE</td>
</tr>
<tr>
<td>1258</td>
<td>06</td>
<td>CRUISE</td>
</tr>
<tr>
<td>2131</td>
<td>06</td>
<td>CRUISE</td>
</tr>
<tr>
<td>2131</td>
<td>07</td>
<td>APPROACH</td>
</tr>
</tbody>
</table>

The purpose of this function is to download to a diskette the following reports for further analysis:
- Post Flight Report
- Previous Leg Report
- Class 3 Report
- System Bit Error Report
- Servicing Report
- Avionics Configuration Report.

Each downloading will create an MS-DOS ASCII file which name will be the aircraft identification followed by an identification of the report, e.g. "F-AKWN.MPF" where MPF represents the Maintenance Post Flight report.

This article has presented the A330/A340 on-board maintenance concept which benefits from A320 experience and whose features bring the system to the level of definition stated as an objective by the ARINC 624 report, On-board Maintenance System.

The A330/A340 maintenance philosophy is effectively built around a standardised English language-based user interface. It allows storage of BITE system fault data within each LRU and provides ground test capabilities for LRU replacement. Additional capabilities, such as the Servicing Report and the Flag and Advisory function, are being designed to further help the maintenance personnel.

Finally the A330/A340 maintenance system is integrated with a new Trouble Shooting Manual design including BITE assisted fault isolation procedures as described in the following article in this issue of FAST, dedicated to the evolution of the trouble shooting manual.
Evolution of the TROUBLE SHOOTING MANUAL for the A319/A320/A321/A330/A340

Airbus Technical Publications Department has just finished retrofitting the concept of the A330/A340 Trouble Shooting Manual (TSM) to the A320. This major endeavour was initiated by Airbus to provide Airlines with a common concept TSM for the A319, A320, A321, A330 and A340 aircraft. The retrofit is being carried out in parallel with production of the A340 TSM and the A330/A321 TSMs. This new concept entails the creation of completely new manual contents for the A320. This article describes the A330/A340 TSM and explains why the original A320 TSM was different from previous TSMs and why the concept was modified. It also explains the evolution and use of the TSM to cover onboard maintenance systems.

From the late 1980s Airbus aircraft began to enter service with onboard maintenance systems installed. These systems are called the Centralised Fault Display System (CFDS) for the A319/A320/A321 and the Central Maintenance System (CMS) for the A330/A340. The A320 was the first aircraft to enter service with such a system in 1988.

Entry into service of the CFDS/CMS introduced a level of fault finding and display capability previously unknown. Consequently, they became the primary tools for trouble shooting on the aircraft.

The CFDS/CMS utilise Multipurpose Control and Display Units in the aircraft cockpit to display faults and to conduct a dialogue with aircraft systems. There is also a Post Flight Report (PFR) printed from a cockpit printer after a flight. The PFR lists the faults which occurred during the flight and correlates the Electronic Centralised Aircraft Monitor (ECAM) faults displayed to the flight crew with faults detected by the CFDS/CMS.

For a detailed description of the A330/A340 CMS see article on page 2.

IMPACT ON THE TSM

Prior to the introduction of the CFDS Airbus TSMs generally conformed to the Fault Isolation Manual (FIM) part of the ATA (Air Transport Association) 100 Specification. However, this specification was created in the early 1970s and therefore did not take into account the use of a CFDS. Consequently, an alternative concept had to be created for the A320 TSM to cover CFDS.
THE A320 TSM

The A320 alternative concept was created in consultation with the aircraft launch customers. In this concept the CFDS was considered the primary trouble shooting tool. The TSM then became a complement to the CFDS for supporting data. A great deal of experience was gained with the CFDS and TSM on the A320. The main conclusions of this experience were:

- maintenance crews did not become as competent at CFDS use as expected, making additional CFDS guidance in the TSM necessary.
- the TSM must be a complete guide to aircraft faults instead of a complement to the CFDS.
- a simpler manual structure was desirable to allow quicker and easier location and correlation of faults, fault messages and fault isolation procedures.

These main conclusions, plus many minor ones, were taken into account for the creation of an improved trouble shooting concept for the A330/A340 TSM.

THE A330/A340 TSM

Some of the conclusions of A320 experience seemed contradictory at first sight: a simpler, but more complete, TSM! The ideal of every TSM user is a pocket book which covers everything, including Maintenance Manual procedures... However, to have a complete TSM, about 11000 fault symptoms and their associated fault isolation procedures are needed for the A330/A340 (an explanation of fault symptoms is given later in this article).

As a result a large manual is inevitable. To compensate for this, ease of access to the data was concentrated on. These, and other, conflicting requirements were harmonised in the creation of the concept.

The resulting TSM conforms with one of the main requirements of ATA 100 - it is written for a competent mechanic who is unfamiliar with the aircraft. As a result, users familiar with the aircraft may find some of its contents obvious, but this information is essential to an unfamiliar user.

In-service experience with the A340 has led to further refinement. The structure and content of this latest version is described in the following paragraphs.

THE A330/A340 TSM STRUCTURE

The structure of the TSM is as follows:

- **Manual level**: Index of Warnings and Malfunctions (I-W/M), Index of CMS Fault Messages (I-CMS).
- **ATA chapter level**: Fault Symptoms (page block 101),
- **ATA section level**: Fault Isolation (page block 201), Task Supporting Data (page block 301).

Some parts of the TSM use a trouble shooting tree structure in text form. The use of flow chart trees on figures, as used in previous TSM/FIM was also considered. However, with the existing state of the art these would have been "dumb" with limited possibilities for "intelligent" electronic use. As text trees can be made intelligent more easily, they were used to allow the future production of trouble shooting on electronic media.

This will also allow the future structuring of the TSM in accordance with Standardised General Mark-up Language (SGML).
These indexes are provided to allow entry to the TSM with the text of a single fault. Combinations of faults are not given in the indexes, but in the fault symptoms pages. The indexes list all faults covered in the TSM and give every location where each fault can be found.

Warnings are defined as ECAM warnings, while malfunctions cover all other faults, e.g. local warnings or crew observations.

The I-WM is divided into four main sections that conform to the main types of faults which can appear on the aircraft and so allow direct entry into the index:

- **I-ECAM:** All ECAM warnings,
- **I-EFIS:** All EFIS (Electronic Flight Instrument System) Primary Flight Display and Navigation Display faults,
- **I-LOCAL:** All local warnings (panel lights, etc.),
- **I-OBSV:** Crew/maintenance observations, all other faults.

Some of the sections are subdivided into further classifications of fault types such as ECAM Engine Warning Display.

The I-CMS is a straightforward alphanumeric listing of the messages without sub-divisions.

The index pages are divided vertically into columns. The left column giving the warning, malfunction or fault message and the CH-PB101 column a cross reference to the fault symptoms pages.

All the warnings, malfunctions and CMS fault messages in the indexes are sorted alphabetically within the sections and/or sub-divisions to ease fault finding.

Crew or maintenance observations can be reported in numerous ways depending on the person doing the reporting. Consequently, to ease finding them in the index, a specific order of writing is used in the TSM. This is system/unit first followed by problem, for example "Landing gear - Slow to extend".
THE FAULT SYMPTOMS PAGES

These pages list "fault symptoms" which appear on the aircraft and are the main entry point into the TSM. The term "fault symptom" describes the association of a warning and/or malfunction and/or a CMS fault message. Therefore, unlike the indices which only describe single faults, these pages give fault symptoms which may consist of a combination of faults.

TSM entry starts with the warnings/malfunctions (log book entry) and is followed by correlations of the CMS fault message (if applicable). This then leads to the reference of the fault isolation procedure.

The fault symptoms pages, located at the beginning of each ATA chapter, comprise a complete list of faults covered by the chapter. They are divided into sections and sub-divided identically to the I/W/M and I-CMS. Also, their layout is similar to that of the A330/A340 PFR to ease correlation of faults.

The pages are divided vertically into three main columns: warnings/malfunctions, CMS fault message and fault isolation procedure references.

CMS fault messages alone are listed in their own fault symptom pages section. This section lists only those fault messages which are not associated with a warning or malfunction. For this section the warnings/malfunctions column is, of course, left blank.

THE FAULT ISOLATION PROCEDURES

The layout is similar to the AMM for ease of use and is divided into the following parts:

1. **Possible causes**
   This provides a list of all the possible causes for the fault and is extracted from the fault isolation procedure. It is provided to enable the collection of all items required to fix the fault and not for "shotgun" trouble shooting.

2. **Job set-up information**
   This lists all the tools, referenced procedures and other information required to carry out the fault isolation procedure and is similar to the Aircraft Maintenance Manual job set-up.

3. **Fault confirmation**
   This specifies any test or procedure necessary to confirm that the reported fault is genuine. It is given to reduce the incidence of unjustified removals and may also provide information on spurious faults.

4. **Fault isolation**
   This gives the procedure to be applied if the fault is confirmed. The procedure is normally structured according to the results of the fault confirmation test.

5. **Close-up**
   If closing-up is required, the action is described in this paragraph. When such action is not required this paragraph is omitted.

   Standard sentences are used wherever possible to ease understanding of the fault isolation procedures.
**A340**

**TROUBLE SHOOTING MANUAL**

**FLAPS**

**TASK SUPPORTING DATA**

1. Special SPCC BITE functions
   A. TROUBLE SHOOTING DATA
      - The SPCCs have TROUBLE SHOOTING DATA for a given fault which shows:
        - the maintenance message
        - the complementary information, if applicable. The complementary information is

**PROX INPUTS**

(1) PPU
The PPU input shows the position carried in digital and hexadecimal values of the I/H

**A340**

**TROUBLE SHOOTING MANUAL**

**POU VALVE BLOCK**

**FLIGHT WARNING COMPUTER 1**
**REP 31-53-00**
**SYSTEM 2**

**27-50-00**

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**FINDING A PFR FAULT**

PFR indicated faults can be found by noting the ATA chapter reference of the fault symptom given on the PFR and the type of fault (eg ECAM Engine Warning Display).

The Fault Symptom pages for this ATA chapter are entered at the appropriate section and sub-division for the type of fault and the ECAM warning found.

The fault is correlated with the associated CMS fault message (if applicable). Then the fault isolation procedure task number, ATA reference and page number of the fault symptom are noted.

The user then goes to the ATA reference and page number in the Fault Isolation Procedures, confirms the task number and does the procedure.

Additional information, if applicable, may also be found in the Task Supporting Data.
FINDING A NON-PFR FAULT

This depends on whether the user knows which aircraft system has generated the fault and consequently the ATA chapter.

If the chapter is known, the TSM Fault Symptoms pages for this are entered at the appropriate section and sub-division for the type of fault. For example, if a flight crew observation that the landing gear (L/G) is slow to extend is reported, ATA Chapter 32 OBSV (Observations) must be entered. From this the Fault Isolation Procedure is referred to as for PFR reported faults.

If the aircraft system is not known, TSM entry can be made via the I-W/M. The L/G slow to extend fault previously mentioned can be found in the OBSV section of the I-W/M. From this a reference is made to the ATA chapter Fault Symptoms and from there the procedure is the same as for PFR reported faults.

ATA / AIA STATUS

In parallel with the creation of the A330/A340 TSM an ATA/AIA (Aerospace Industries Association) task force was formed to update the ATA 100 FRM/FIM (Fault Reporting Manual/Fault Isolation Manual) specification to cover aircraft with a CMS. All of the major American airlines and some major European airlines were represented on the committee. Most major aircraft manufacturers were also represented.

The experience gained with the A320 and A340 TSMs was a major contributing factor in the definition of this new specification.

Subject to approval, the new FRM/FIM specification will be issued in 1994. It is worth noting that the TSM concept described in this article is almost identical to the FIM part of the new specification.

CONCLUSION

The improved TSM was issued for the A340 aircraft. In-service experience led to further refinement as mentioned earlier. This latest version is being retrofitted to the A320 with a phased introduction starting in late 1993 and finishing by early 1994. In parallel it will also be applied to the A321, and used in the future for the A319. For the A330 and A340 the latest version was introduced at the beginning of 1994.

The latest version of the TSM provides the following main benefits:

- simple structure for ease of use,
- comprehensive coverage of all probable faults,
- indexes of all ECAM warnings/malfunctions and CMS fault messages,
- consistent trouble shooting documentation for A319, A320, A321, A330 and A340 leading to benefits in dispatch reliability and reduced maintenance costs,
- possibility to produce an electronic version,
- similarity to the forthcoming industry standard FIM defined in the ATA 100 Specification.
Ground handling requirements for the A330 and A340 follow the Airbus tradition. Logical lay out enables ground handling teams to work smoothly without interference between each other, leading to shorter turn-rounds and more efficient working. The Airbus policy of continuous customer consultation has resulted in ground handling which meets the real needs of airline and airport staff.

A330/A340
Ramp handling

From the ramp handling view-point, the A330 and A340 aircraft are the same. All ground service connections are to recognised industry and international standards, thus there is no need for special-to-type ground service equipment. When an airline is considering the purchase of a new aircraft, one important question that is always asked is: "Do we need special ground equipment?"
For all Airbus aircraft the answer is: "No special equipment required"; this means no additional costs in the purchase of expensive special equipment.

Another point that needs to be considered is the cost of keeping an aircraft on the ground during turn-round. This has always been important to an airline, but in the current financial situation it can be critical to an operation (the cost of keeping a large aircraft on the ground can be upwards of US $7000 per hour, or about US $116 per minute, per aircraft).
GROUND SERVICE CONNECTIONS

The A330 and A340-300 share the same structure, except for the number of engines, the A340-300 differs only in that it has a shorter fuselage. The ground service connections are identical on all models and conform to the same international standard as the earlier models of Airbus aircraft. They are positioned along the underside of the fuselage, except for the refuel/defuel connectors, which are located at the leading edge of the wings.

EXTERNAL ELECTRICAL POWER

The external ground power panel is located just aft of the nose landing gear bay on the fuselage lower centre-line and can be reached without steps. It contains two receptacles (ISO R 461), together with the conventional selectors and indicators mounted to the rear of the receptacles. Each receptacle has a capacity of 90kV, and accepts both type ISO 1 and ISO 2 connectors. Provision is made, adjacent to the receptacles, to support the weight of the external electrical cable.

A ground power control unit (GPCU) is incorporated into the aircraft's electrical network to regulate the external supply and protect the aircraft's circuitry.

A no-break power transfer function is also provided to allow the transfer of electrical power between two electrical sources with no interruption of the supply to the concerned busbars.

PNEUMATICS

Low and high pressure air supplies are connected to the aircraft at the low pressure and high pressure service panels which are positioned on the forward face of the belly fairing, to the left of the aircraft centre-line. In this position the connectors are accessible to supplies of air from either mobile units or via the passenger bridge. Both service panels can be reached without steps.

Two standard 8 inch (MS 33562) low pressure connectors interface with the ground supply, to provide conditioned air to heat or cool the passenger cabin, as required, without using the air conditioning packs.

The high pressure air service panel is located immediately behind the low pressure panel, and comprises two standard 3 inch (MS 33740) connectors. This supply can be used for engine start, or as a power source for the aircraft's air conditioning packs.
FUEL
The refuel/defuel panel is located on the rear face of the belly-fairing, to the right of the aircraft centre-line. Optionally, this panel may be positioned on either the left or right wing, out-board of the refuel coupling.
From this panel, the aircraft can be refuelled automatically via the Fuel Control and Management Computers (FCMC), individual tanks can be refuelled, inter-tank transfers can be made, or the aircraft defuelled.
Pressure refuel couplings are provided on both the left and right wings as standard on the A340, and on the right wing only on the A330. Each coupling comprises two standard 2.5 inch ISO R45 connectors, positioned behind a forward opening access panel. Refuel time for the A340 using all four couplings - left and right wings simultaneously - is just 30 minutes empty to full. Gravity refuelling can be accomplished through a filling point on the upper surface of the outer wing tanks.

WASTE WATER
The waste from the toilet system is collected in waste tanks located behind the bulk cargo compartment. Two waste tanks are provided, giving a total storage capacity of 700 litres; optionally a third waste tank can be installed increasing the total capacity to 1050 litres. These tanks are connected to a waste water service panel located on the underside of the fuselage, approximately two metres aft of the potable water service panel. The drain and flush/fill connectors are of the standard Roylin type (4 inch and 1 inch respectively). After draining, the waste tanks are flushed with fresh water from the ground service vehicle, and then precharged with 18 litres of disinfectant per tank.

POTABLE WATER
The potable water service panel is located on the underside of the fuselage, just aft of the rear passenger door. This panel is positioned to the left of the aircraft centre-line, with an access panel opening towards the centre-line. The standard 0.75 inch Roylin connector interfaces with conventional ground equipment. With a flow rate of 8.75 litres per minute, filling time is 8 minutes for the standard two tank layout and 12 minutes with the optional third tank.
Potable water is supplied from two water storage tanks, which have a total storage volume of 700 litres usable capacity. Optionally, a third storage tank may be installed to increase the total storage capacity to 1050 litres.
The volume of water taken on-board can be preselected, in steps of 25% of the tank's capacity, on the Forward Attendant's Panel (FAP) which is positioned adjacent to the left forward passenger door.
When the tanks are full, the control handle on the potable water service panel automatically returns to the 'Normal' position. Once filling is completed, surplus water remaining in the filling line is automatically emptied overboard to prevent freezing during flight. The system is drained through the service panel and two drain ports, one located approximately midway between the forward cargo door and passenger door number 2, the other between the aft cargo door and the rear end of the fuselage.
DOORS

The A330 / A340 have three pairs of conventional plug Type A passenger doors, two pairs of doors are positioned in the forward area of the passenger cabin, with the third pair located at the rear end of the passenger cabin. All six doors can be serviced by conventional passenger bridges, mobile lounges or passenger ground stairs. Conventional plug Type 1 emergency exits are provided just aft of the wing trailing edge although a Type A door is available as an option.

The forward and aft lower deck cargo compartments are each provided with an outward opening, hydraulically actuated door. The distances between the forward cargo door and the right passenger doors number 1 and 2, is sufficient to allow simultaneous operation at the cargo compartment and catering, or other activities at both passenger doors. Space is also available for the positioning of a mobile air conditioning unit, if required.

At the rear of the fuselage, the arrangement of the aft cargo door, bulk compartment door and passenger door 4 is the same as on other Airbus widebody aircraft, allowing simultaneous operation at all three doors.

Both the forward and aft cargo compartment doors are wide enough to allow the loading of a range of standard pallets and containers. Maximum loads for the A330 and A340-300 are 22,861 kg in the forward cargo compartment and 18,507 kg in the aft cargo compartment. For the shorter fuselage of the A340-200, the maximum loads are 18,507 kg in the forward cargo compartment and 15,241 kg in the aft cargo compartment.

The door to the bulk compartment is a manually operated, inward opening door which is retained in the open position by spring mechanism.

The total volume available for bulk cargo is approximately 19.7 cubic metres, maximum load is 3468 kg.

CONCLUSION

"The A340 has been extremely reliable for a brand new aircraft ..." Just one of the compliments for the A340 during the first months of commercial service. Part of the reason for good dispatch reliability is the careful arrangement of the ground service connections on the A340 and its sister the A330 due to the coordination between the airline specialists and Airbus designers.

A Ground Handling brochure and video is available from D. Saxton, Airbus Industrie AEEC-CTF Tel/Fax +33 61 93 55 75. Please specify Pal, Secam or NTSC format for video.
Airbus customers have been operating their A300s across the North Atlantic, the Bay of Bengal and the Indian Ocean under the 90-minute ICAO recommendations since 1976. However, ETOPS (Extended Range Twin Engine Operations) officially began in 1985 with the newly issued ETOPS criteria.

By the time second generation ETOPS aircraft enter service in 1994, nearly ten years of ETOPS experience will have been accumulated. This article describes the Airbus Industrie approach to getting early ETOPS approval for the A330, its latest twin-engined aircraft.
The current Airbus ETPS fleet is comprised of the A300, A310, A300-600 and the A320; the first fly-by-wire aircraft to receive this clearance.

ETOPS started with jet aircraft of proven maturity, backed by several million hours of experience, which mostly went into North Atlantic service, with a 120-minutes diversion time (Figure 1). ETOPS then developed into 180 minutes diversion time, opening most of the world's routes to twins.

In 1992 twin-engined ETOPS service exceeded three and four engines aircraft service across the North Atlantic. More than 100 operators are now flying ETOPS worldwide. To date, the safety record of ETOPS has been immaculate.

**THE ORIGINAL CONCEPT**

The target for ETOPS twins is to establish a level of operational safety consistent with that of the three and four engine long range fleet. Owing to their advanced design, the first generation ETOPS products could achieve a level of system integrity equal to, or better than, that of other long range aircraft, with only the need for limited additional redundancies and systems performance enhancements. However, in the context of ETOPS missions, certain failures on twins are potentially more critical than on other aircraft.

The improvements to be envisaged not only include the engines but also certain other aircraft functions necessary to complete a safe flight or a diversion. For a twin, there is no way to achieve the same level of fully independent redundancies as on a three or four engine aircraft because of the possible removal of the engine as a drive source for systems and because of the possible damage to multiple system channels in the case of rupture of the engine rotating parts.

As an example, multiple generators all installed on one engine with one drive and close routing of harnesses does not equate to generators on separate engines. Since multiple system redundancies are definitely limited in their effectiveness, the response to this design constraint has to be through superior reliability and added conservatism in the maintenance and operational practices applied to ETOPS aircraft.

This is why the ETOPS criteria emphasize the reliability aspects and require that reliability be established with a very high degree of confidence. The original ETOPS criteria therefore address:

- design (redundancy and performance),
- reliability (statistical approach)
- maintenance (preventive programme and human factors),
- operations (dispatch configuration, human factors).

The outstanding safety record of the first generation ETOPS fleet has verified the validity of this approach.

**THE NEW GENERATION**

The second generation of ETOPS aircraft will enter ETOPS service by mid 1994 with the A330, after less than six months of non-ETOPS operation.

The reduction of the amount of direct service experience needed to demonstrate the ETOPS reliability objectives with
sufficient confidence and its replacement by related experience is the most remarkable change to the ETOPS assessment process for second generation ETOPS. In addition, this second generation of twin-engined aircraft has been designed with ETOPS in mind from the start. Such ETOPS design features, as increased protection time against cargo hold fire and stand-by electrical power, are now basic.

In the area of maintenance and operational practice, the lessons from previous ETOPS have been applied and the operators benefit from precise guidelines to prepare for ETOPS. This includes sophisticated simulated ETOPS programmes to expedite the acquisition of the necessary level of experience.

The concept of a family of products is extensively used to permit the operators to gain experience on products of the family of the candidate aircraft or engine. Simulated ETOPS, either on the candidate aircraft or on an aircraft from the same family, is used by the operators to achieve ETOPS readiness quicker.

Airbus products are grouped into families (Figure 2). Operators of one model in one family may claim credit for this experience for an ETOPS programme on any other model of the same family. Operators may also obtain assistance from Airbus or from an ETOPS-experienced operator to bring in the necessary expertise at the start of their ETOPS programmes, and to transfer this knowledge to their personnel.

**THE DESIGN PHASE**

The lessons of past ETOPS programmes have led to the introduction of a number of design features that did not exist in the first ETOPS aircraft. The driving factors for these changes were:
- minimizing diversion causes other than propulsion failures,
- minimizing crew workload in all diversion scenarios,
- minimizing weather encounters during diversions,
- increasing systems performance and integrity in the diversion configurations,
- easing preventive maintenance.

A typical example of this ongoing process to optimize the design for ETOPS is the expanded list of services available to the crew for a diversion on stand-by electrical power. Since the early days of ETOPS, stand-by electrical power has been increased. On A310 ETOPS, it powers such services as normal pressure fuel feed to the engines, control of cockpit temperature, wing anti-ice control, ATC operation, and more. On the A330, stand-by electrical power supplies wind-shield anti-ice, landing lights, weather radar, precision approach means, etc., to minimize crew workload even in the event of adverse weather conditions.

First generation ETOPS aircraft had a relatively low single-engine altitude capability. This increases the exposure to adverse weather in case of single-engine diversion. The A330 will be capable of flying above the weather on one engine. Other design characteristics are also improved, such as fuel alerts, Flight Management System modes and on-board maintenance capability.

The lessons of all the significant service events on first generation ETOPS aircraft were carefully taken into account and system integrity was raised to an unprecedented level for twin engine aircraft. Airbus not only considers its own experience but also that of the ETOPS world fleet. For example the occurrence of several fuel cross-feed valve failures on a competitor's aircraft led Airbus into designing a completely fail-safe fuel cross-feed system for the A330. The MMEL limitations of first generation ETOPS aircraft were also re-assessed and new features introduced to alleviate the most penalizing aspects. On the A330 the APU bleed system is capable of pressurizing the aircraft (with an altitude limitation) thus permitting ETOPS with one engine bleed unserviceable.

**THE RELIABILITY DEMONSTRATIONS**

ETOPS assessment requires high levels of reliability to be established with high levels of confidence. The first generation of ETOPS products had millions of hours of service experience available for statistical reliability verifications to be made. The reliability assessment process was therefore a straightforward exercise of identifying the failure modes, rates and scenarios, significant to ETOPS, from the data base of actual experience.

Analytical assessment methods were also used to evaluate the effect of longer flight time and diversion time. For the A300 and A310, calculations were made based on eight hours mean flight time within which a maximum diversion time of three hours was considered. However such analytical techniques are not sufficient to demonstrate the intended level of reliability with a high level of confidence, if experience is not available.

In the case of technologies used for the first time, the failure rates, and sometimes the failure modes considered in the
analyses, do not always fully reflect service experience, especially in the first years of operation when unexpected events may occur. Limitations were also confirmed in the effectiveness of analytical reliability assessment methods in such areas as software, human factors and environment.

Because of the high level of confidence expected in an ETOPS reliability assessment, it is virtually impossible to introduce completely new technologies directly into ETOPS service. For the A320, the JAA requested 300,000 flight hours to establish the desired confidence level. In the case of first-generation ETOPS aircraft, the validation of the analytical reliability was based on direct experience data gathered on the candidate engine/airframe combination. However, it soon appeared feasible to achieve the same level of confidence in the validation process by using related experience, i.e. propulsion or system experience, from another application of the identical product or a closely similar product.

After the successful ETOPS introduction of engine/airframe combinations, depending progressively more on related experience rather than on direct experience, the manufacturers and the Authorities developed the concept of Technical Transfer Analysis and backed it by sophisticated test programmes to confirm the applicability of the related experience to the candidate product.

Attempts were also made to establish the ETOPS reliability and level of confidence by analyses and tests only, without the basis of a family of products (engine or aircraft) but the success was limited. A330 ETOPS reliability demonstration is a sophisticated seven-step process:

- Establish a database of experience for the technologies utilized in all ETOPS significant systems and propulsion (basis A320/A330).
- Perform analytical ETOPS reliability assessments.
- Perform Technical Transfer Analyses (engineering comparison and lessons learned) between the candidate product and the family of products used as a basis of related experience (Figure 2). For A330 the references for systems are A320 and A340 and the references for engines are the current family of General Electric, Pratt and Whitney and Rolls Royce engines of which growth versions are used.
- Perform special endurance testing (e.g. 3,000 ETOPS cycles on engines) to confirm the applicability of the related experience to the new product (unless sufficient direct service experience is used for this purpose).
- Use the Systems Integration Test Bench to confirm the specific aspects of the system integration on the candidate product. This test tool, nick-named the "Iron Bird", has been used by European manufacturers for more than 30 years and is now being introduced in the USA.
- Validate the reliability of the candidate product on the basis of related experience and direct experience as necessary. The amount of direct experience required depends on the degree of similarity between the candidate product (aircraft or engine) and the original family, and on the level of ETOPS approval contemplated (75, 90, 120, 180 minutes).
- Institute the ETOPS continued reliability programme for the candidate aircraft and the family of products. Such a process exists in Europe for all ETOPS aircraft by the ETOPS Reliability Tracking Board.

Steps of approval of increasing diversion time (opening up progressively more demanding areas of operation) are instigated in conjunction with the reliability
assessment process. The results of the initial ETOPS reliability demonstrations and of the continued reliability programme are reflected in the initial ETOPS Configuration. Maintenance and Procedures document and its subsequent revisions.

**THE MAINTENANCE PROGRAMMES**

The influence of human factors on the reliability of products is most obvious in the early stages of introducing a new aircraft in the fleet of an operator. Even at later stages the adequacy of certain servicing practices or the ability to minimize human errors may heavily influence the reliability of important systems and propulsion. ETOPS requires little or no additional maintenance checks but definitely requires high awareness in performing maintenance.

The main characteristics of an ideal ETOPS maintenance programme are:
- **full maturity of the maintenance documentation and procedures,**
- **personnel awareness,**
- **thorough understanding of systems operation and trouble-shooting techniques for the technologies concerned,**
- **familiarity with all the line maintenance tasks,**
- **effective feedback between reliability and preventive maintenance programmes through an ETOPS maintenance quality plan,**
- **effective control of human factors.**

For the A330, an ETOPS maintenance readiness programme involving Airbus and selected operators has been instituted to validate the programmes, the procedures, the training and any human factor aspect. This programme uses both A340 and A330 data.

**THE OPERATIONAL ASPECTS**

The preparation of ETOPS flights is as important as the actual conduct of the flight. Dispatchers must work as a team with flight crews to provide them with the best preflight and in-flight assistance. The maturity of the operational documentation and procedures is a key factor. For the A330, Airbus is conducting ETOPS operational readiness programmes at the start of the operation jointly with the first operators. Such programmes validate the documentation, procedures, training and any human factor aspects.

**THE RECORD AND PERSPECTIVES**

First-generation ETOPS aircraft accumulated an outstanding record of safe operation. The ETOPS fleet is growing at a steady pace and many operators are joining the club every year. Owing to the innovative efforts of the manufacturing industry and operators, many improved methods have been developed and proven in the areas of design, reliability demonstration, maintenance and operations. ETOPS is entering adulthood. It is important to retain its high standard of operational safety while the ETOPS world fleet becomes larger and more diversified.

The reduction of the amount of direct service experience prior to approval is essential to the economics of ETOPS, but must be achieved with any compromise to safety. The methods that gave ETOPS its safety record are more important than ever:
- **Design for systems integrity,**
- **Validation of the reliability on the basis of applicable experience, using the Technical Transfer Analysis method,**
- **Implementation of comprehensive continued reliability programmes,**
- **Implementation of ETOPS maintenance programmes and their adjustment to the results of the ETOPS reliability programmes and to the operating environment of individual operators,**
- **Integration of human factors at all stages of ETOPS.**

The A330 heralds a new era of ETOPS design and operation, based on evolutionary rather than revolutionary principles. Airbus Industrie's tried and trusted approach of using derivative assessment as a basis for accelerated ETOPS on the A330 has met with Authority approval and will set the standard for ETOPS on future Airbus models.

**FIRST ETOPS CONFERENCE**

With the A330 poised to enter into ETOPS service in the summer, the very first Airbus Industrie Conference devoted entirely to ETOPS was held in Toulouse from 8-10 February 1994.

For over twenty years, Airbus Industrie has been amassing an enormous amount of experience and expertise in the design of twin-engined aircraft. For many years the technology outpaced the regulatory environment governing twin-engined operation until the ETOPS rules were formulated in the mid-1980s. Now, ETOPS has come of age. We are on the brink of seeing the first of the new generation ETOPS aircraft - the A330 - start flying under these very special rules.

It has been anticipated that an ETOPS Conference, bringing together airlines, airworthiness authorities and engine manufacturers, might attract an audience of about one hundred. In the event, the number of registrations totalled 330 - an appropriate number! - and the largest conference/hotel complex in Toulouse was selected as the venue.

The Conference was opened by Mr. Bernard Ziegler, Senior Vice-President Engineering. Participants were then treated to the public premiere of a new film on ETOPS, "Time Flies", which is a general introduction to the subject and examines the development of twin-engined operations from the very earliest days of this century to today's supremely reliable stable of big twins.

Two of the three days of the Conference took place in a single auditorium, in which participants heard presentations ranging from Accelerated ETOPS to the Economics of ETOPS. The presentations were tailored for both ETOPS and non-ETOPS airlines alike. Airlines considering starting ETOPS operations heard, for example, how to formulate an approach to the authorities for operational approval and how to determine the area of operations. Airlines already flying ETOPS were able, and eager, to share their experience with prospective ETOPS operators.

For one day, a series of smaller presentations and workshops were organised, building on the main presentations and allowing a better interaction between Airbus Industrie specialists and participants. In this way, up to six sessions were conducted simultaneously and delegates were able to choose between subjects covering specific Airbus aircraft types, or attend presentations covering aspects such as training, flight operations and dispatch, weather minima and suggestions for preventing engine shut-downs.

Airlines and airworthiness authorities were also given the opportunity for private discussions to assess their individual positions and formulate on-the-spot responses to Airbus Industrie's own ETOPS stance.

The ETOPS Conference was a first and unique gathering of the best of the world's Airbus experience in this all-important subject. Judging by the positive response of the participants, it will not be the last.

"Time Flies" the ETOPS video, can be obtained from Paul Clark, Airbus Industrie, AICM-S, Telefax +33 61 93 49 66. Please specify Pal, Secam or NTSC format.
UNDERSTANDING THE PROCESS OF ICE ACCRETION

by Claudius La Burthe
Flight Test Scientist,
Airbus Flight Operations

Airbus airframes and systems are designed for in-flight icing resistance. However, the need to satisfy ETOPS certification rules led Airbus Industrie to investigate the ice accretion process in detail, in association with Canadian government agencies and Boeing.
Fuel reserves for ETOPS have to be based on an assumed diversion leg of up to three hours, flown at or above 300kt and possibly flown at a flight level of 10,000 feet (FL100). It is true that flying at FL100 in North Atlantic winter weather can be terrifying in a light aircraft. The icing accident record in the region for these aircraft is well known and heavy. With this experience, a standard icing policy was applied by authorities to all aircraft, and aircraft manufacturers complied. This required provisions to sustain continuous icing over a 1000 nm straight flight leg.

The resulting fuel penalty was enormous and the feeling was that the icing threat had been over-estimated. Therefore, Airbus and Boeing jointly decided to investigate the case. Many different studies were launched, all aimed at more realistic rules, including:

- better definition of the icing threat (meteorological approach)
- study of ice accretion at high speeds (speed effect approach).

In 1990, it was jointly decided to support a study at Penn State University, called "Assessment of aircraft icing potential using satellite data" being conducted by Dr. J. Curry. That study clearly established the possibility of predicting (short term) reasonably accurate water contents by data fusion between satellite infra-red imaging and computer meteorological models. Some side results mentioned in the report support the idea that icing patches should be very limited in size.

Although the study only covered a one-month period and was called a "pilot study", subsequent events confirmed the result.

Through contact with specialists, it was then discovered that the Canadian Government was funding an icing research exercise called CASP II (Canadian Atlantic Storms Program). Following an earlier CASP I campaign, that research was initiated by the need to protect the Canadian cod fishing fleet from the risk of blizzard. The problem is that those small ships operate off the coast of Newfoundland, in mixed hot/cold waters due to oceanic streams. In winter they can encounter extreme icing conditions, up to the point of capsizing because of the very heavy weight of ice accumulated on the superstructure in a very short time. Airbus and Boeing asked if they could participate in this program and were made very welcome by the Canadian government.

CASP II took place from January to March 1992 in St John's, Newfoundland. The program involved about a hundred people including many high level scientists, two research aircraft fully equipped for icing measurements and very significant support by Canadian weather services, particularly in the field of satellite coverage. During over 200 flight hours about a hundred icing encounters were recorded.

The results are of extreme interest in all fields related to icing; they not only confirm that the icing threat in ETOPS had been initially over-estimated, but also considerably augmented the current knowledge of icing.

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**JUST A LITTLE BIT OF SCIENCE...**

- **What is an icing atmosphere?**

  An atmosphere which is susceptible to the production of icing is necessarily at sub-zero °C temperature and must also contain droplets of liquid water. That water is called super-cooled liquid water (SLW) and analysts refers to the SLW content (SLWC). This phenomenon only happens when the atmosphere is disturbed, due to meteorological reasons possibly aggravated by the effect of mountains (orographical effect). An icing atmosphere is localised and unstable, and therefore does not last very long.

- **Does an icing atmosphere always lead to ice accretion on aircraft?**

  Absolutely not! Aircraft pick up ice much less often than they meet icing conditions, which are predicted by weather services on their meteorological charts almost every other day over the North Atlantic. In fact, the icing mechanism is rather complicated. Detailed study shows that a problem of energy is raised. It is very likely that if a group of different aircraft flew into the same icing cloud, most of them would not collect ice and only a few would suffer from significant icing.

- **Does speed have an effect on ice accretion?**

  Absolutely yes! In very simple terms, the effect of speed is illustrated here:

  ![Ice crystals](image)

  1. Low speed
  2. Increasing speed
  3. High speed
DESCRIPTION OF ICE ACCRETION MECHANISM

A wing leading edge flying into icing air is supposed to be exactly at ambient air temperature (negative 5°C). That air is loaded with water droplets, but many air particles pass around the leading edge without touching it (continuity of airflow). However, water droplets are much heavier than air particles and they do not pass around so easily. Some of them therefore impact on the leading edge (Figure 1).

Also, it is a rule of supercooled water that it is unstable, and supercooled liquid water freezes immediately after the impact. Ice accretion results from the continuation of this process.

Double horn shape

> Why the double horn shape?

The above process leads to an uneven distribution of water droplet impacts on the leading edge (Figure 1).

It is easily conceivable that those which are right in the middle would not be deflected very much and would impact instead on the upper and lower sides of the leading edge. This starts the double horn shape, which is a divergent process and which is further enhanced by ram effect (Figure 2).

But if the droplets are very heavy, as in the case of freezing rain, deflection is limited, and ice accretion takes place in an arc shape (Figure 3).

Ram effect

The impact mechanism generates energy both in the air and in the water which generates a rise in temperature. Aircraft leading edges are heated by the friction of high speed air, this temperature rise being highly dependent on speed (Figure 4).

For air only, the temperature rise is +4°C at 150 kt and +16°C at 300 kt at FL100. It is very important to take this temperature rise into account for the assessment of ice accretion.

Significant icing is not possible if the speed is such that the ram effect brings the leading edge temperature above zero. For example, no significant ice accretion is possible in air above -16°C if aircraft speed is maintained at 300 kt.

Run-back ice and shear forces

> What happens when an aircraft is flying in icing atmosphere where leading edge temperature is positive?

Due to ram energy, water droplets do not freeze on impact, but explode into numerous little globules which are blown by the airflow along the wing surfaces. But wing surfaces aft of the area heated by ram energy are at a negative temperature and cool the water down. It often happens that the cooling is quicker than the blowing off and water freezes on the spot. This process is called "run-back ice" (Figure 5).

Efficiency of the blowing off process depends on the shear forces present in the boundary layer. The faster the aircraft, the cleaner the wing.

Sublimation

> What happens to an iced wing once the aircraft is out of the cloud?

The situation is hardly ever considered. Ice will not stay as it is because of sublimation, which is the direct change of water from solid state to vapour. Once out of cloud, ice thickness will necessarily decrease. The sublimation rate depends on relative air humidity and may reach a rate of one millimetre per ten minutes. This is quite an impressive figure, which is worth considering for flights of long duration.
CASP II CONCLUSION

Although numerous icing events (about 100) were encountered during the CASP II experiment, very few were of significant importance for aircraft flying at FL 100, and none at all if the speed was assumed to have been 300kt. This surprising outcome results from a number of factors unfavourable to icing, which have to be considered.

North Atlantic climatology related to icing

It was found that North Atlantic winter weather conforms to its legendary severity mainly at lower altitude. The absence of orographic effects lets the frontal systems develop in a classical "horizontal" manner. Weather moves east rapidly. Precipitation of multiple types is heavy on the ground, but water content at altitude remains moderate. Cumulo-nimbus clouds are rare, very small and with moderate activity.

Stratiform clouds dominate and carry most of the SLW which is far from evenly distributed in them. Most of the SLW lies in the upper few hundred feet of the layers. Due to ever-present micro convection, water content is extremely irregular. If peak values can be impressive, average figures remain moderate and so does the ice accretion. By definition, a temperature inversion layer sits on top of every stratus cloud layer (Figure 6).

The consequences for aircraft are of prime importance:
- If icing is encountered, a small altitude change (a few hundred feet) may relieve the threat. This is not conventional, but atmospheric physics are in operation!
- Flying close to the top of a stratiform layer probably involves the greatest risk of icing. Flying above the layer is much more calm and the atmosphere is much dryer, thus prone to active sublimation.

Size of icing clouds

Typical icing clouds are hardly ever extensive horizontally, even taking the worst case which would be to fly along a cold front. It is difficult to quote a figure before all CASP results are available, but it is clear that an aircraft flying at 300 kt would never remain in icing cloud for more than a few minutes (and would have no ice accretion, due to speed). Repetitive encounters are possible in an area where a complex weather system sits, but not all would be a real threat. It has also been found that no firm correlation exists between cloud size and droplet size.

Effects of speed and sublimation

It has been shown above that speed protects aircraft from icing due to ram effect. The CASP II results confirm that neither of the aircraft involved ever iced at their maximum speeds, 230 and 250 kt respectively. It was said that ram effect may produce run-back ice, but it was found that the increased level of shear forces encountered at high speeds reduces run back ice to negligible proportions.

In spite of everything, if an aircraft iced during an ETOPS diversion, sublimation would significantly decrease the drag penalty during the rest of the leg.

These results can be expanded to include oceanic areas of similar latitudes. Icing risks are necessarily aggravated by the proximity of mountains. Ice accretion on jet airliners at medium flight levels differs from the icing encountered by light aircraft flying at lower levels and speeds.

The research in no way alters the experience of icing gained by the thousands of magnificent men and women who have traversed the Atlantic in their light flying machines.
A new home for

AIRBUS CUSTOMERS’ SUPPORT

Product support, by its very nature, means going out to be with our Operators. This develops people who are at home all over the globe. In the case of Airbus’ support staff this is true, but they have also been subjected to wanderings in Toulouse as well. The growth of the Airbus fleet has been reflected in the number of staff to support it, imposing office changes and even, until recently, Support staff being installed on two different sites in Toulouse.

All has now changed with the delivery of the “B6” building in January this year. This magnificent structure, which reflects an image of modernity and openness, is an appropriate symbol of Support. Elegance however is not an end in itself. The new building brings all the Toulouse staff together and provides them with an environment in which it is easier to work even more effectively, through physical proximity and modern communication means. This is essential to be able to face the continuing and growing demands for support, a support that is more and more essential to our Operators in the present difficult times.

The building has worked well from the initial occupation and will be an exceptional working place. It has been designed with room for growth.

Once the present margins have been used, the modular design and foundations already in place will allow another unit, and some 150 people, to be added without any need for significant interference with those working in the building.

Airbus Support staff will be able to move into the 21st century in offices that belong to that time and also provide an excellent functional base for their operations.
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Handling an aircraft on the ground is a very serious business, which is approached in different fashions by different aeroplane operators.

In some countries where unemployment is high, woman power is used, with adequate (male) supervision of course, to keep the aircraft to the high standard of cleanliness that today’s passengers have come to expect.

In other, perhaps more mechanically minded countries, multi-purpose machines are used. This very cost-conscious operator has grass-cutting equipment attached to its tractors to ensure that the long journey between the terminal on one side of the aerodrome and the maintenance area on the other is not wasted. It is particularly interesting and welcome to note that the welfare of the staff has not been forgotten in the drive to cut costs - the wind direction indicator (WDI) on the tractor allows the driver always to cut the grass in the direction best suited to prevent the dust from blowing into his face.

Such attention on the part of the management, to the detail of human relations and morale building, is to be commended and shows the direction which other companies will have to follow if they are to compete.
In our view, 100% commitment to support is a 24-hour responsibility.

A significant measure of Airbus Industrie's commitment is that some 3,000 people are directly involved in support for our constantly evolving family of civil aircraft. A total of 23 different languages are spoken by our staff, which indicates the global scope of our activities in this vital part of the civil aviation market. A multi-million dollar investment programme also ensures that our international support facilities will continue to match our increasing worldwide customer base.