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New Avionics Systems —Airbus A330/A340

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30.1   Overview

The A330/A340 project is a twin programme — the first time that an aircraft has been designed from the outset both with four engines, and also with two engines. Both aircraft types have essentially the same passenger and freight capacity. The four-engined A340 is optimized for long-range missions, but is also efficient at shorter ranges. With two engines, the A330 offers even better operating economics for the missions where an airline does not need the very long range of the A340.

The realization that on the two different aircraft very many features could in fact be engineered the same way without a penalty, was the key to obtaining substantial commonality between the two products. This approach has provided very substantial advantages for the operators, the airframe manufacturer, and for the equipment vendors. In effect, by designing for both sister aircraft from the outset, the requirements were engineered in common, and any added features for either of the two aircraft could be introduced at a point in the design where they cost very little extra in terms of price, weight, reliability/maintainability or fuel burn.

As a result, the two aircraft use the same parts (except the engine-related parts), can use the same aircrews, use the same airport and maintenance environment, and cost almost the same to develop as a single aircraft. And both are supremely efficient.

The A340 is offered in two configurations, allowing operators to tailor capacity and capability to demand. The larger A340-300 has the same fuselage length as the A330 and, while seating 300 to 350 passengers, has seat-mile costs close to those of the latest 747, making it an economical alternative on long-range routes with lower traffic densities.

The A340-200, seating 250 to 300 passengers, has the longest range capability of any commercial airliner available. Its low trip costs, coupled with the operating flexibility of four engines, make it an ideal aircraft for taking over when long-range twins become uneconomic.

While the A340 serves very long routles, the A330 is designed to serve high-growth, high-density regional routes. At the same time, it has the capability to operate economically on extended-range international routes. With typically 335 seats in a two-class arrangement, the A330 has a range of 4500 nmi with a full complement of passengers and baggage and 3200 nmi with maximum payload, making it ideal as a direct replacement for the costlier trijets and as a growth replacement for earlier twinjets.

30.2   Highlights

The A330 and A340 are built on the technological background established by two previous, complementary, product lines.

The A300/A310 series is the world's best-established twin-jet twin-aisle aircraft programme, with a very large number of technologically advanced features that transfer to larger, longer-range aircraft.

The A319/A320/A321 series is the world's most advanced single-aisle aircraft programme, again offering a large number of features that are found on much larger aircraft.

During the entire development process, there has been an insistence on securing the maximum commonality that could be achieved with the other programmes without loss of efficiency. Using selected features from each of these product lines, updated as needed, resulted in an all-new A330/A340 aircraft programme remarkably free of teething troubles, while at the same time providing a new benchmark for aircraft in this size category. As an added benefit, the technological features of the A330/A340 can, in many cases, be used to improve the established older product lines.

30.3   Systems

Before the entry into service of the A330/A340, the world's most technologically advanced airliner, in any category, was the A320. Its design formed the basis for the A330/A340 systems.

30.4   Cockpit

The A330/A340 cockpit is designed to be identical to that of the A320, from the point of view of the crew. The exceptions to this rule are associated with the size of the aircraft and to the added needs of the long-range mission, such as improved dispatchability, polar navigation capability, and of course, engine-related features.

The result is that the 130-seat-capacity short/medium haul A319 up to the 340-plus seat capacity very long-haul A340 have the most advanced flight deck of any airliner, enabling the same crews to fly any of these aircraft with minimum additional training needed.

30.5   User Involvement

The design of the A330/A340 cockpit has evolved from the same methods that were used successfully on the first Airbus Industrie A300.

The initial design of the cockpit (and the systems) was based on three features:

- The existing cockpit from the previous aircraft (the A320 in this case).
- The geometry of the A330/A340 nose section (which is based on the geometry of the A300, A310, and 300-600).
- Applicable new research and development work carried out since the A320 had been designed.

This initial design was reviewed by a task force consisting of pilots and engineers of each of the launch airlines in the light of their experience with the A320 or with other aircraft that were operating on the intended routes for the A330 and A340.

The task force met a number of times over a period of over a year. At each of these steps the design of the A330/A340 was refined, and certain features were mocked up for the next iteration in the review. The final design of the aircraft system and cockpit is essentially the one that the airline task force experienced and "flew" in the simulators during their final sessions.

30.6   Avionics

The avionics of the A330/A340 are highly integrated for optimal crew use and for optimal maintenance. As with all previous new and derivative aircraft since the A300FF of 1981, the primary data bus standard is ARINC 429 with ARINC 600 packaging. Other industry bus standards are used in specific applications where ARINC 429 is not suitable.

30.7   Instruments

The six CRTs on the main instrument panel display present flight and systems information to the pilots. This arrangement provides excellent visibility of all CRTs.

Flight information is provided by the Electronic Flight Instrumentation System (EFIS) consisting of a PFD and a ND in front of each pilot.

Systems information is provided by the Electronic Centralized Aircraft Monitor (ECAM) consisting of the engine/warning display on the upper screen and aircraft systems display on the lower screen.

Sensors throughout the aircraft continuously monitor the systems and if a parameter moves out of the normal range they automatically warn the pilot.

During normal flight the ECAM presents systems displays according to the phase of flight, showing the systems in which the pilot is interested, e.g., some secondary engine data, pressurization, and cabin temperature. The pilot can, by manual selection, interrogate any system at any time. Should another system require attention, the ECAM will automatically present it to the flight crew for action.

Should a system fault occur that results in a cascade of other system faults, ECAM identifies the originating fault, and presents the operational checklists without any need for added crew actions.

The information display formats currently in use enable the pilots to assimilate the operational situation of the aircraft much more easily than on the previous generation of aircraft.

There are substantial advantages on the maintenance side as well, in that the entire Electronic Instrument system consists of only three LRU types, enabling significant dispatchability and spare stocks availability. In fact, all the flight information (including standby) is presented on only 11 instruments of 6 types.

A new EIS, using liquid crystal displays, is being installed on the A330/A340 and A320 family of aircraft deliverable from 2001, offering improved capabilities and cost of ownership.

30.8   Navigation

Dual Flight Management Systems (integrated with the Flight Guidance and Flight Envelope computing functions; FMS) combine the data from the aircraft navigation sensors, including the optional GPS installation. Backup navigation facilities are included in each pilot's MCDU, allowing the aircraft to be dispatched with an inoperative FMS.

The FMS permits the crew to select an optimal flight plan for their route from a selection in the airline navigation data base, allowing the aircraft to fly automatically, through the autopilot or flight director, from just after take-off until the crew elects to carry out a precision approach and automatic landing. The "canned" flight plan captures the data needed for flight from the specifications entered by the crew prior to departure, as well as along the route as conditions change and more current information on weather and routing becomes available.

New FMSs, with improved cost of ownership and capability, are being installed on aircraft delivered from mid-2000. The same new FMSs are being installed on the A320 family.

30.9   Flight Controls

The flight control system of the A330/A340 is essentially the same as that of the A320, with five computers of two different types allowing the pilot to control the aircraft in pitch, roll, and yaw. The layout of the pilot controls is essentially the same as that of the A320 series, as are the handling qualities of the A330/A340. The technology features are also essentially the same, with extensive use of dissimilarity in the hardware and in the software, and extensive segregation in the hydraulic and electrical power supplies and signalling lanes. As with the A320 series, mechanical signalling is used for the rudder and for the horizontal stabilizer trim backup.

Detail changes have been introduced reflecting the longer mission times, specially of the A340, to provide better access to the system, and the opportunity has been taken to reduce the variety of backup submodes that the crew must use, making the aircraft even easier to fly.

Like the A320 series, the A330/A340 is a conventional, naturally stable airliner. The electronic flight controls offer a number of advantages to the pilot. There is a large reduction in manually operated mechanical parts, easier troubleshooting, and no need for rigging. Optimal use of the control surfaces is facilitated, as is the use of maneuver load alleviation.

The passengers and crew benefit as well, since the aircraft is more comfortable and easier to fly with precision in turbulence, while the flight envelope and structural protection features allow the crew to immediately use the whole capability of the aircraft should it be needed in an extreme situation.

30.10   Central Maintenance System

The A320, with its Central Fault Display System (CFDS), pioneered the industry standard for Central Maintenance Systems (CMS).

This industry background of experience has been built into the A330/A340 CMS. It enables trouble-shooting and return-to-service testing to be carried out rapidly and with a high degree of confidence, from the cockpit. Much of the CMS information may also be accessed remotely, via ACARS, giving the capability for the aircraft to be greeted upon arrival by a maintenance technician that already has a good idea of the exact nature of any defect, and who has likely been able to procure from stores the proper spare LRU required to resolve the fault.

Compared with the previous generation of CMSs, such as the A320 CFDS, the A330/A340 CMS has been improved in a number of respects, allowing trouble-shooting to take place on more than one system at a time, and with even clearer data available for the job. There has been a significant improvement in dependability as well, with great attention being paid to maintainability standards by the systems designers and the equipment vendors, and the incorporation of a maintenance message filter facility that enables known false message to be eliminated by the CMS, so that the mechanic does not apply the maxim "*Falsus in Uno, Falsus in Omnibus.*"*

30.11   Communications

There is a quiet revolution going on in the way that the crew communicates with the ground. This has been taking place in two ways. The A330/A340 uses the same full-capability standardized flight crew audio and frequency selections system as used on the A320 series, and also largely used on other recent derivative aircraft. This is a break from the traditional highly customized lower-capability systems.

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*"False in one thing — false in all."

The other aspect of the revolution is more far-reaching, in that voice communication is giving way to data communications, with the advantages of lower error rates, more timely service, and lower costs. This started with highly customized ACARS systems for company communications, using VHF frequencies.

The A330/A340 is equipped with a standardized ACARS system that can be used by any customer, with allowance for each customer to easily introduce his own custom features to reflect his own needs.

These initial ACARS systems have been extended to offer worldwide coverage, even in mid-ocean and sparsely inhabited areas, using the Inmarsat facilities and HF data link, and to cover not only company communications but also ATC services, starting with predeparture and oceanic clearances.

On aircraft delivered since 1998, the ACARS unit has been replaced by the Air Traffic Services Unit (ATSU), which is designed to also accommodate safety-related ATC functions using the Aeronautical Telecommunications Network (ATN), offering the majority of ATC and other communication services now using voice, and more importantly, offering profitable migration to the ATN. The ATSU is the first unit to host software from a number of different vendors. The same ATSU is also used on the A320 family of aircraft.

The ATN upgrade is being implemented to be available when the corresponding communication and ATC services are in service.

30.12   Flexibility and In-Service Updates

The first generation of aircraft with widespread digital systems, such as the A300FF, A310, and B767, suffered from some of the same disadvantages as their analogue-system predecessors in that their avionics were not designed to accommodate unplanned change. Once a design change was made, equipment had to be removed from the aircraft, program memories had to be reloaded in the avionics workshops (sometimes by physically changing parts), and the equipment reinstalled. At some point the airframe manufacturer usually got involved to certify the change. There was an advantage in the avionics shop, because reloading a program and retesting is a faster and cheaper activity than installing a kit of new electronic parts, but the major cost of carrying out the change on the aircraft stayed the same.

The A330/A340 systems have to a large extent overcome this disadvantage, in that those digital LRUs that have been identified as requiring in-service change now have facilities for updates to be included *in situ* on the aircraft, at greatly reduced cost.

Two techniques are used, depending on the criticality of the LRU concerned, and on other practicalities.

1. On-Board Replaceable Memories (OBRMs) are memory modules that are located on the (accessible) front panel of an LRU. They come in industry-standard sizes, cost much less than the LRU itself, and can be "recycled" many times. The visible part of the OBRM contains the LRU's software part number section. OBRMs comply with the toughest criticality criteria, enable classic configuration control of the LRU and require no tools to change. They have been in use on the A320 since 1988.
2. The other technique in use is on-board data loading using 3.5 in. diskettes and other media. These are a little slower and are even less expensive than OBRMs, but do require a data loader to be carried to or installed on board the aircraft, and an adaptation to the aircraff's classic configuration control techniques. The same data loader is used for the FMS data base.

Both techniques enable software updates to be carried out overnight on the whole fleet.

Another aspect is flexibility in dealing with airlines' changing needs. The basic equipment for the aircraft is designed with a number of pin-programmable features that correspond to frequently requested airline changes, and other systems like the FMS where the airline loads a database which specifies its own preferences. These features allow airlines to pool databases and standard spares at outstations and still obtain the kind of operation that they need. Another feature is partitioned software, where heavily customized systems like ACARS can be certified just once for all users, with one set of "core" software. The airline may load its own additional operational software on top of this core to reflect its own needs.

Lastly, certain systems like the optional Aircraft Condition Monitoring System (ACMS) which used to be heavily customized, use a combination of these techniques to enable an airline to select the features that it needs out of a very powerful selection which forms a superset of the needs of all the customers.

30.13   Development Environment

The development of each Airbus Industrie aircraft has been supported by an Iron Bird whole-aircraft systems rig, and by supporting systems rigs that enable work to proceed simultaneously, without mutual interference. The A330/A340 model is no exception, and a number of facilities have been constructed specifically for this programme. These methods are now being used by other airframe manufacturers.

Proper software development is an essential part of systems development throughout the aircraft, and a number of software tools have been developed, notably in the areas of formal methods, rapid prototyping, automatic coding, and rapid data recovery and analysis. These are supplemented by large, fast data recording and telemetry facilities on the test aircraft fleet, associated with real-time and rapid-playback test data displays for the benefit of the flight test observers on board the test aircraft and for the test and systems engineers on the ground.

The result of this environment, the proper use of features from previous programmes, and the proper management of test data flow and the resulting decision process, has created an aircraft that has had a remarkable trouble-free period of introduction into service. This is true both in terms of customer satisfaction and in terms of measurable parameters such as delay rate, which have been up to an order of magnitude better for A340 than for the previous derivative long-range aircraft that entered service.

30.14   Support Environment

The A330/A340 airplanes have a number of unique support features, apart from those previously described.

As with other Airbus Industrie aircraft, an airframe-wide Automatic Test Equipment unit is available to customers, along with an airframe-wide test program suite. No other airframe manufacturer offers this facility for avionics.

The Aircraft Maintenance Manual and Trouble Shooting Manual have been carefully designed to integrate with the CMS for easier, faster fault rectification. For those airlines that wish to use it, a software package for a PC-compatible lap top is available to further speed fault-finding.

The documentation has also been designed to be compatible with open industry computer text and graphics standards, to facilitate the introduction of intelligent maintenance documentation systems.