A safe operating environment for Long Range Operations
Paul CLARK and André QUET

A340-500/600 Maturity programme
Landri FEL

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Richard CUTLER
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In a nutshell...

Worldwide Airbus Customer Services

Passengers comfort at diversion airfields

Cover illustration:
Temporary fasteners like soldiers on parade.

This issue of FAST has been printed on paper produced without using chlorine, to reduce waste and help conserve natural resources. Every little helps.
There is no doubt in anyone's mind that Extended Twin Operations, or ETOPS, has been a resounding success. The concept of twin-engine aircraft flying more than one hour from an adequate diversion airfield has become commonplace. The success of ETOPS is down to huge efforts on the part of airframe and engine manufacturers, the regulatory authorities and the operators themselves. The reward we are reaping today is an exemplary track record and the considerable operational freedom of twin-engine aircraft. All Airbus wide-bodied twins are certified at up to 180 minutes maximum diversion time and the A320 family up to 120 minutes. Despite the huge number of route opportunities that ETOPS affords, moves are afoot to push the boundaries still further. The impetus for an extension of ETOPS comes from the gradual improvements in the range abilities of modern long-range aircraft.
However, we are entering into a new phase of long-range travel which will require a more radical and a more structured examination of certification and operational rules than a mere extension of ETOPS. New operating areas are opening up. Trans-polar flights are already being undertaken with temporary safeguards in place. Soon, we may even see regular flights over areas of very high terrain, such as the Himalayas.

In order for such flights to be accomplished at the highest levels of safety, a complete review of the regulatory environment is called for. This is now under way, with the new rules being referred to as LROPS, or Long Range Operations.

**Today’s situation**

Although we like to think of ETOPS as a coherent set of design and operational regulations, this is not actually the case. ETOPS is rather an accumulation of policies that have built up over a period of more than fifteen years. This proliferation of policies inevitably compromises the original safety principles that guide ETOPS. Certainly, today’s regulations do not ensure the appropriate level of safety we will need for the new extreme areas of operation.

The mismatch between the ETOPS regulations and the operating environment is very apparent when it comes to potential diversion airfields. A winter routing from Singapore to Los Angeles takes an aircraft over some of the remotest corners of Siberia, where airport facilities and the weather are poor and unpredictable. The hazards of diverting to airfields in the Aleutian Islands are even worse. Cold Bay airfield is adjacent to an active volcano, which has been responsible for two all-engine flameouts. Fatalities occurred at Shemya airfield as a result of a diversion in the 1990s, as bad weather precluded medical assistance being flown in.

The new polar routings take aircraft in the vicinity of Longyearbyen airport on the island of Spitzbergen, the most northerly in the world. The airfield is surrounded on three sides by mountains and is plagued by bad weather for much of the year. The crews of polar flights might also consider some Siberian airfields as potential diversion airfields, but they should be prepared for temperatures of as low as minus 60 degrees Centigrade in the case of Yakutsk. Making a safe landing is one thing. Safely evacuating passengers in such extremes is quite another.

The extreme operating environment of the North Pacific and North Pole areas clearly merit a specific regulatory review. However, there are other areas of the globe that could be opened up to air traffic subject to an appropriate regulatory review.
For example, existing airways skirt the Himalayas and Tibetan plateau to avoid the highest terrain, yet aircraft performance and systems technology are now available to enable over-flight of such regions in complete safety. Also, many South Pacific and South Atlantic routes might be established. For example, routeings from South America to Australia would take aircraft close to the South Pole, with a theoretical diversion time of no less than eight hours!

Airlines will continue to seek new markets to take advantage of the range capabilities of their aircraft. Inevitably, the growth of air traffic in these extreme regions will present a serious challenge to operational safety. A simple extrapolation of today’s cruise diversion rate suggests that six flights would need to divert to airfields in extreme areas every year by 2010. The existing regulations and policies, coupled with current aircraft design and operational practices, may compromise the safety of passengers and crew in the extreme areas of the world. This is not an acceptable situation, so something needs to be done.

What is LROPS?

LROPS can best be defined as a regulation that will encompass the design, certification and operation of all aircraft (irrespective of the number of installed engines) on long-range missions involving flight over remote and operationally challenging zones. Such missions would include any flight further than three hours flying time from an adequate airfield and any flight, irrespective of diversion time, where the operating conditions at existing airports present a serious risk. Such areas will be designated by the authorities. The concept was born out of an Airbus initiative, in response to the authorities’ concern, to address the best way of enabling such operations to be conducted with maximum safety.

Where ETOPS ends and LROPS starts

ETOPS criteria control the design, maintenance and operation of twin-engine aircraft so that diversions can be safely conducted when needed. Diversion airports must be safe in terms of equipment, navigation and communications, and weather.
There is a presumption that passengers and crew can be safely evacuated from the aircraft after landing. ETOPS diversions are not necessarily emergencies. The concept is so well established that a captain may elect to conduct a precautionary diversion in order to resolve an uncertainty regarding the aircraft. However, flying in extreme areas might change a flight crew’s reaction to an in-flight problem. Conducting a precautionary diversion to a remote and operationally difficult airfield may actually pose a greater threat than continuing the flight. This may be particularly true of a medical emergency, for example.

The problem to resolve is how to designate the area of operation and how to change aircraft design in order to minimise the need for precautionary diversions if safe continuation of a flight is uncertain in the mind of the crew. Whereas ETOPS is based on the idea that diversion airfields are safe, LROPS will be based on the idea that diversions would not be needed at all.

The boundary between ETOPS and LROPS will therefore be a function of both the diversion time to an alternate airfield and the severity of events at airfields in increasingly adverse conditions. Another fundamental concept is that LROPS must apply to all aircraft, irrespective of the number of installed engines.

Thus, LROPS will apply to all flights with diversion times beyond 180 minutes and any flight over an area designated by airworthiness authorities as “extreme”. Updated ETOPS criteria (taking into account the lessons from past experience) will replace the current set of ETOPS exemptions and policies for twin-engine aircraft operating in all other areas, but such aircraft will be prohibited from operating in the extreme areas. However, an LROPS-certified twin-engine aircraft may be permitted to exceed 180 minutes in the event of an expected diversion airfield being closed, and subject to special permission.

The absolute limit of diversion time may be up to 240 minutes and actual diversion times cannot exceed the capacity of the most limiting system. This is typically the cargo fire extinguishing system.
Non-LROPS three- and four-engine aircraft will not be able to exceed planned diversion times of 180 minutes and will not be able to fly in the designated extreme areas.

Although in today’s operations there are only few flights that would qualify as LROPS, the authorities will have to examine the economic impact of retroactive application of the LROPS rules and transition clauses (Grandfather clauses) will probably be adopted.

**The regulatory package**

It is envisaged that LROPS, together with ETOPS, will be a part of the aircraft Type Certificate. The FAR/JAR 25 rules and guidance material will cover the airframe and FAR 33 and JAR E rules and guidance will embrace the engine.

So far as the operational approval is concerned, ETOPS and LROPS will be written into FAR 121 and JAR OPS1 material. ETOPS for corporate and fractional use is not applied, but these types of operation would need to be covered for LROPS in the FAR 135 and JAR OPS2 rules and guidance material.

Both the JAA and FAA LROPS proposed rules and guidelines are expected to be issued for public comment at the end of 2001. Implementation of JAA LROPS is targeted for the end of 2002. In order to facilitate limited polar operations in the meantime, the FAA published a Policy Letter in April 2001. In parallel to the JAA and FAA activity, an ICAO regulatory working group on LROPS started meeting in June 2001.

**The objectives for Airbus aircraft**

All A340 and A380 aircraft will be certified for LROPS, with retrofit solutions available for aircraft already delivered. Rolls-Royce have already agreed to certify the Trent engine for LROPS, although discussions are not yet under way with CFMI and the Engine Alliance. Today’s A340-200 and A340-300 aircraft are LROPS-ready without any modification. These aircraft are only limited by their cargo fire protection capability, for which the certified time is 4.5 hours. Engine reliability is already significantly better than the limit currently proposed by the FAA and JAA for twin-engine aircraft.

For the A340 two levels of LROPS will apply in the initial phase. A basic LROPS approval will allow operators to fully meet the LROPS rule from day one. However, the lead-time for the design and implementation of some LROPS items is longer than the timescale for the implementation of the rule. Once the full package is available then some remaining operational limitations will be removed.

The full design package for LROPS will be released once the new rules become effective. The goals will be to enhance safety, improve operational flexibility, apply a “no diversion” philosophy, and improve operating economics. Among the benefits for A340 and A380 operators will be unrestricted access to all LROPS routes without flight planning constraints, fuel penalties or specific training or procedures. Furthermore, full access will be given to routes over the Himalayas, Antarctica and other high terrain areas once these become available.

**The technical package**

An objective is to achieve levels of reliability and design so that diversions to the nearest airport followed by evacuations are no longer mandatory. A series of measures is under study to address the safety of both the aircraft and its occupants, as well as in-flight and on the ground after a landing. The key design principle will therefore be to have time margins allowing the crew to choose the safest airport rather than the closest. Enhanced indicating and procedures will help the crew decision.

One significant reason for unnecessary diversions is false cargo fire warning. An LROPS aircraft will therefore be equipped with long duration cargo fire extinguishing systems and supplementary fire detection measures in order to provide the crew with additional information before taking a decision to divert.

Another major reason for diversions is medical emergency.
LROPS therefore requires an expanded medical kit and a data-link with medical personnel on the ground. In this way, unnecessary diversions can be avoided and, crucially, so can incorrect decisions to land as soon as possible when it may be in the best interests of the patient to continue flight to an airfield where appropriate medical facilities are available.

Both of the foregoing reasons for diversion are not at all connected with the number of engines, thus underlining the need to develop a rule for long-range operations covering all aircraft.

Another part of the LROPs package concerns oxygen provision. Today’s regulations require descent to 10 000ft in the event of depressurisation (with some exceptions if supplemental oxygen is carried). An aircraft burns fuel at a much higher rate at this lower altitude than in the cruise. The effect is that the amount of fuel on board at the critical point of the mission needs to be sufficient to cater for the depressurisation case. This in turn limits the distance an aircraft can fly from a diversion airfield. For a twin-engine aircraft, the situation is somewhat more penalising, because of the regulatory need to consider the simultaneous failure of an engine with depressurisation. In this case, the twin is left with 50% of its installed power and the remaining engine must be operated at Maximum Continuous Thrust, further impeding fuel efficiency. Long diversion times are a huge disadvantage for a twin-engine aircraft.

Airbus is developing an On Board Oxygen Generation System (OBOGS) for LROPs, which will enable a depressurised aircraft to maintain a higher altitude than the current limit of 10 000ft. The effect will be that fuel reserves can be significantly reduced for LROPs aircraft, as they will never be required to descend to uneconomic flight levels following depressurisation. If fuel reserves are reduced, then the zone of operation can be widened, opening up safe operation of multi-engine aircraft in extreme areas.

Among the other measures being developed for the LROPs package are changes to pressurisation and air bleed systems, long-range communications, crew rest areas, hydraulics, and brake and anti-skid systems.

The economics of LROPs

Eliminating unnecessary diversions will save operators considerable sums. Diversions are known to cost anything from $1m to $3m depending upon the location of the diversion airfield and the practical problems of rescuing both the aircraft and occupants.

The provision of LROPs will enable the provision of air services on routes that would otherwise remain excluded. Linking cities by over-flying extreme areas will eliminate costly non-direct routings that are flown today. More direct routings will eventually be possible over areas of high terrain, such as the Himalayas, thanks to LROPs.

Full LROPs will permit operation in extreme areas without any need for an increase in fuel reserves.

LROPs offers a considerable regulatory and economic advantage to quads over twins on long routes that take an aircraft further than 180 minutes from a diversion airfield and on routes in extreme areas. Twin-engine aircraft face limitations resulting in severe economic penalties which available technology cannot remove.

Further information

If you would like further information on LROPs, please contact André Quet (andre.quet@airbus.fr) who updates a comprehensive CD-ROM on the subject four times a year.

A video cassette or DVD entitled Polar Landing is available from Paul Clark (paul.clark@airbus.fr) or André Quet. This film describes a scenario of landing a large commercial transport at Longyearbyen airfield in Spitzbergen. (If you would like a video cassette as opposed to DVD, please specify format.)

The JAA LROPs Working Group website has a public section: http://europe-aviationrulesmaking.org

Grandfather clauses

It is clear that the imposition of LROPs on airlines already operating over these extreme areas will have some impact. Some may apply for exemption to these stringent safety rules. If such exemption is given it would no doubt be for a temporary period. The precise formula has yet to be agreed.

Conclusion

The great thing about LROPs is that it combines the best of two worlds. We can draw upon the tremendously impressive reliability of engines thanks to ETOPS practices, and combine that with the enhanced systems redundancy of the four-engine aircraft.

Now we must all act to create a regulatory framework so that operators can serve markets by over-flying extreme areas of the world with the highest levels of safety.
Maturity is the sum of reliability, maintainability, operability and user satisfaction.

In this era of intense competition, and congested skies and airports, one delay of an aircraft’s departure, for whatever reason, can have a serious knock-on effect in an airline's operating schedule. It creates a serious irritation factor for the passengers and the airport authorities and sometimes has significant financial consequences for the airline. It is therefore beholden on the manufacturers of the aircraft, its engines and systems to try to make them as reliable as possible, so as to reduce their share of the causes of delays.

With the launch of the A340-500/600 programme, Airbus decided simultaneously to launch a Maturity Programme in association with Rolls Royce for the engines, and many of its component suppliers. This programme is even more rigorous than those conducted on previous Airbus aircraft, but is a natural evolution of the Maintainability and Reliability programme, which started in the early 1970s on the A300, where practical experience is fed into the design.
THE PROGRAMME

Objectives

Deliver a mature product that meets all customer expectations at its entry into service (EIS). The principal objective is to have 98.5\% Operational Reliability* of the aircraft at entry into service, and 99\% after one year of operation. This means that the aircraft has to be mature from its initial EIS, in terms of its reliability, how easy it is to maintain and operate, and its acceptance by its users. This will be achieved by involving the designers and engineers from Airbus, its contractors and suppliers, and from the airlines, from very early in the project. Not only will the aircraft be mature at entry into service but also the documentation, training and the tools. The aim is to satisfy all users.

*Operational reliability measures the percentage of scheduled flights that depart and arrive without incurring a technical interruption of the flight.

Scope

The maturity programme coordinates activities covering:
- The suppliers of the components, including design, production and support of their equipment,
- The design of the structure and systems,
- The integration of the systems,
- Flight test and product support.
The whole product is covered but twelve subjects have been chosen for particular attention. They are:
- Flight controls
- Hydraulic systems
- Fuel system
- Landing gear
- Bleed air
- Powerplant
- BIT and on-board maintenance system
- Electrical generation
- Structure
- Cabin (especially pax services)
- Lower deck facilities
- Cargo
Some 45 suppliers are also deeply involved in the maturity programme.

Highlights

Targets have been set, imposing very high levels of reliability for the equipment and the systems. They were set first at aircraft level then cascaded down through the systems to the component level. Suppliers are committed to meeting these targets.

Particular focus has been placed on reliability testing of systems and equipment, which include a combination of endurance and environment tests to accelerate ageing, followed in some cases by in-service evaluation.

Since passenger comfort is very important, specific exercises are being undertaken to ensure the maturity of the cabin items at entry into service. The third aircraft will have a full cabin interior. During the flight test programme, before real passengers are allowed into the aircraft, simulated passengers will generate heat and use the systems. This will be followed by 100 flight hours of routine long-range flights with full loads of Airbus employees, then 250 flight hours with different airlines, with their employees and guests on their routes.

Maintenance is always important, but it becomes even more so during the introduction phase of a new aircraft. This period when everyone is learning is much less stressful when the aircraft components and systems actually are the same and in the same place as described in the Technical Documentation and as described during the training courses. Therefore verification exercises will be conducted to ensure that the theory matches the reality.

Tasks

- Influence design using all lessons learned from past programmes.
- Enhance the quality and readiness of support services at EIS of the aircraft.
- Improve development tools and methods to achieve and demonstrate maturity at EIS.
Development process

Three features, continuing throughout the development process, have been designed to bring early maturity:

- Teamwork with suppliers, in which mixed teams define, and follow up, everything from component specification to final testing and quality of support.
- Concurrent engineering in the design offices. Multidiscipline teams were created to integrate performance, safety, reliability, maintainability, industrial and support requirements into the design. One of the most significant benefits of this method is the speed at which required changes can be incorporated in the design.
- Validation and verification (V&V) plans were developed for systems and equipment.

Validation = Are we building the right product?
Verification = Are we building the product right?

The questions were asked at the level of the component, the system and at aircraft level. V&V covers such items as endurance, environmental condition, tolerance to partial failure, maintainability and technical documentation, following a detailed checklist. Traceability was established between the design requirements and means of Validation & Verification.

Design tools

Probably the most significant step forward in aircraft development in recent years has come with the introduction of Computer Aided Design and Computer Aided Manufacture (CAD CAM). Each night the latest versions of the drawings are electronically transmitted to all Airbus and major Supplier design offices, which means, for example, that a designer of the hydraulic system installation always has the latest versions of the design of the structure to which to attach his hydraulic pipes and components. This is a major step forward from the days of paper drawings being sent to design offices in different countries and has led to a more mature design much earlier in the aircraft’s life than on previous aircraft.

CAD also gives the designer the ability to confirm accessibility of components very early in the design phase. CAD also leads to easier and better configuration management. Each agreed design is stored so that subsequent modifications to the design can be accurately matched to the correct configuration of the aircraft.

The computerisation of design has also led to much easier and more accurate programming of software for machine tools, giving better quality of manufacture earlier in the programme. Previously a design had to be interpreted by the writer of the software then written in a language that the machine could understand. Now the design computers and the machine tool computers can speak to each other in the same language, leading to much less rework.

Component testing

New laboratory testing methods have been defined, mainly for computers.

Highly accelerated life tests (HALT), combine thermal, vibration and operational effects to determine the operational and failure limits of the computers beyond their normal functional envelope. For example: Once a computer has been satisfactorily tested to its normal functional envelope testing will continue with increased stresses such as increased temperature, until the computer starts to misbehave, to the extent that if now shut down and allowed to cool, it will restart and operate normally. This is the operational limit. Once the operational limit has been defined testing continues until the computer fails completely – the failure limit.
Highly accelerated stress screening (HASS), is similar to HALT and is based on HALT results but is run systematically in production on each computer to eliminate premature failures. Each computer will be tested beyond its functional limit without reducing its operational life. These individual tests will move to random tests when Airbus and/or the Supplier is satisfied that normal production computers systematically meet their required reliability level.

These two types of tests are used to ensure that new computers enter service with the required level of reliability. A similar approach is being used for certain electrical and hydro-mechanical components which previous experience has shown a need for more rigorous testing and control.

Some thirty components, in addition to the Powerplant components, have been subjected to testing beyond the Specification requirement.

System integration testing

The first stage of the testing now takes place on the designers’ computer screens. With the 3-dimensional capability of the design program, designers can now solve most installation issues on the screen. However, in addition, Airbus and its suppliers have made heavy investments in new test rigs and facilities. Rigs have been built for:

- Cabin system avionics
- Bleed air system
- Flying controls*
- Water/waste
- Cargo loading
- Landing gear

*The flying control rig is an addition to the Iron Bird, which was described in an article in FAST 24.

These rigs are fitted with real hardware in realistic installations with powerful environ-ment simulation where necessary.

Whole systems can be modelled and their operation simulated on the screen. Whole sequences can be tested and proved and as the real hardware arrives it can be connect-ed to the model and its operation verified.

Three examples follow of where all this effort is being applied:

Bleed air system

A thermal analysis of the valves was conducted and correlated with data recorded on the flight test aircraft.

- New motors for the valves have been tested under very demanding conditions since 1998.
- New valves with integrated motors are much simpler. They have been on test since 1999 and flying satisfactorily since July 2000. These valves are less susceptible to wear, blockage and contamination. Simpler regulation also makes trouble-shooting easier.
- The number of sense lines has been halved, significantly reducing the possibility of leaks. Combined with a new leak localisation system, which directs the mechanic to the closest access panel will also reduce trouble-shooting time.
- Specific attention has been paid to electric harness and connector design to reduce intermittent failures.

The combined effects of these efforts, plus an integration test rig for a complete wing, with real equipment, airflows and tempera-
tures, and accelerated life tests combining thermal shocks, vibration and running the equivalent of 50,000 hours for valves, sensors and computers, demonstrates the maturity of the system before entry into service of the aircraft.

The mean time between unscheduled removals (MTBUR) will be doubled for valves and temperature sensors.

**Flight control servo**

The in-service experience described in the following table shows what needed to be done and what was done.

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**In service experience**

<table>
<thead>
<tr>
<th>Design solution</th>
<th>New testing</th>
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<tbody>
<tr>
<td>Cracks in Servo Control body</td>
<td><img src="image" alt="Servo valve logic preventing pressure peaks" /></td>
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<tr>
<td></td>
<td>Precise assessment of loads and cycle numbers</td>
</tr>
<tr>
<td>Breakage of actuator rod end</td>
<td><img src="image" alt="New roller bearing selected after comparative test of 12 solutions" /></td>
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<tr>
<td></td>
<td>Corrosion tests of attachment assembly</td>
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<tr>
<td>Water ingress and internal condensation in equipment</td>
<td><img src="image" alt="All solutions selected have been successfully proven in-service" /></td>
</tr>
<tr>
<td></td>
<td><img src="image" alt="Operating test with ice build up" /></td>
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</tbody>
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**Landing Gear**

A full-scale test rig has been built using the four actual landing gear legs and doors, with the associated hydraulic system components, pipes and computers. The rig is being used to test the system for correct operation during 6000 extension and retraction cycles. 1000 cycles were completed before first flight. Brakes from two suppliers, nose wheel steering, tyre pressure and brake temperature monitoring are also being tested on the same rig.

**Maintainability**

During the design phase many potential issues were discovered and solved before any parts were produced. On previous aircraft, accessibility was generally proven, or inaccessibility discovered, on full-scale wooden mock-ups, which were made from the manufacturing drawings. Therefore any changes needed, resulted in modifications to the early aircraft. CAD has avoided most if not all modifications to the early aircraft for maintenance task reasons.

Any maintenance tasks coming from the A340-300 that have been changed for the A340-500/-600 will be verified before EIS. Aircraft Maintenance Manual (AMM) tasks, with associated tools, will be used, and verified, by the mechanics on the Airbus flight line to maintain the flight test aircraft and the early delivery aircraft.

Because of the importance and quantity of information, generated by the onboard computers, recorded, and read by flight and maintenance crews, it is absolutely essential that the information is correct. This information is known as BITE, from Built In Test Equipment. BITE will be systematically verified on all four flight test aircraft, with analysis of each Post Flight Report and check of all BITE functions on each onboard computer. The BITE tests have been developed and validated in parallel with the development of the software for the components, and given the same priority. The verification process is in stages:

- At the computer level by the Vendor. This activity is audited by Airbus.
At system level to ensure that the computer interfaces correctly with its neighbours and systems.

At aircraft level with the production equipment operating in its proper environment.

A dedicated BITE verification team will be located in the Flight Test department.

Operability

Flight operations

Three principal documents are being prepared, the MMEL (Master Minimum Equipment List), FCOM (Flight Crew Operating Manual), CDL (Configuration Deviation List). As with Maintainability, items that differ from the A340-300 will be verified during the flight test phase. Following analysis they will be presented to the airlines and Airworthiness Authorities, with the justification for their inclusion in the relevant document. The aim is to have complete and checked documents available for the route proving flights.

Ground handling

Operation of water and waste servicing, refuelling and cargo loading systems will have particular attention to ensure trouble free EIS. This exercise will form part of the maintainability and technical publications verification tasks. The aircraft will be made available at three airports to verify all the ground handling tasks.

Conclusion

As aircraft get bigger the cost of malfunctions become more onerous. The airframe and engine manufacturers and their suppliers are therefore making greater efforts than ever before to make their products as mature as possible at entry into service. Even greater attention has been paid to the experience gained from previous versions of the equipment. Test programmes have been greatly enhanced to ensure that systems and equipment demonstrate the required levels of reliability from the beginning of their commercial operation.

Similar efforts have gone into ensuring that maintenance tasks, trouble-shooting and training procedures are also mature.

Many additional activities have been added to the flight test programme to validate all the preceding efforts. However the manufacturers can only go so far. Airline training is also a major element in aircraft performance. Airbus is working closely with all its customers to ensure training is best adapted to their needs, so that the aircraft can operate as the reliable money making tool that they purchased.
A380 Maintenance Status Report

by the Design Maintenance team of
Airbus Large Aircraft Division

Dick CUTLER
Director Maintenance

Mike LE VOIR
Manager Maintenance Costs

Norbert SEEHAFER
Manager Structure/Maintainability

Christian SIAMES
Manager Avionics

Richard WILBY
Manager Systems/Reliability

It may be obvious but as aircraft get larger and the range gets longer, the greater the challenge to meet the marketing requirements for operating economics. Performance measures take on a new meaning for Very Large Aircraft and this, coupled with the increasing demands from customers for high aircraft availability at the minimum cost, places maintenance high on the list of A380 design priorities.

This article explains how Airbus is meeting the challenge through the development of the processes to ensure that the A380 meets the customer’s expectations.
### Maintenance in the Design Process

**Background**

The A380 is truly a 21st century aircraft which will complete the Airbus family (see figure 1). It falls into the category of the Very Large Aircraft (VLA) meaning “Any classical aircraft significantly above 500 passengers and/or 400 tonnes.” The launch version of A380 will have a maximum take-off weight (MTOW) of around 560 tonnes and carry 553 passengers in a typical three-class cabin layout. A freighter version has also been launched. The basic design is such that the family can be easily extended to a higher capacity, longer range and also for short haul, high-density operations.

To achieve the necessary step forward in operating economics, advanced technology is required and the opportunity must therefore be taken to ensure that this same technology works for maintenance.

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Seats</th>
<th>Range (nm)</th>
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<tbody>
<tr>
<td>A318</td>
<td>107</td>
<td>3250</td>
</tr>
<tr>
<td>A319</td>
<td>124</td>
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<td>185</td>
<td>3000</td>
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<td>4150</td>
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<tr>
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<td>550</td>
<td>8000</td>
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</tbody>
</table>

There are other constraints relevant to VLA concerning environment and airport compatibility. For example the dimensions of the aircraft (see figure 2) have to be tailored to suit the airport requirements requiring span and length to fit into an 80-meter box and the height of the fin must satisfy airport obstacle clearance recommendations.

During the project’s feasibility phase it was clear that owing to the large airline investment in operating a fleet of VLA the availability of the aircraft, in terms of operational reliability, maintenance down time, and the cost of maintenance, would be factors crucial to the success of the aircraft and therefore had to be considered at the same level as the more traditional design objectives.

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**Figure 1**
A380... A family within a family

**Figure 2**
In accordance with existing airport infrastructures and master plans, the A380 is designed to fit within a box 80m square and 80ft high

- **Height:** 24.1 m (79ft 1in)
- **Span:** 79.8 m (261ft 10in)
- **Length:** 73 m (239ft 6in)
To put this into effect, in 1994 Customer Services maintenance specialists were invited to participate in the early design team meetings. At this time the basic Reliability and Maintainability philosophy was outlined and the relevant service experience issues were first identified. In September 1996 the Large Aircraft Division incorporated the maintenance function into design engineering with a direct reporting line to the Chief Engineer.

The feasibility and concept design phases saw the establishment of the aircraft’s top level requirements (see figure 31) including the design targets for maintenance which have now been cascaded down to detailed requirements to enable their practical use by the design teams. These requirements have been established together with Airbus Customer Services and Marketing, and further elaborated with airline inputs largely coming through workshops and Customer Focus Group (CFG) meetings.

Advanced technology issues have been addressed together with the airlines and the way forward to the detailed definition and develop-ment phases is clear.

Working in close co-operation with the airlines will continue throughout the programme.

Maintenance Philosophy

Although the A380 is an advanced technology aircraft and will be the largest civil aircraft built, the maintenance philosophy is a pragmatic one where the emphasis is on the need to minimise new skills and processes and to utilise advanced technology as an opportunity for optimising reliability and maintainability.

The primary objective of maintenance is clearly to maintain the highest levels of airworthiness but this is not incompatible with the requirement to achieve very high aircraft availability at the minimum practical costs.

These demanding requirements have been more formally expressed in terms of design targets for operational reliability, maintenance down time and direct maintenance costs. Service readiness and product maturity complete the high level requirements.

The maintenance concept will be a combination of “on condition” maintenance focusing on traditional in-situ checks for structures and installations and systems condition monitoring facilitated by enhanced onboard maintenance and information systems.

Emphasis is placed on reducing line maintenance work by insisting on the ‘designed in’ ability to defer
actions through fault tolerant design with optimised redundancy.

The need for new skills has to be avoided as far as possible because the aircraft will be operated side by side with other aircraft using the same maintenance personnel.

**Maintenance as part of the design process**

As mentioned above, establishing a set of coherent and credible maintenance requirements is the first task. The process demands that each requirement is validated by design and verified by design reviews as the work progresses (see figure 4). The maintenance specialists work in close liaison with the design teams to ensure that the evaluation is concurrent and carried out in 'real time'. Outputs from the process can be used to provide useful inputs for Customer Services. Classical reliability and maintainability evaluation processes are used where a 'top-down' approach is used to apportion requirements to component level; the evaluation and analyses are then accomplished 'bottom-up' by building up confidence from component level up through the systems until the aircraft level is reached. The process is such that comparisons with targets can be made at each level.

The two engine manufacturers, Engine Alliance and Rolls Royce, have compatible methods, and the equipment suppliers will provide data to substantiate the maintenance activities as part of the overall process.

During the design process it is important to keep the designers fully aware of in-service experience so that any shortcomings can be designed out from the start. Comprehensive service experience files have been built up to identify past problems together with the known drivers for aircraft delays, low reliability and maintenance costs (see figure 5).
The service experience data has been compiled from Airbus Customer Services data. Probably the most important feature during the conceptual studies leading up to the launch of the A380 has been teamwork. "Maintenance Focal Points" representing the different engineering groups and the Large Aircraft Division have met at regular intervals for matters concerning overall co-ordination, and maintenance policy. Progress and specialist working groups have developed the processes and procedures for reliability, maintainability and maintenance costs. The specialist groups are now producing first comparisons against the targets. Maintenance has been fully involved in the design decision-making process through design reviews.

Potential customers have been involved with the process from the beginning through dedicated workshops and customer focus group meetings that will continue until entry into service.

Reliability

Top Level Aircraft Requirements (TLAR) for operational reliability have been established and apportioned down to the level of systems, sub-systems and components. This is an iterative process and follows the evolution of the design architecture. New innovative processes have been developed for a more rigorous evaluation of the design against the targets and because of the priority given to operational reliability two independent evaluation methods are being used in parallel.

The first method uses extensive availability models based on forecasting system malfunctions which lead to potential delays or cancellations, and rectification times. The objective being to ensure that the sum of those occurrences for which rectification exceeds the planned downtime (e.g., normal turn round time) meet the objectives.

The second method is based on the System Safety Assessment approach where probabilities are assigned to potential failure conditions likely to result in flight or ground interruptions. Calculations are made to demonstrate performance of design against the targets.

In both cases if targets are not met then the ‘drivers’ or bad performers are identified (see figure 6) with corresponding design action required to improve the reliability or to decrease the rectification time.
This again is an iterative process that matures as the design evolves.

Component reliability must be coherent with the maintainability and maintenance cost objectives and the policy is to place challenging targets on A380 equipment suppliers particularly for components that have under-performed in the past.

Systems and component reliability are obviously critical factors in the early achievement of aircraft maturity and maturity assurance is planned through the design ‘Verification and Validation’ process and the introduction of intensive accelerated reliability testing to ‘shake out the bugs’ early enough so they can be fixed before entry into service.

**Maintainability**

Maintainability is all about controlling maintenance expenditures arising from the inherent design characteristics. The A380 brings its own challenges, not the least being the size and weight of the components. They need particular attention to ensure that they can be handled and transported in a similar manner to today’s large aircraft components. Targets and requirements have been set accordingly and more extensive use of computer aided design in the form of space allocation models and digital mock-ups simulating life size mechanics are being effectively used to assist the design in coming up with the right maintainability solutions at an early stage (see figure 7). Hard mock-ups are used for specific issues to validate the simulation scenarios. The maintainability qualities, together with the tooling and maintenance practices will be subject to verification and airline demonstration before entry into service.

**Direct Maintenance Costs**

Maintenance Cost control methods are being applied to the A380 design. Cost targets have been established at aircraft level as a proportion of the cash operating costs judged to be appropriate for
A380 Design Features and Maintenance

Advanced materials for structure

Maintenance objectives have a major influence in establishing the Design Service Goal which is used in setting up the initial inspection threshold and repeat interval for structures items, and on the selection process for advanced materials (see figure 94).

Two examples of advanced material technology for fuselage shells are Glare® - a laminate incorporating...
alternating layers of aluminium and glass-fibre reinforced adhesive (see figure 10) - and laser beam welding of stringers to skin.

Glare® offers a significant weight reduction over conventional metallic structure and has very good fatigue and damage resistance characteristics. Initially there was some airline concern over the possibility of debonding and repairability but these issues have been satisfactorily addressed through detailed review with designers and repair specialists, and a visit to Delft University’s Material Laboratory to examine the detailed testing for corrosion resistance, FOD, lightning strike and debonding. Extensive fatigue testing has demonstrated remarkably slow crack growth characteristics such that there is no need to inspect for fatigue damage throughout the service life of the A380. Corrosion resistance has been shown to be superior to conventional aluminium sheet because if the outer layer corrodes the glass-fibre layer prevents further penetration of the corrosion.

Repair scenarios have been demonstrated showing that the material can be repaired using conventional means with no special skills or tools required. A Glare® panel has been installed on the fuselage of a German Air Force A310 which has been in-service since October 1999 serving as an in-service demonstrator (see figure 11).
The second example, Laser Beam Welding (LBW) has an obvious use in the production of the lower fuselage shell (see figure 12), due to the welding speed. A potential advantage for maintenance is that eliminating fasteners eliminates a source of corrosion and fatigue cracks. Repairs are also conventional just like riveted metallic structures. The A380 will not however be a first for LBW, as it will be installed on the A318. Again, laser beam welded structures have been tested for damage, fatigue tolerance, and corrosion, and proved as good as or superior to conventional construction.

Composites technology will be extended to include the centre wing box and, like the A340-600, the rear pressure bulkhead.

The new materials and other aspects of structural design have been presented and discussed with airline specialists through several workshops and Customer Focus Groups. The level of airline participation in such design reviews will continue throughout the development phase.

**Systems**

Variable frequency generators will be used for electrical power, which is attractive for maintenance because it eliminates the complexity of high speed rotating machinery for the constant speed drive part of integrated drive generators (IDG). There are some small additional complexities for some components such as fans that need constant frequency, but overall, significant benefits are forecast for operational reliability and maintenance costs.

The traditional Airbus three hydraulic system architecture will be replaced by two hydraulic systems and two electrical systems for flight controls. Advantages for maintenance can be seen in improved system redundancy, for example aircraft dispatch with one pump inoperative and ground testing from either hydraulic or electrical sources (see figure 13). The 5000 psi hydraulic system is new for civil aircraft although there is considerable military experience and Concorde employs 4000 psi so it is not such a big step. Reduction in component size, connections and piping should improve maintainability and the new sealing technology will provide an opportunity to reduce hydraulic leaks.

Qualification testing with existing hydraulic fluids and components has demonstrated that under the higher pressures the fluid does not degrade and there has been no evidence of erosion. Employing four systems (two hydraulic/two electrical) will show a small increase in maintenance costs and delay rate for flight controls compared to the traditional systems but this is more than compensated for by reducing the number of hydraulic systems.

Advances in digital computer technology will lead the way to more system integration reducing
Conclusion

The A380 Programme is now well into the definition and development phase, which is geared to entry into service in March 2006. The design project teams have now been replaced by aircraft component management teams cascading down to the design and build teams. The teams are multi-disciplinary with maintenance activities represented at the appropriate levels. The maintenance engineering work is becoming more intense and will continue as such until entry into service. Ground support equipment and tooling for both on and off aircraft work needs to be defined early to support the maintainability studies. Maintenance programme development with the airlines will commence in 2005. The very high priority attached to the maintenance in design is recognised as being one of the most important roles in ensuring that the A380 meets the expectations of our customers.
The A319-100 Corporate Jetliner (CJ) is derived from the standard A319-100, including in its configuration specification a variety of items which are optional extras on the standard aircraft. Many of the systems on board are identical to those on the standard aircraft. The fuel system is something of an exception having evolved to cater for a range increase from less than 4,000 to better than 6,000 nautical miles. To achieve this the fuel capacity is increased by two thirds again compared to the standard A319.

A319 Corporate Jetliner
Fuel System

By Alex Seaman
Senior Engineer
Hydro-mechanical systems
Airbus
Additional Centre Tanks (ACT)

The CJ (Corporate Jetliner) retains the two-cell wing tanks and the centre tank of the standard aircraft.

In addition, it has six "ACTs" (additional centre tanks), numbered from 1 to 6 in order of installation (see figure 1). The ACTs are installed in the forward and aft cargo compartments with 2 in the forward compartment and 4 in the aft compartment. The ACTs are of the same size as standard cargo containers, modified to suit their particular locations within the cargo compartments.

Fuel capacity

A great advantage of the CJ is the flexibility offered to customers in terms of fuel capacity against cargo capacity (see figure 2). Any number of ACTs can be fitted, up to the full set of six tanks, allowing the fuel capacity to be tailored to the mission. To remove or re-install a full set of 6 ACTs takes only 24 hours (or less with practice). This task does not require removal of the cargo bay doors, unlike some other aircraft.

Vent system

On the standard aircraft each wing tank vents to a surge tank near its tip and the centre tank is connected via a vent pipe to the left wing surge tank (see figure 3-4).
Unlike the other ACT systems the CJ has a single vent valve to close the vent line, before it joins the centre tank vent pipe, instead of a valve within each ACT.

There is also a valve within ACT 4 to close the vent line to the forward ACTs in the event of damage to their vent line (from rotor burst for example).

There is a centre tank external ventilating system on all single aisle aircraft with centre tanks. This system continuously bleeds pressure cabin air across the bottom of the centre tank. The air flows back between the bottom of the tank and the vapour seal membrane (which seals the bottom of the centre tank from the air conditioning compartment) to a drain system near the aft edge of the membrane. The air then flows along the drain line, via a leak monitor to a drain mast and overboard.

All A319 and A320 aircraft have two-cell wing tanks and the CJ is no exception. Each wing is arranged with an inner cell from root to rib 15, an outer cell from rib 15 to 22 and motorized ball valves at rib 15 which open to allow the fuel to transfer by gravity from outer to inner when the inner cell is depleted.

Fuel is used to cool the integrated drive generators (IDG) on each engine. Some of this fuel can be recirculated from each engine to its wing tank. This feature is found on the CJ as on standard aircraft.

**Fuel feed**

The main fuel pumps on the CJ are common to A319 and A320. There are two pumps in each wing tank inner cell (see figure 4c) feeding fuel to their respective engine and two pumps in the centre tank, one of which normally feeds each engine.

All six pumps are identical but a valve associated with each wing tank pump ensures that fuel is fed in sequence, emptying first the centre tank and then the wing tanks. On the CJ the centre tank pumps feed the engines for most of the flight.

The APU fuel pump system on the CJ is the same as that on the standard aircraft. Fuel for the APU is tapped from the left hand engine feed pipe, within the centre section. The APU feed pipe running aft from the APU pump in the centre section to the APU is separate from the lines to the ACTs in the aft cargo compartment.

All single aisle aircraft have a single crossfeed valve in the centre section. This valve is normally closed to separate the left and right engine feed systems. The valve can be opened to allow an engine to be fed from the opposite wing tank and also for defuel of the aircraft.

There is a low pressure fuel valve in each engine feed line and the APU feed line. When closed this valve isolates its engine or APU from its fuel supply. This feature is common across all single aisle aircraft.

**Refuel and defuel system**

The refuel/defuel system is used for routine refuelling of the aircraft and can also be used if it is necessary to defuel the aircraft. The standard coupling for pressure refuelling is under the leading edge of the right wing (see figure 57). As an option a second coupling can be installed on the left wing on CJ as on other single aisle aircraft.
Using either coupling it is normal practice to refuel the aircraft by refuelling all necessary tanks in parallel under automatic or manual control as on all single aisle aircraft.

The standard refuel / defuel control panel is in the right hand belly fairing (see figures 5 & 6). The CJ refuel/defuel control panel includes a large separate panel for the extra ACT switches and high level lights. This panel fits only in the belly fairing location so the options to relocate the panel to the wings, which are available on the rest of the single aisle aircraft, are not available on CJ.

Automatic refuel involves control logic in the FQIC. On CJ, as on other aircraft with ACTs, the control logic needs to take account of the extra fuel volume available so the standard A319/A320 FQIC is replaced by a unit developed to handle the extra capacity. To control the refuel of the CJ ACTs there is additional logic in the Auxiliary Fuel Management Computer (AFMC). This computer is unique to the CJ and ensures that automatic refuel targets the ACTs in the correct sequence, with fuel going into ACT 6 only if there is insufficient space in ACT 5, into ACT 5 if there is insufficient space in ACT 4 and so on as far as ACT 1 which is refuelled only if there is insufficient space in the centre tank. Automatic refuel targetting for the wings and centre tank remains under the control of the FQIC.

Defuel is carried out using the engine feed pumps and the ACT transfer pump. The engine feed pumps pressurize the engine feed lines and with the cross feed valve open, both engine's feed lines supply fuel, via the defuel / transfer valve to the refuel gallery. From the refuel gallery the fuel leaves the aircraft via the refuel coupling, or is transferred to another tank via that tank's refuel valve. The ACT transfer pump is used to transfer fuel by suction to the centre tank from the ACT selected (using the ACT rotary selector in the cockpit). Unlike other ACT systems the CJ ACT transfer pump is used on the ground only.

The ACT transfer system is unique to the CJ. Double-walled
pipes permanently installed in the aircraft connect the refuel gallery to the ACTs via a refuel valve in the centre tank and return the fuel from the ACTs to the centre tank via a transfer valve. A much smaller set of pipes bleed cabin air through a series of valves into the forward and aft ACT groups to provide the pressure needed for transfer to take place. Auto transfer is controlled by the single Auxiliary Fuel Management Computer (AFMC) operating together with an Auxiliary Level Sense Control Unit (ALSCU) via a network of relays. The AFMC ensures that the ACT fuel is transferred to the centre tank in sequence starting with the highest numbered ACT and finishing with the fuel from ACT 1. This simple sequence serves to balance the aircraft during transfer and ensures that the centre of gravity of the aircraft remains within limits.

**Figure 6:** Refuel/defuel control panel

**Cockpit controls**

Manual transfer is controlled by the crew via the additional cockpit overhead fuel panel (see figure 7) if necessary. Unlike other ACT systems, manual transfer in flight on CJ relies solely on air pressure.

The CJ fuel quantity indication (FQI) system differs from that fitted on other single aisle aircraft. On all aircraft the FQI system calculates the quantity of fuel in each individual tank and on the aircraft in total. This calculation is performed by the single Fuel Quantity Indicating Computer (FQIC) for the wings, centre tank and ACT(s) (if fitted) on all aircraft except CJ. On CJ the FQIC calculates the quantities in the wings and centre tank only. The ACT quantities are calculated by the dedicated AFMC.

The FQI system includes
capacitance probes in each tank to measure the quantity of fuel in that tank plus other sensors to measure fuel properties. The FQIC receives fuel data from the wings and centre tank. It uses this to calculate quantities and other information for output to the AFMC and also for control of automatic refuel of the wings and centre tank. The AFMC receives fuel data from the ACTs plus the information output from the FQIC. It uses the data to calculate ACT and total aircraft quantities for output to ECAM and other receivers and also for control of automatic refuel of the ACTs.

The FQIC receives data from temperature probes in each wing tank cell. The temperatures calculated are transmitted to ECAM for display. On CJ (only) this transmission is via the AFMC.

All single aisle aircraft have magnetic level indicators in their wings and centre tanks. These provide a secondary means to calculate the fuel quantity manually. These devices are not installed in conventional ACTs, nor in the ACTs in the CJ.

There is a tank level sensing system to monitor the presence or absence of fuel at various levels within the tanks and perform a variety of control functions. This system includes a high level sensor in each tank, including the ACTs, to sense tank contents at high level and end refuel of that tank. The system also has low level sensors of which the use is control of engine feed from the centre tank plus control and monitoring of transfer of fuel from the ACTs.

The level sensors associated with the ACTs in the CJ are supported by a single Auxiliary Level Sense Control Unit (ALSCU). This unit performs a comparison of low level sensor wet states to monitor whether ACT transfer is progressing in the correct sequence and if not to trigger a cockpit warning. The involvement of level sensors in monitoring transfer is unique to CJ. On conventional ACT systems the level sensors are used for control and indicated quantity is used for monitoring. The ALSCU also contains the logic associated with the detection of damage to the forward ACT vent and refuel/transfer lines and their subsequent isolation.

**Conclusion**

On the A319 CJ, the manner in which the ACTs can be easily installed and removed gives the operator a greater degree of operational flexibility than has ever been known in the past. Because of this flexibility, the A319 CJ is the only Corporate Jetliner that can be converted for normal airline passenger operation. This adds significantly to its residual value.
Fasteners hold all the parts of an aircraft together.

Depending on the size of the aircraft they may number between one and two million...

By Regis Delcamp
Airbus Fasteners Specialist
Types of fasteners

Fasteners are required to work in a great variety of conditions, such as different environments, loads to be carried or transferred, and types of materials to be attached. This leads to a requirement for many different types and sizes. The larger Airbus aircraft have bolts of greater than one inch in diameter. Airbus manages more than 500,000 fastener part numbers in its Spares Parts database.

Fasteners can be divided into two main families:
- **Permanent fasteners** are those which are destroyed if they have to be removed.
- **Removable fasteners** are those that can be removed without damage, and may be re-used under certain conditions.

**Permanent Fasteners**

**Solid Rivets**

Used mainly for attaching fuselage skin panels. Many different variants of material, head form and surface protection are used.

**Blind Rivets & Blind Bolts**

Used in areas where it is impossible to get access to one side of the assembly. They also have many different variants of material, head form and surface protection.

**Pins & lockbolts**

Hi-lok, hi-lite, swaged and bull-nose pins & lockbolts are used in various places. Some are clearly clearance fit, some are clearly interference fit whilst others may have a very small clearance or a minor interference: these we call transition fit. They also have many different variants of material, head form and surface protection. The principal benefit of this type of fastener is that they can be locked by a single person; there is no need for a second person to hold the head whilst the other tightens the nut. Pins are used in association with collars or nuts.

**Taper-lok pins**

Used in high strength areas, such as the wing/fuselage junction and main landing gear fitting to wing attachment. They are installed with interference fit and locked with nuts. They also have many different permutations of material, head form and surface protection.

Fasteners are chosen for the type of load they are required to carry: shear or tension. Their location, and these loads will determine the type of head required.

- Countersink 100°, shear, special shear & tension
- Countersink 130° (for composites only)
- Protruding shear & tension
- Hexagonal shear & tension
- 12 points shear & tension
- Castelled shear & tension
- Self align & self-seal

**Different materials are used**

- Monel
- Aluminum alloys (various)
- Titanium
- Titanium-Colombium
- Steel Alloy
- Corrosion Resistant Steel

And a variety of different surface finishes are used for protection

- Passivated
- Sulphuric Acid Anodized
- Hi-Kote
- Ion Vapor Deposit (I.V.D)
- Cadmium

Some fasteners may be installed with lubrication such as

- Cetyl Alcohol
- Dry Film
Permanent Fasteners (cont'd)

Collars & sleeves

Collars and sleeves are used in association with hi-lok, hi-lite, and swaged pins or lockbolts.

Collars are self-locking with a hexagonal part that breaks off at a uniform fixed pre-loaded value. The pin is held in position by a key in a hexagonal recess in its end.

Sleeves are swaged on to the threaded part of a lockbolt. The long tail of the lockbolt is used to pull the assembly tight, then the sleeve is swaged on to the body of the bolt. Finally the lockbolt breaks at the groove (see figure 1). The collars and sleeves also have many different variants of material and surface protection.

Removable Fasteners

Bolts

Bolts are always locked by nuts and are mostly installed with washers under the nuts. They have many different variants of material and surface protection. They also have many different forms of head. Some heads have recesses for different tools such as torq-set, Philips, tri-wing and hi-torq.

Screws (fully threaded)

Screws are fully threaded, are locked by nuts and are generally used to attach parts of secondary structure. They also have many different variants of material, head form and surface protection.

Nuts & anchor nuts

Nuts may be plain with no locking device, self locking or castellated, which are locked by a split-pin. Sometimes they are tightened to a specified torque. Anchor nuts are fixed in position and used when there is only access to the head of the screw. Some may be sealed to prevent leakage of liquids. They also have many different variants of material, and surface protection.
**Repair situation**

Repair of an aircraft almost inevitably results in fasteners being removed, installed, or reinstalled. Although this may appear to be a straightforward task, installation and reinstallation calls for considerable attention, particularly with fasteners, since the performance of the fastener may depend on the quality of the installation. The performance of the fastener, once installed, may be seriously affected by the way it is fitted particularly if the diameter of the hole is out of tolerance for the diameter of the fastener. In this case it is often necessary to enlarge the hole and to install oversize fasteners.

The fastener to be installed must be the one called for in the repair instruction. Either from the specific repair instruction or from the one defined in the SRM (Structural Repair Manual).

If the specified fastener is not available, substitution is possible, but a fastener providing the same level of performance must be obtained.

The fastener called up on the drawing, or repair instruction, will have an Airbus part number such as ASNA2026VBV5-17. This fastener has a 100° countersink (or flush) head for shear loads, and is made of titanium.

4. **ASNA 2026** is the specification, which defines the shape, material and loads to be carried.

5. **VBV** defines surface finish and lubrication. In this case ion vapour deposit.

6. **5** gives the diameter of the plain part of the fastener in 16ths of an inch.

7. **-17** gives the length of the plain part of the fastener in 16ths of an inch.

The airframe manufacturers draw up specifications for the hardware to ensure that quality standards are met, but Airbus doesn’t manufacture fasteners.

Companies that specialise in the manufacture of fasteners make them to meet the airframe manufacturers specifications. However, they give the fasteners their own part numbers. Hence the need for cross-reference tables giving approved interchangeable part numbers. (See Standards Manual Part 3 on next page).
Airbus provides helpful documentation for use during repairs such as: Structural Repair Manual (SRM) Chapter 51.

**Structural Repair Manual (SRM) chapter 51**

**Fasteners General**

This section provides a brief description of the fasteners followed by tables giving 'Fasteners Identification'. The fastener is identified by a 'Standard Number', without diameter and length codes, eg. NSA54760b(y)(-)(-). These lists are very useful for quickly identifying fasteners, with the associated technical information on: type of fastener, head form, material, protection and lubrication, diameter (ie. nominal, 1st or 2nd oversize).

The table also gives 'Data for Installation'. There you are guided to the table or paragraph numbers in the SRM to find the 'Hole Drill Data', 'Torque Value' and 'Installation & Removal data'.

**Call-up & Designation**

This section provides drawings of the fasteners in alphanumeric Standard Number order and designation (ie bolt, screw etc.).

**Fasteners Oversize**

A list of 'Original Designation' (Part Number without diameter and length) including the hardware manufacturer’s designation of the fastener which has been removed, and the part numbers of the First and Second Oversize fasteners to be installed in its place, if necessary. When a fastener hole is damaged and outside the tolerance for the nominal diameter of the original fastener, an oversize fastener must be installed. For other acceptable oversizes, use those listed in the 'Alternative' column in the 'Fasteners Alternative' topic.

**Fasteners Alternative**

It is a list of acceptable alternatives to the original fasteners used, or that may be called up in a repair. Note that the alternative fastener is acceptable to replace the original fastener, but the original must not be used to replace the alternative. This is called one-way interchangeability.

**Hole & Drill data**

This section gives an overview about the holes and drills applicable to the fasteners that may be necessary for the repair. The tables show the minimum and maximum diameters for the standard and oversize fasteners.

**Standard Torque Value**

When it is necessary to assemble a threaded fastener it is important that the fastener and nut be tightened to the correct torque value. Under or over tightening can cause the fastener to fail. The tables show the minimum and maximum torque values for the standard and oversize fasteners with associated nuts.

**Standards Manual (SM)**

The Standards Manual is effective for all Airbus models. It sets common standards for all the designers on the Airbus programmes, and contains, amongst other things, information about US, European, National and Airbus domestic standards for finished and semi-finished products.

Standard parts, which are not found in the Standards Manual, shall not be used on Airbus aircraft without prior approval of Airbus. The sections of the SM that will be of most use to persons doing a repair are mentioned on the next page.
**SM Part 2**

It has a collection of data sheets giving dimensions and technical data.

**SM Part 3**

It contains a list of all standard part numbers approved by Airbus for use on the Airbus programmes. Each ‘Standard Part Number’ is listed with a ‘Proprietary Part Number’, followed by a ‘CAGE = Commercial and Government Entity code’ (FSCM = Federal Supply Code for Manufacturers) code. These codes identify the suppliers of the proprietary parts. These suppliers have been qualified by Airbus.

**SM Supplement**

It is a Cross Reference List for Alternative Fasteners, providing part numbers of these fasteners. They may be used in lieu of those fasteners originally installed during manufacture or called up in the Airbus repair instruction. In this part the Standard Number (as provided in the SRM) has the diameter and length codes added to give the part number eg. NSA5476BV9-41.

The alternative part numbers are to be considered as one way interchangeable with the original fasteners. The SM Supplement provides the information to easily identify alternative part numbers to verify if alternatives are in stock or to help with ordering.

**Repair Engineering Support for Fastener availability**

Airbus does not stock standard hardware, as a variety of competing suppliers ensure access to a much larger stock at market prices than Airbus could provide. Some of the principal suppliers are in the following list.

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**Honeywell**

**Honeywell**

**HARDWARE**

**PRODUCT GROUP**

Phone: +49 40 538 07 60
Fax: +49 40 538 80 64
Site: HAMBKCR
Spec 2000 Site: LAXBKCR
Email: hpg.aogdesk@honeywell.com
Or one of their regional offices

**EUROFAST**

**EUROFAST**

**DEPARTMENT DGM**

Phone: +33 16 006 9650
Fax: +33 16 006 1275
Email: EUROFAST@aol.com
Internet: www.eurofast.fr

**SATAIR**

**SATAIR**

**S/A**

Phone: +45 3247 0100
Fax: +45 2513 434
Site: CPHSAX7
Spec 2000 Site: CPHSAX7
Email: pph@satair.com

**Fairchild**

**Fairchild**

**Fasteners Direct**

Phone: +49 825 187 570
Fax: +49 825 11 652
Site: ASCEBCR
Email: ascbecr@t-online.de

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**THE LAST MINUTE HELP**

If you have problems with fasteners and can't find the solution in the Airbus documentation, Airbus Customer Services can be contacted 24 hours a day at the number specified on page 38.

In addition, Airbus has very close cooperation with Honeywell Hardware Product Group (HPG) in order to provide fast technical support in the event of hardware availability problems. To this aim, Airbus has a permanent office to liaison directly with the repair and supply specialists.
In a nutshell...

COMING UP

Airbus Materiel Symposium 2001
Los Angeles, USA
4-6 September 2001

Around 500 invited customers and suppliers will attend the 2001 Airbus Materiel Symposium whose theme this year is “Sharing Materiel Values - People, Practices, Progress”. The symposium will promote communication and information exchange between the supplier and airline community and topics will include a common approach to measurement of lead and repair times. The agenda for the symposium consists of presentations and discussions, customer-supplier bilateral meetings, as well as Service Value Meeting follow-ups.

Airbus Materiel Symposia are traditionally held every 3-4 years. The last symposium took place in Kuala Lumpur in 1997. Preparation is already under way for this conference and includes input from our customers (operators and maintenance centres) and suppliers.

14th Airbus Human Factors Symposium
Dublin, Ireland
2-4 October 2001

The next HFS, Airbus' 14th, is now scheduled for the 2nd, 3rd and 4th of October 2001, in Dublin, Ireland in cooperation with IFALPA. It will be largely formatted after the 12th and 13th Symposia. The former was performed with the US ALPA last September in Aspen, Colorado. The main objective is to hear the active voice of pilot associations and have them participate as fully-fledged representatives of our users' community. Once more, wide opportunities for dialogue will be created, in an effort to ensure constant improvement.

Airbus Conference for Training on Entry-Into-Service (EIS) A340-600
Toulouse, France
16-17 October 2001

In preparation for the entry-into-service of the A340-600, Airbus Training is organising a conference to brief all customers well in advance about new training programmes, and provide information on a range of peripheral items. General subjects linked to this aircraft programme such as the Maturity Programme, the Flight Test results and the future of Distance Learning will be presented.

The key topics for flight crew, cabin crew and maintenance training will be covered by presentations about training policies, taxing. Future Air Navigation System (FANS), JAR 66 compliance, training media, crew rest facilities, etc.

RECENT EVENTS

A310/A300-600/A300 Airbus Technical Symposium
Munich, Germany
June 2001

The A300/A310 Technical Symposium was held in Munich. 262 participants attended this symposium from 43 Airlines, 18 vendors and various other organisations.

Presentations, questions and answers are available on CD-ROM (see address below).

11th Performance & Operations Symposium
Puerto Vallarta, Mexico
March 2001

The 11th Performance and Operations Conference organized by Airbus Flight Operations Support gathered 194 pilots and other flight operations people from 78 airlines plus 14 people from 7 vendors and 15 attendees from 10 other organizations (authorities, service providers...).
This type of conference has been organized every two years since 1980.

This year, 72 presentations including 4 presentations from Airbus operators and 2 from vendors were given during 7 different sessions.

Tuesday was devoted to Looking Ahead and Airbus Flight Safety initiatives. One day all the presentations dealt with Operations while a specific performance session dedicated to Performance programs was also organized. The following day 3 sessions ran in parallel for Fly-By-Wire, A300/A310/A300-600 and performance issues. Finally the last morning was dedicated to Less Paper Concept (LPC) issues. Every day demonstration stands for various software products (LPC, Performance Programs, LOMS, and New Electronic Instrument Systems) were constantly overcrowded by visitors.

All the participants were given a 600 page Conference book including detailed articles about all the subjects addressed during this event and a CD-Rom containing both the articles and the Powerpoint presentations.

116 questionnaires received at the end confirmed that this conference was definitely a success.

13th Airbus Human Factors Symposium
Toronto, Canada
June 2001

The 13th Human Factors Symposium (HFS) was held in Toronto, Canada in the presence of some 100 delegates mostly composed of Canadian aviation professionals including airlines, IATA, JCAO, airworthiness authorities, safety organisations as well as several aeronautical colleges and universities. The whole event was partly sponsored by a local airline, in this case SkyService, now also related to Air Canada. The key objective of these types of events is to give a thorough review of the practical Airbus approach and philosophy towards safety, design, operations and training.

The leading motto of this 13th HFS was proactive safety and what we really have in store to implement it. Panel discussions were also held after each session to involve delegates on specific themes for which solutions can be contemplated: indeed more and more new evaluation and creation tools are becoming available. To mention just a few highlights:

The Safety Panel...

• urged for more operationally-oriented accounts of typical events through amplified use of modern media,
• recommended to better link crew alertness to situational awareness and action taking,
• asked for an enhanced manufacturer’s role in concentrating in-service experience, provided airlines also take a major share in disseminating lessons learned.

The Cockpit Panel...

• realized the need to balance information levels, both in documentation and training to avoid overload,
• confirmed the benefit of making the design philosophy apparent to line pilots as well as their understanding of human factors issues in designs where human-machine interface (HMI) is involved,
• advanced the idea of a general information course on design and operating philosophy before starting specific transition training.

The Information Panel...

• confirmed the concept of three levels of information,
• promoted a dispatch-oriented approach to e-documentation,
• highlighted the urgent need for a common industry approach to less paper in the cockpit.

The Operational Panel...

• focused on the need to understand the reasons for standard operating procedures (SOPs) and the consequences for not abiding by them,
• confirmed that challenging our safety assumptions and principles is vital for any further progress,
• identified the need to take the operational context better into account and to associate line and management pilots in SOP development.
CUSTOMER SUPPORT

USA/CANADA

Gérard RAYNAUD, Senior Director Customer Support
Tel:+1 (703) 834 3506
Fax:+1 (703) 834 3484

CHINA

Emmanuel PERAUD, Director Customer Support
Tel:+86 10 6456 7720
Fax:+86 10 6456 76942 /3 /4

REST OF THE WORLD

Jean-Daniel LEROY, Vice President Customer Support
Tel:+33 (0) 5 61 93 35 04
Fax:+33 (0) 5 61 93 41 01

RESIDENT CUSTOMER SUPPORT ADMINISTRATION

Philippe BORDES, Director
Resident Customer Representation Administration
Tel:+33 (0) 5 61 93 31 02
Fax:+33 (0) 5 61 93 49 64

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Airbus operates 24 hours a day every day. AOG technical and spares calls in North America should be addressed to
Tel:+1 703 729 9000
Fax:+1 703 729 4373

AOG technical and spares calls outside North America should be addressed to
Tel: +49 40 50 76 3001/3002/3003
Fax: +49 40 50 76 3011/3012/3013

Airbus training centre Toulouse, France
Tel:+33 (0) 5 61 93 33 33
Fax:+33 (0) 5 61 93 46 65

Airbus training subsidiaries:
Miami, Florida
Tel: +1 305 871 36 55
Fax:+1 305 871 46 49

Beijing, China
Tel:+86 10 64 57 33 40
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Since the 1920s airlines have been aware of the fact that their aircraft may have to divert to airfields that may provide less comfort than the scheduled departure and arrival airfields.

Temperatures at these diversion airfields may descend to -60°C, so special passenger clothing for emergency evacuations is being developed.

It has been demonstrated that with adequate fur coats and thermal socks passengers have a better chance of reaching the emergency igloos alive!
The Airbus A340 can fly non-stop for up to eighteen hours. There’s no middle seat in our business class either. You see, we think passengers should be able to enjoy their in-flight movies. Without interruptions.