JULY 2003

Just happened… Coming soon… 2

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Technology platform for future development
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Lithium thickened grease
Higher performance General Purpose grease for Airbus aircraft
Céline Normand

From the archives…
Extended Range Operations – The Beginning

Customer Services
Around the clock… Around the world

FAST 32

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This issue of FAST has been printed on paper produced without using chlorine, to reduce waste and help conserve natural resources. Every little helps!
The 17th Human Factors Symposium gathered approximately 100 human factors and safety specialists from more than 20 Airbus operators. The symposium was organised in co-operation with Finnair, which is celebrating its 80th anniversary.

On-time delivery of spare parts requires integration and management of flexible supply chains between supplier activities and customers’ requirements. Physical distribution qualified communication and IT-based monitoring systems are key to harmonising all spares related processes.

Airbus Spares Support and Services presented the new Customised Spares Logistics (CSL) concept that transfers the transport responsibility from the customer to Airbus. Airbus Spares Support has a clear mandate to continue improving the Spares Logistics. Key points covered included increased transparency for pricing of standard options, retrofit modification offers, reduced lead-time for service bulletins and kits, and aircraft configuration tracking.

The increasing awareness that leasing companies play a full part in the Airbus customer community with their own specific requirements was a major benefit of the conference.

The programme included actual in-service issues covering structure, engine and systems for purely technical matters and general topic discussions on maintenance economics, reliability enhancement and others.

Awards for excellence in reliability were given to All Nippon Airways, Jet Blue and TAM.

The 12th Performance and Operations Conference was attended by 229 representatives from 92 airlines and 21 representatives from vendors, authorities and other organisations.

As part of our commitment to increase safety performance, Airbus plans to continue its constructive dialogue with all parties at this Rome conference. This gathering follows on from the first very successful conference held in Hong Kong.

The programme will cover the integrated Airbus safety plan with tailored solutions, the evolution of Flight Operation Monitoring (FOM) package and regulatory aspects.
A competitive new aircraft programme with a life span of 40 to 50 years requires the introduction of advanced and new materials – combined with new manufacturing technologies – which allow for further optimisation as the aircraft family evolves. Thus, the A380-800, the launch version of the A380 family, establishes a “technology platform” for future developments.

An “Initial Set of Structural Design Drivers” was established in early 1997, giving guidance for a preliminary selection of possible materials for different sub-components of the airframe. The materials choice results from a down-selection process, which reviewed material performance, manufacture of components and associated costs at the same time.

Results from manufacture and structural testing of full-scale demonstrators supported the decision-making process for selection of structural design concepts, materials and manufacturing technologies in order to ensure that only mature technologies and proven concepts were taken on board.

Design solutions and material applications envisaged were also reviewed with structure and maintenance experts from airlines to get approval with respect to inspections and repairs. Workshops with airlines are regarded as a key element of the “technology down-selection process”.

Advanced materials and technologies for A380 structure

Jérôme Pora
Deputy Director Structure
A380 Programme
In cases where the structure is prone to damage (e.g., foreign object damage), the design may require in addition damage-tolerant material characteristics. Corrosion prevention is another important criterion to be considered for the selection of materials & processes, especially in the bilge area of the fuselage, which may be exposed to aggressive agents coming from different sources. Part of the goal is to select the most appropriate material for the specific application, which would lead to the lightest possible structure. For this purpose, composite materials are good competitors, but an understanding of design drivers and maintenance requirements is needed.

In parallel, production cost investigations and purchasing activities are also necessary. Thus, material selection is not only driven by design criteria.

The distribution of materials for the A380 shows that aluminium makes up the largest proportion with 61% of airframe structure weight (Figure 3).

Performance improvement initiatives must first address this large proportion of airframe weight and search for improved materials. The specific direction in which to go is given by the “drivers for structural design”, e.g., high strength and/or damage tolerance, stability and corrosion resistance. So there was a strong demand for further improvements of primary aluminium structure on the A380, in particular on the wing, of which more than 80% of its structural weight is still composed of aluminium; size limitations were also challenged.

The major achievements in aluminium alloys for the A380-800 are listed below:

- The introduction of very wide sheet material on Fuselage panels has made possible the reduction of joints, and resulted in weight reduction.
- The application of aluminium-lithium extrusions on main deck cross beams due to the availability of a new generation of alloys made it possible for aluminium-lithium to compete with Carbon Fiber Reinforced Plastic (CFRP) on this type of application.
- The selection of the brand new 7085 alloy for wing spars and ribs, which surpasses conventional high strength alloys for very thick plates and very large forgings.
- Titanium alloys have been selected in numerous applications due to their high strength, low density, damage tolerance and corrosion resistance to replace steels. However the high price of these alloys is a limiting factor in some cases.

The unique challenges of the A380 raised the titanium applications from 5-7% in weight on previous Airbus aircraft to about 10%. Pylons and landing gears alone increased the titanium content by 2%.

- The primary structure of the A380 pylon is the first all-titanium design at Airbus. On A380, the commonly used Ti-Al-4V alloy will be implemented also in a beta-annealed condition to maximise fracture toughness and minimise crack growth rate.
- The A380 will also be the first Airbus using the new titanium alloy VST55531 developed through a cooperation programme with the Russian producer thus providing designers with an exceptional combination of fracture toughness and high strength. This alloy has been selected for the fitting between wing and pylons. Further applications are under study.
A380 COMPOSITE MATERIAL APPLICATIONS

The major composite material applications on structure are shown in Figure 4. For the A380, Airbus benefits from earlier programmes because it was the first manufacturer to make extensive use of composites on large transport commercial aircraft, the A310 was the first production aircraft to have a composite fin box; the A320 was the first aircraft to go into production with an all-composite tail; about 13% by weight of the wing on the A340 is composed of composite materials and the A340-600 has Carbon Fibre Reinforced Plastic (CFRP) keel beams.

The A380 will be the first large commercial aircraft with a CFRP composite centre wing box, representing a saving of up to one and a half tonnes compared to the most advanced aluminium alloys. On the A380 the centre wing box will weigh around 8.8 tonnes, of which 5.3 tonnes is composite material. The main challenges are the wing root joint and the component thickness. These composite components could be up to 45mm thick. For this specific application, Airbus has reapplied a large benefit from the A340-600 CFRP keel beams, 16 metres long and 23mm thick, each of which carries a force of 450 tonnes.

A monolithic CFRP design has also been adopted for the fin box and rudder, as well as the horizontal stabiliser and elevators as on A340-600. Here the main challenge is the size of the components. The area of the CFRP horizontal tail plane is close to that of the A310 cantilever wing. As for the centre wing box, the size of the components justifies the intensive use of Automated Tape Laying (ATL) technology. Furthermore, the upper deck floor beams and the rear pressure bulkhead will be made of CFRP. The first of these is produced with a Pultrusion process where continuous fibre reinforced plastic is pulled through a tool. For the second one, different technologies were tested such as Resin Film Infusion (RFI) and Automated Fibre Placement (AFP), due to the shape. RFI has been selected.

In the unpressurised parts of the rear fuselage AFP has been selected to produce panel skins, due to the double curvature of these panels. The highly loaded frames remain machined in high strength aluminium alloys, however Resin Transfer Moulding (RTM) is used to manufacture those that carry less load.

The A380 wing fixed leading edge (wing-f-1-nose) in thermoplastics aims at weight and cost savings. This technology has been developed for the A340-600, demonstrating weight saving, ease of manufacture, improved damage tolerance, and improved inspectability when compared to the A340 metallic component. Further applications of thermoplastics are under investigation, such as secondary bracketry in the fuselage.

The choice of CFRP for movable surfaces on the wing trailing edge is regarded to be state-of-the-art. The use of RTM is agreed for movable-surface hinges and ribs, when the shape of the components is difficult to obtain using conventional technologies.

Inner flaps and leading edge high-lift devices are exposed to foreign object damage and a standard metal design weighs no more than a composite design. For weight reduction, a hybrid design has been adopted on the A380 flap track beams in which CFRP replaces aluminium on lateral panels and secondary ribs.

The introduction of CFRP ribs has also been accepted on the cantilever wing box in replacement for aluminium alloys, for the first time at Airbus.

Finally, mid and outer flap, flap track fairing as well as spoilers and ailerons, follow the evolution of CFRP application at Airbus.

For sandwich structures, the main innovation is the introduction of light honeycomb to replace conventional aramid paper honeycomb. This is the case on large structures such as the belly fairing (more than 300 sq.m) and floor panels. The trend to apply a monolithic design to replace sandwich when possible is followed on the A380 on which body landing gear and wing landing gear doors have adopted the monolithic concept.

But composite materials and technologies must contribute to competitive aircraft performance at affordable costs. On the A380, advanced manufacturing technologies such as Automated Fibre Placement, Automated Tape Laying, Resin Film Infusion and Resin Transfer Moulding have contributed to cost reductions in composite manufacture. Finally, the size of A380 components generates the possibility to design very large composite parts, reducing the assembly costs and increasing the volume of materials to be produced, moving the A380 one step further in the development by Airbus of composite applications on airframes.

**GLARE TECHNOLOGY**

GLARE skins are implemented on the upper fuselage panels. GLARE is a hybrid material, built up from alternating layers of aluminium foils and unidirectional glass fibre fabrics impregnated with epoxy adhesive (Figure 5). The alternating layers are built up in a mould, which forms the single or double curved GLARE skin. The so-called “splicing concept” arranges two aluminium foils with a slight overlap forming a single aluminium layer. The splices are staggered with respect to each other, while the pre-fabricated adhesive layers are continuous (Figure 6).

Local reinforcements are achieved with additional layers in between the surface layers forming “integral doublers”. Thus, thickness variations are included in a “one-shot-curing” cycle. The completed GLARE lay-up, in its mould, is bagged and vacuum applied before curing in an autoclave at 120°C.

The manufacturing approach allows for increased fuselage panel width, compared to panels made from aluminium sheet material, thus reducing the number of longitudinal panel joints on the aircraft.

The motivation to review GLARE for fuselage panel application started in the field of fracture mechanics because of the outstanding resistance to crack growth. On the other hand, glass fibres have a lower elastic modulus compared to aluminium; depending on the fibre orientations, GLARE would be about 15% less stiff, for the same thickness, compared to standard alloy Al2024. This is why GLARE is not an appropriate candidate for structural parts to be designed for stability, e.g. buckling.
A large proportion of the A380 structure and components will be manufactured from the latest generation of Carbon Fibre Reinforced Plastic composites and advanced metallic materials, which, besides being lighter than traditional materials, offer significant advantages in terms of operational reliability, maintainability and ease of repair. The major innovations are:

- Fibre laminated skins (GLARE) implemented on the upper fuselage panels.
- Application of laser beam welding technology in combination with 6000-series aluminium alloys on lower fuselage panels.
- A centre wing box in Carbon Fibre Reinforced Plastic.
- Introduction of advanced aluminium alloys developed for the wing box addressing the identified design criteria.
- Introduction of aluminium-lithium alloys.
- Introduction of new titanium alloys, and increased proportion of titanium in lieu of Steels.

Last but not least, the A380 led to the increase of thickness, size and volume in general of aerospace materials, and the development of associated manufacturing facilities.
Following the entry into service of two A319s to complement its fleet of five A340-300s, Air Mauritius has become the 20th airline to benefit from Mixed Fleet Flying (MFF) between Airbus aircraft, underlining Airbus’ leadership in the domain of Flight Operational Commonality.

All Airbus aircraft after the A300 and A310 – from the 107-seat short- to medium-range A318 to the 550-seat long-range A380 – share Flight Operational Commonality, allowing operators to integrate further traditionally fragmented flight operations and training groups.

This is an account of the background and some of the achievements since the previous article on this topic in FAST magazine no. 17, issued in December 1994.
FLIGHT OPERATIONAL COMMONALITY
IMPORTANCE AND HISTORY

Flight crew related costs represent a significant portion of overall operating expense, which explains airline interest in any possible reduction. Flight Operational Commonality between aircraft helps to reduce the cost of training pilots, and increases pilot productivity through shorter training times and greater crew scheduling flexibility.

Initially, commonality credit was limited to Single Licence Endorsements (JAA – Joint Aviation Authorities – terminology) or Same and Common Type Ratings (FAA – Federal Aviation Administration – designations) awarded to crews flying aircraft of comparable configuration and mission capability, such as the A300/A310 or 757/767. Similar flight handling was key.

In 1983, Airbus decided to launch the A320 knowing that several years later it would be followed by the A330 and the A340. The concept of a true aircraft family with a very high level of commonality emerged at the same time and resulted in a strategic industrial choice having huge consequences on the aircraft design and operation.

OBJECTIVES AND CONSEQUENCES

This strategic industrial choice had three objectives:

• Raise the overall safety of the flight by a high level of commonality. The behaviour of the crew on any aircraft of the family is similar in terms of aircraft and system handling; thus the skills and flight experience gained on the former aircraft apply to the new one.

One flight deck standard...                        ...one integrated family

10 aircraft

3 aircraft types

Common
• flight deck
• systems
• procedures

Fly-by-wire electrically signalled
• flight controls
• thrust control

Short- to medium-range capability in 4 sizes

Medium- to long-range capability in 2 sizes

Long- to very long-range capability in 4 sizes
• A high level of commonality to optimise the training. A pilot trained on one of the aircraft of the family can safely control the flight path and handle the systems of any other aircraft of the family without the need for special additional skills or lengthy training. Thus the transition training needs to address the essential differences.

Furthermore, in the case of Mixed Fleet Flying, recurrent training can be shared between two aircraft types, and credit given for take-off and landings done on one aircraft to allow a pilot to remain current on the other one.

• A high level of commonality to allow safe Mixed Fleet Flying.

This strategic option has had tremendous repercussion on the aircraft and cockpit design. It has dictated the implementation of:

• The fly-by-wire system, providing similar handling characteristics within and outside the normal envelope of all the aircraft of the family.

• The cockpit layout, similar throughout the family.

• The integrated automated systems – Automatic Flight System (AFS) – and display units, with similar data and parameters, providing the same operational philosophy and procedures.

As a consequence, for example:

• A pilot trained to handle a system failure using the ECAM “Read and Do checklist” on one type does not need any additional training on use of ECAM on the other types of the family.

• A pilot proficient in flying Non Precision Approaches on one type will not need additional training on the other types to fly Non Precision Approaches.

Therefore, Airbus operators may take advantage of shortened pilot training between types – Cross Crew Qualification, (CCQ) – and Mixed Fleet Flying (MFF) opportunities.
CURRENT STATUS OF AIRBUS CCQ

A total of 38 airlines currently fly more than one Airbus fly-by-wire type, operating at least one member of the A320 Family (A318, A319, A320 or A321) with an A330 and/or an A340, or both A330 and A340. All have benefited from Airbus’ unique Flight Operational Commonality to reduce pilot training cost by up to 90% when transferring between aircraft types. This makes crew training and conversion shorter through optimised training courses known as CCQ.

CCQ is the Airbus term for applying the concept of FAA Advisory Circular 120-53 to related aircraft types such as the A320, A330 and A340. This thorough methodology from the FAA Advisory Circular has been recognised by the JAA in JAR OPS 1 as well as by the Canadian Authorities. CCQ programmes are based upon an in-depth analysis presented in Operator Difference Requirement (ODR) tables. Airbus has selected base aircraft, and developed ODR tables and CCQ programs from the base aircraft to all other aircraft from the fly-by-wire family.

Those basic Airbus ODR tables are made available for use by all Airbus operators upon request. The operator may have to customise the Airbus basic ODR to suit its specific fleet and routes, before submission to its national authority.

The Airbus CCQ courses are approved under the Airbus Type Rating Training Organisation (TRTO) and operators may wish to customise the recommended CCQ course to match with their training media, if conducted in their own company.

What is key to the CCQ course, is that all items which have been identified as the result of the commonality analysis in the ODR tables, must be included in the CCQ training course. Consequently, depending upon the training media used by operators and duration of the simulator session (three hours versus four hours for example),
structure and length of the operator CCQ course may differ from the one proposed by Airbus.

**MFF REGULATIONS & PRACTICAL CONSIDERATIONS**

Airbus defines MFF as an airline operation with multiple aircraft types, requiring different licence endorsements, by one pool of pilots. Flight Operational Commonality is not a prerequisite for MFF. In other words: the same pilot can fly an ATR turboprop on one day and a 747 the day after, provided he or she complies with the rules regarding initial qualification, recency of experience, recurrent training, proficiency and line checks for each of the aircraft types. The JAA allow MFF to be conducted with two types maximum, whereas the FAA does not impose a limitation.

MFF increases crew scheduling flexibility, resulting in a more efficient flying roster and reduced reserve requirements. Until the mid 1990s, however, large-scale MFF by ordinary line pilots was not customary for two reasons:

- Airline concern about the safe operation of more than one aircraft type by a single pilot pool.
- The prohibitive cost and loss of productivity associated with at least doubling the initial qualifications, quarterly recency requirements and (bi-)annual training and checking events.

Deemed very innovative at its inception in the early 1990s, MFF with Airbus aircraft was initially approved by the European Aviation Authorities and the American FAA.

Many of the world’s regulatory authorities have since rewarded the profound Airbus Flight Operational Commonality by allowing operators under their responsibility to conduct MFF of any Airbus fly-by-wire combination with the following credits:

- Pilots qualified on one aircraft type may obtain additional ratings through CCQ (a saving of 65-90% relative to the full type rating course).
- Take-offs and landings in one type may count towards recency in other types as well.
- Recurrent training, proficiency and line checks may alternate between types.
In order to assist its operators in setting up their MFF application to their national authorities, Airbus has developed a specific briefing as well as a set of recommendations for the content of alternate recurrent training and checking programmes. Those documents are made available upon request; in addition, if the need arises, a team of experts will assist the customer for an introductory briefing on this concept to their national authorities.

Current MFF operators include some 20 airlines. These represent all areas of airline operations, from flag carriers with worldwide networks to specialised charter airlines, from those with over 100 Airbus aircraft to those with less than 10 and from recent start-ups to long established airlines.

Pilots are the first to recognise that MFF enhances both their professional activities and personal lives through a more varied range of flying and destinations. This is highlighted by the operation of a pool of Air Mauritius pilots that operate A319s to Indian Ocean destinations and A340s to Europe and other long haul destinations.

**RECENT ACHIEVEMENTS AND NEXT STEPS**

In 2001, Airbus applied for the operational evaluation of the A340-500/-600 by JAA in Europe, the FAA in the US and Transport Canada, and requested that this evaluation be conducted jointly, as harmonisation of the procedure between JAA, FAA and Transport Canada was on the way.
The ultimate goal was to demonstrate that pilots flying the A340-500 and -600 could be granted the Same Type Rating as that of the A340-200/-300.

The JAA set up a Joint Operations Evaluation Board (JOEB), the FAA had already a Flight Standardisation Board (FSB) in place, and Transport Canada nominated an Operational Expert (OE).

The joint process was successful and the Same Type Rating was granted. Recommendations from the three authorities are detailed in a JOEB report for the JAA team, in the FSB report for the FAA, and in the OE report for Transport Canada. The structure and content of the reports is harmonised, but references to respective regulations of course differ. This is the only barrier for a joint report.

Nevertheless, it is a big achievement, allowing our operators to use “recommendations” from these reports when developing their training programmes and operations. FAA and Transport Canada had already such a process in place. With the JOEB process, the JAA equivalent, all operators in JAA member states will have access to the report when finalised and released by Central JAA.

In April 2003, the same process was applied to the A318, with the same success, and Airbus is confident that this joint evaluation will continue for the coming A380. The fact that transition from JAA to the EASA (European Aviation Safety Agency) occurs in the same period, will certainly not hinder the process.

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**SOME QUOTES FROM THE OPERATORS**

**Capt. Richard J. Hall**
Chief Pilot Airbus
Cathay Pacific
MFF A330/A340

“One of the attractions of going for Mixed Fleet Flying was the advantages that it would bring in terms of mixing long and short haul flying and this has been very popular with our pilots in terms of maintaining recency and currency and competency – we can mix maybe two long hauls with two or three short haul flights in order to achieve the target hours for a month.”

**Gerhard Ulver**
First Officer A320/A340
Austrian Airlines
MFF A320/A340

“In May this year, I had six flights on the A340 and 10 flights on the A320. I really do enjoy this Mixed Fleet Flying because I am very fond of having a variety in my job, so with Mixed Fleet Flying you have a good variety – you get a wider horizon, not only in your flying standards but even in your private life.”

**Capt. Mike Ferguson**
Chief Training Captain Airbus
MyTravel Airways
MFF A320/A330

“Our recurrent training is the same for both mixed fleet and for non mixed fleet flyers. The Mixed Fleet Flying pilots alternate checks in the simulator every six months between the A330 and the A320 Family.”

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**Joint approval exercise**
A340-200/-300 and A340-500/-600 STR endorsement

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The Joint Aviation Authorities (JAA), Federal Aviation Administration (FAA), and Transport Canada Civil Aviation (TCCA) completed the second phase of a joint evaluation of the Airbus A340-200/-300 and A340-600 aircraft on October 1, 2002.

**Jean-Claude Albert**
Joint Operations Evaluation Board Chairman

**Ron Tidy**
TCCA Operational Evaluation Chairman

**James Kling**
FAA Flight Standardization Board Chairman

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Airbus’ unique Flight Operational Commonality allows airlines to further optimise flight crew training programmes and to practise Mixed Fleet Flying in a practical and economical way. Judging by the large number of operators which currently take advantage of this, it has met with worldwide acceptance from regulatory authorities and airline pilots alike.

Airbus aims to continue to provide the highest possible levels of Flight Operational Commonality in current and future aircraft programmes to help airlines achieve better efficiency overall.

A380 BUILDING ON FAMILY STRENGTHS

The A380, entering into service in 2006, extends the Airbus tradition of innovation and commonality. The aircraft will benefit from enhanced technology levels. However, its pilot-aircraft interface will not be significantly different from that of existing Airbus new generation airliners, making it a full member of the integrated aircraft family.

A consistent pilot-aircraft interface... ...whilst enhancing technology levels

Fly-by-wire

Expanding the family with a fourth type

Conclusion
With very long-range airplanes such as the A340-500, an increasing number of flights will be conducted far away from regular diversion airports. Alternate airports along new routes like the Polar and Arctic route systems are subject to the most extreme weather conditions and would require special precautions.

Many Aviation Authorities and the International Civil Aviation Organisation (ICAO) consider that on such new routes, existing regulations would be insufficient to maintain the high level of safety achieved on other international operations.

The Joint Aviation Authorities (JAA) were first to undertake a review of the European regulations, soon followed by other countries and the ICAO.

JAA draft rules are available. They were published for public comments and declared technically mature on 25 June 2003. They comprise ETOPS provisions for two-engine airplanes and LROPS provisions for three- and four-engine airplanes with certain specific provisions for business jets. These are the first rules to be published by an Authority.
For two-engine airplanes, the emphasis is on engine reliability and means to protect diversions under extreme conditions. For three- and four-engine airplanes, the emphasis is on avoidance of diversions.

For business jets operated as commercial transport, specific regulatory provisions take into account the size of the aircraft and the nature of the operations, in particular the fact that most concerned flights are not scheduled.

On the occasion of the regulatory review, lessons learned from ETOPS and other long-range operations were taken into account. Many service events potentially affecting safety have occurred during ETOPS flights. ETOPS overall safety record is excellent, but these flights have proven to be vulnerable to human errors by maintenance, dispatch and flight crew. Design precautions required by the new rules will address some of the factors involved in these service events. However operators must absolutely adopt or retain the most stringent ETOPS safety policies to maintain the excellent safety record of ETOPS flights.

Australia, Canada, Hong Kong, New Zealand and Singapore have already announced their intent to review their ETOPS and long-range regulations.
**BASIC REGULATORY PRINCIPLES**

All draft rules in preparation will address existing routes as well as new routes. The new routes are longer than most current flights. On such routes, the distance to divert to an airport will be far greater and the available airports, if any, may be located in areas with very severe climate and limited infrastructures such as the Polar areas.

Most two-engine airplanes, even those approved for ETOPS, will not be capable of operating the new routes due to insufficient engine reliability and systems redundancy. Only the most recent engines are reliable enough to conduct such flights with two-engine airplanes. Furthermore the fuel reserves necessary to ensure a safe diversion at low altitude in case of engine failure may make such routes uneconomical for two-engine airplanes.

Three- and four-engine airplanes are much less affected by this problem. Three and four-engine airplanes have been safely flown on routes with very severe conditions, although not as extreme as what is contemplated now.

Even airplanes with an old design have an excellent safety record on these routes. Higher system redundancy and operational capability (such as the capability to fly safely with two engines failed) are essential on the extreme routes.

**OPERATIONAL SAFETY ON THE NEW EXTREME ROUTES**

To maintain the intended level of safety when operating the new routes one may either design to avoid diversions or adopt operational precautions to protect the safe conduct of diversions.

Protecting the safe conduct of diversions will typically be the solution for operators of two-engine airplanes who have to divert to the nearest airport in case of engine failure. They will have to implement and validate a Passengers’ Recovery Plan to ensure the safety of all occupants in case of diversion followed by an evacuation at airports in severe climate areas. The Recovery Plan may need survival equipment carried onboard the airplane for use at airports in the Polar areas. It may also require investments in airport facilities – Search and Rescue (SAR) services, medical services, snow removal, shelters, ground transports, etc – for the protection of evacuees.

Operators of three and four-engine airplanes do not need to divert to the nearest airport in case of engine failure. Other causes of diversion may be designed-out or minimised with appropriate technology. In the rare cases when a diversion is needed, its effect may be minimised by design that allows the crew to fly to a more welcoming, although more distant airport.

Airbus LROPs design will preclude diversions through specific design features and technology so that the A340 and A380 operators flying the new routes are not penalised by the implementation of costly Passengers’ Recovery Plans. The Airbus LROPs package will be made available to A340 and A380 operators when the rules are in place.
Thule and Yakutsk are needed for twin-engine aircraft to stay within 3 hours (at least) from an airport.

YYQ - Churchill
FAI - Fairbanks
LYR - Svalbard (Spitzberg)
RVN - Rovaniemi
CTS - Sapporo-New Chitose
OVB - Novosibirsk/Tolmachevo

**KEY FEATURES OF FUTURE ETOPS AND LROPS RULES**

**FUEL RESERVES**

For two-engine airplanes, the ETOPS fuel reserves (critical fuel scenario) should no longer be calculated with current conservative margins covering the worst possible combination of adverse operational contingencies. New lower ETOPS fuel reserves will decrease the economic burden on ETOPS operators but require closer crew monitoring of the fuel situation during the flight. New sophisticated fuel alerts (only on new aircraft) should compensate for this change.

Fuel reserves of three and four-engine airplanes are not affected by the failure of one or even two engines. However conducting a diversion with a depressurised cabin may require more fuel than the normal route reserves if the diversion time from the critical point of the route is very long. The possibility for airplanes fitted with new technology oxygen systems to perform a depressurised diversion at a higher altitude will overcome this economic penalty.

**PLANNING MINIMA**

Conservative planning minima for en-route alternate airports remain in place for ETOPS. Two-engine airplanes do not retain precision approach capability in some of the degraded system configurations that may exist during a diversion (e.g. in case of electrical emergency). For this reason, their planning minima may not benefit from a reduction.

Three and four-engine airplanes operated over LROPS routes should also apply a system of planning minima at diversion airports. However three and four-engine airplanes normally retain Category II Autoland capability in all the degraded system configuration cases that may lead to a diversion. Their planning minima will therefore be much lower than those of two-engine airplanes. This will be the case of Airbus A340 and A380.

**RECOVERY PLAN**

Implementing a Recovery Plan at designated alternate airports in Polar areas (and other areas with severe weather) is a completely new requirement with far reaching implications. Under the new rules, concerned operators will have to ensure the safety of all occupants until they are eventually flown to a commercial airport. This concerns all aspects of the occupants’ wellbeing during the diversion and on the ground, including the worst-case scenario of an evacuation under Polar weather conditions. Recovery Plans will require specific training for flight crew and cabin crew to cope with very cold temperature and wind chilling effect issues during an evacuation. Individual survival kits may be needed. Airport safety services (SAR and RFPS) are a key part of the Recovery Plan.

Operators are normally required to perform a demonstration of their Recovery Plan at alternate airports selected by the Authority. However, airplanes certified with the capability to operate safely for very
long diversion time may designate other more distant alternate airports and achieve excellent operational results while avoiding costly Recovery Plans, provided crew procedures do not require diversion to the nearest airport. This is the certification objective for Airbus A340 and A380 LROPS technology package.

**DIVERSION TIME LIMITED BY THE CAPACITY OF TIME-DEPENDENT SYSTEMS**

The maximum diversion time of all airplanes approved for LROPS and for ETOPS beyond 180-minute diversion time should be limited by the certified capacity of any time-dependent function. The cargo fire suppression time, or any other time limit in a critical system will appear as certified limitations in the Flight Manual resulting in diversion time limits after application of appropriate operational margins.

These limitations will normally apply at the one engine inoperative speed. However in the case of cargo fire suppression, the limit will be applied to the all-engine operating speed. Diversion time limits above 180 minutes will not be applied as fixed distance limits in still air and ISA conditions as in current ETOPS criteria, but as real time limits under the day’s forecast wind and temperature conditions.

**DESIGN CRITERIA ORIGINATING FROM LESSONS LEARNED**

Service experience has shown greater vulnerability of ETOPS to particular human error scenarios. The most serious events have resulted in both engines shutting down (either temporarily or permanently). They involved line-maintenance errors, servicing errors, errors during the application of the pre-departure ETOPS service check, errors in fuel planning or fuel management, etc. A number of system-related events were also observed, including a total electrical failure, multiple hydraulic failures and multiple air bleed failures.

Future rules will impose design solutions that have proven more robust against known human error scenarios:

- Demonstration of engine operation without flameout in suction feed configuration.
- “Smart” fuel alerts detecting potential fuel shortage situations before they can affect flight completion or a safe diversion.
- More comprehensive list of electrical services available in back-up electrical configuration and higher integrity of the electrical generating systems.
- Higher integrity of the air-bleed sources including the APU.

Although these requirements are driven by ETOPS service experience, some of them may become useful improvements for three and four-engine airplanes and have been retained as LROPS requirements by the JAA.
APPLICABILITY OF NEW RULES – GRAND FATHER CLAUSES

The conditions of application of new rules to existing airplanes may have a significant economic impact on operators flying the Siberian routes and other long routes over the Pacific. Compliance with the operational criteria in the case of airplanes not designed to the new rules may lead to increased cost. Discussions are continuing regarding the cost of applying proposed rules to existing airplanes. Three and four-engine airplanes of an older design might be unable to comply with proposed rules at an acceptable cost, requiring some form of dispensation. The design of Airbus A340 is essentially compliant with proposed rules and should not need significant retrofit action.

Two-engine airplanes would inevitably have to comply with the new rules in case of flight beyond 180-minute diversion time, but retroactive application to other ETOPS flights is still a matter of discussion between the Aviation Authorities.

Unlimited extended range
8 hours diversion time

- Existing two-engine airplanes up to 180 minute diversion time
- Existing two-engine airplanes beyond 180 minute diversion time
- Future two-engine airplanes

- Already certified three- and four-engine airplanes
- Voluntary compliance with three- and four-engine airplanes
- Three- and four-engine airplanes on routes over high terrain
- Future three- and four-engine airplanes

BUSINESS JETS ENGAGED IN COMMERCIAL OPERATIONS

Landing strip in foothills of the Himalayas
CONDITIONS OF APPLICABILITY OF THE NEW RULES

Two-engine airplanes currently approved for ETOPS up to 180 minute diversion time should not be subject to new design requirements and should therefore require no retrofit action as long as they continue to be operated below their currently approved maximum diversion time. However the legal means to transform current Operational Approvals into “Certifications” have yet to be defined by concerned Aviation Authorities. Concerned operators may benefit from some or all of the changes of the operational requirements resulting in some improvement of their ETOPS operating cost, in particular from a reduction of the ETOPS fuel reserves.

Once the new rules are finalised and adopted, two-engine airplanes with highly reliable engines may become eligible for ETOPS flights beyond 180 minute diversion time if they are modified to achieve compliance with all the necessary design and operational provisions. The main hardware changes will concern time-limited systems such as cargo fire suppression, fuel alerts, electrical generating systems, pressurisation, fuel-feed to the engines and of course engine reliability. The main operational changes will concern retention of engine reliability and the implementation of a Passengers’ Recovery Plan.

Future airplane types will have to comply with all aspects of the new rules.

On most existing routes, the proposed rules should not affect three- and four-engine airplanes because of the 180 minute rule threshold. For routes with more than 180 minutes diversion time (North and South Pacific ocean, South Atlantic, South Indian Ocean and South Pole routes), the impact of proposed rules will be different for A340 and for other three- and four-engine airplanes of an older design.

The only design provision clearly considered as retroactively applicable by all involved Aviation Authorities concerns cargo fire suppression systems. A340 operators who will need more than four hours of protection time (basic A340 protection complement) may need to install larger capacity cargo fire extinguishing bottles.

JAA operational rules should affect the calculation of the fuel reserves. Current ICAO rules (Annex 6) reflected by all countries in their national operational rules require that any airplane carry enough fuel to complete a depressurised diversion. Proposed rules should impose a check of the weather at the alternates used in this calculation, but only if the diversion time exceeds 180 minutes. The planning minima applicable to the en-route alternates should be lower than those of two-engine airplanes as four-engine airplanes normally retain full Category II Autoland capability in all degraded system configurations leading to a diversion. Proposed rules should also require consideration of forecast icing conditions in the fuel calculation. Conversely, the proposal should allow calculating the fuel reserves at a diversion altitude higher than 10,000ft if there is enough oxygen available. Airbus LROPS design will take full advantage of this possibility.

Three- and four-engine airplanes operated on routes with very long diversion time and/or over areas with airports subject to severe weather may benefit from voluntary compliance with the new rules if LROPS technology is available from the manufacturer to draw maximum advantage from the new rules. Airbus will make LROPS technology available for retrofit on all A340 to achieve economic gains via optimised fuel reserves and a drastic decrease of the number of diversions made possible by this technology.

Under current rules, routes over high terrain (higher than the two-engines-out net ceiling of the airplane) are only permitted where alternate airports are available within 90 minute flying time. This limitation has constrained the opening of direct routes over high terrain areas such as the Himalayas and Tibet plateau or the Antarctic. Outstanding engine reliability of modern four-engine airplanes opens the way for a revision of this rule so that quads are treated the same as twins, letting them operate based on the extremely low probability of a double engine failure. This possibility already exists in ICAO Annex 6, but has never been used, as engine reliability was not sufficient. Work is in progress with JAA on this subject.

Future airplane types will have to comply with all aspects of the new rules.

All future rules should contain specific provisions applicable only to business jets. These provisions will be governed by the size of the airplane (with an upper limit of 19 passengers) and by the type of operation (on-demand flights only). JAA proposes an intermediate step of approval at 120 minutes diversion time for two-engine business jets and a more complete set of criteria beyond 180 minutes. Two-engine business jets are treated separately from three- and four-engine business jets for the same reasons as larger aircraft.
Airbus is committed to the implementation of technology that will avoid diversions and optimise fuel reserves. Airbus considers this approach as most effective to maintain and further improve operational safety over the new very long routes. A340 airplanes already in service essentially comply with the draft rules. Further product improvements will be made available to operators to maximise safety, operational flexibility and economics under the new regulatory environment.

Airbus LROPS design is optimised to draw maximum benefits from JAA LROPS criteria when they become effective. However, A340 and A380 will be also certified to other ETOPS/LROPS rules as necessary. The Type Design criteria prepared by JAA and ICAO as well as those drafted by ARAC are technically similar and the final rules should be no obstacle to the validation of Certificates between concerned countries. Draft Operational Criteria differ on many key aspects. Depending on the operators’ fleet, operating policies and route network, the economic impact of the new rules may be substantially different. The revision of ETOPS rules and the implementation of LROPS rules will have a significant impact on the safety and economics of very long flights; especially those conducted in areas with severe operating environment. Operators interested in such flights should imperatively seek participation in the rulemaking process of their country. Airbus recommends that they follow any formal regulatory consultations and adopt a proactive attitude towards the national rulemaking process of their country with attention to the elements that have the more economic impact.

Examples of potential regulatory concern are applicability of new rules to existing operations and existing airplanes, criteria for the calculation of fuel reserves, criteria for the choice of alternate airports and implementation of a recovery plan, diversion time limitations not driven by airplane certified capability or any other criteria that may penalise current or future operation.
The General Purpose (GP) greases are used on many components of Airbus aircraft systems such as landing gears, flight controls and door mechanisms to ensure, by lubrication, the correct performance of the system and to avoid excessive wear, which leads to component damage. Two types of GP greases are currently used on Airbus aircraft, clay thickened greases and lithium thickened greases.

With the introduction a few years ago of greases with lithium complex chemistry that improved the grease performance, the aviation industry pushed for the use of one single type of grease, the lithium thickened GP greases. In order to progress towards harmonisation in the field of lubrication and to qualify lithium thickened greases approved by the aviation industry, an Aerospace Material Specification is currently being prepared by the Society of Automotive Engineers in conjunction with Airbus and Boeing. This specification will include compatibility test requirements to ensure that all qualified greases will be compatible with each other. Once the new products are qualified, the specification will be recommended for use for Airbus and Boeing systems maintenance. Airbus also intends to introduce these lithium thickened greases in the production of its aircraft.
USING GREASE AS A LUBRICANT

Many mechanisms used in aircraft need lubrication to ensure the correct performance of the system and to avoid excessive wear, which leads to component damage. Instead of fluids, grease is required when the lubricant has to stay in the mechanism during its operation.

Grease is a mixture of base oil (70-95%), thickening agents (5-15%) and additives (0-15%). It is used to reduce friction and wear between moving surfaces. It also provides protection against corrosion and prevents ingress of contaminants and other fluids such as de-icing fluid, fuel, paint strippers and water, into the moving joint.

Grease is frequently sealed into ball and roller bearings so it has to be compatible with different sealing materials. Due to its solid nature, grease does not perform the cooling and cleaning function that is expected from liquid lubricants.

A thickener is the solid constituent of grease that retains the liquid constituent in the product. The oil constituent saturates the thickener and when load is applied the base oil is released thereby providing lubrication to contacting surfaces. The thickening agents used are lithium soap/lithium complex, calcium soap/calcium complex, bentonite clay.

The oils used are either mineral or synthetic. Mineral oils are derived directly from crude oil by refining whereas synthetic oils are manufactured by a chemical process. Typical synthetic base oils are poly-alphaolefins (POA), ester/di-esters and silicones.

The additives are used to improve the properties of the grease. They are corrosion and oxidation inhibitors, anti-wear agents and extreme pressure additives. Dyes are also added to differentiate one grease from another.

As a consequence, making grease is a choice of:

- Proportion of base oil. This has an impact on lubrication properties.
- Type and proportion of thickener. This has an impact on grease properties; its resistance to temperature, environment and loads.
- Type and proportion of additives that can be:
  - corrosion inhibitors to minimise corrosion,
  - oxidation inhibitors to minimise oxidation of the oil,
  - extreme pressure additives to improve load-carrying capability,
  - anti-wear additives to minimise wear.

SPECIFICATIONS OF GP GREASE IN CURRENT USE

The commercial aviation industry has utilised material specifications for greases generated by the military authorities for the majority of aircraft applications requiring the use of grease products (for instance, but not limited to landing gear and flight control systems). These specifications have emanated from countries within the NATO alliance. Examples of such specifications are:

- MIL specifications from USA,
- DEF-STAN specifications from UK,
- AIR specifications from France.

By reviewing these military specifications the NATO countries, plus Australia and New Zealand, have identified the degree of interchangeability of the qualified products, i.e. the level of operational use. Three levels of interchangeability exist:

1. **Standardised product**
   A product that conforms to specifications resulting from the same or equivalent technical requirements. The standardised fuels, lubricants and associated products are identified by a NATO code.
2. Acceptable product
One that may be used in place of another product for extended periods without technical advice.

3. Emergency substitute
A product that may only be used in an emergency on the advice of technically qualified personnel of the sponsor Service, who will specify the limitations.

The following specifications for GP grease are the most commonly used for Airbus applications:

<table>
<thead>
<tr>
<th>NATO Code</th>
<th>G395</th>
<th>G354</th>
<th>none</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent grease specifications</td>
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<td>UK.</td>
<td>F</td>
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<tr>
<td>GP Grease Thickener type</td>
<td>Clay</td>
<td>Lithium</td>
<td>Clay</td>
</tr>
<tr>
<td>Qualified grease product (non exhaustive list)</td>
<td>Aeroshell 22</td>
<td>Mobil Grease 28</td>
<td>Nyco Grease 22</td>
</tr>
</tbody>
</table>

**General properties**

| Temperature range | -54 °C to +177°C | -73°C to +121°C | -60°C to +120°C |
| Dropping point (°Cmin) (Temp. at which grease becomes liquid) | ASTM D2265 232°C | ASTM D2265 165°C | ASTM D566 170°C |
| Water washout – resistance (%loss, max) | ASTM D1264, 41°C 20% | ASTM D1264, 38°C 20% | none |
| Low T° torque without water | ASTM D1478 54°C 0.98 max | ASTM D1478 73°C 1.0 max | IP 186 -50°C 0.2 max |
| Starting Torque(Nm) | 0.098 max | 0.1 max | 0.075 max |
| Running Torque(Nm) | | | |

*Note 1:* The specification MIL-PRF-23827 has been recently revised to divide greases into Type I and Type II for lithium and clay thickened greases respectively. The specification Def Stan 91-53/1 has also been revised to Def Stan 91-53/2 to restrict the qualified GP greases to lithium thickened greases into the issue 2.

*Note 2:* The Airbus specification AIMS 09-06-001 has been developed in 1989 to qualify a new grease Amna G4789. This lithium soap-thickened grease was introduced to replace a clay-thickened grease Aeroshell 7 on flight control systems to improve the behaviour of the flap and slat mechanisms in the presence of water. The lithium grease had been shown in laboratory tests to be capable of retaining more water within the grease than the clay-thickened grease. Finally the in-flight trial carried out on ten A310 aircraft from five operators, demonstrated that the lithium-based grease prevented lockouts on flap and slat mechanisms.
FLEXIBILITY

Over the years, airlines have enjoyed the flexibility of using greases from different suppliers for the same maintenance task. Such convenience although not necessarily systematic or frequent, is globally appreciated due to airline mergers, fleet expansion, third party work, and nature of the aircraft business.

It is acknowledged that airlines have advantages in limiting the number of GP greases on their stocks and therefore are interested in grease products that have large applicability across a given aircraft type as well as across several aircraft types (ideally a unique grease brand that is valid across all the aircraft). Airlines are also constantly seeking higher performance from grease products.

Airbus policy is to give the airlines the choice to select either a limited number of GP greases or to be as flexible as maintenance providers require.

COMPATIBILITY ASPECTS

Until January 2000, there was an understanding in the industry world-wide that crossing between GP grease brands and possibly even crossing between specifications of GP greases would have no significant chemical effect. This practice was largely benign at a time when mainly clay thickeners were used to manufacture GP greases (provided they are used under same thermal application range).

In the last few years, new greases with lithium thickeners and more recently lithium-complex thickeners have been made available on the market offering an alternative to clay thickened greases across most of the aircraft applications.

Grease manufacturers agree that a mix between clay and lithium thickened greases would not necessarily result in a significant reduction in the chemical compatibility of the greases. There are several clay greases that have been successfully tested for functional interchangeability with lithium thickened greases. However it is appreciated that the biggest chemical alteration in lubrication performance (although still considered potentially ‘minor’ in terms of aircraft functional interchangeability), could come from the potential mix between ‘clay’ and ‘lithium-complex’ grease thickeners.

Following an accident in January 2000, suspicion was put on the potential lack of compatibility between clay and lithium thickened greases. The Federal Airworthiness
Authorities (FAA) requested the Air Transport Association (ATA) to review the industrial standards concerning lubrication of aircraft mechanisms. Several meetings involving many parties, ATA, Airlines, FAA, Airbus, Boeing, grease manufacturers, NTSB and others, were hosted during 2002 to clarify the situation around the potential lack of compatibility between clay and lithium thickened greases.

Finally, in March 2002, the FAA dispatched the first issue of a dedicated FSAW 02-02 (Flight Standard Information bulletin for Airworthiness) as guidance for Aviation Safety Inspectors (ASI) in the event an operator requests to change to a grease type or brand not specified on the Qualified Products List (QPL) of the MIL-SPEC for the specific aircraft application. This FAA document was revised to FSAW 02-02C on May 22nd 2002.

Airbus issued a Service Information Letter (SIL 12-008) to inform airlines on best maintenance practices to avoid detrimental effects on mechanisms which need frequent lubrication as defined in the Maintenance Planning Document (MPD).
half, their MPD servicing intervals for around 3-4 services (i.e. temporarily double the number of lubrications). Furthermore, Airbus advises operators about possible alteration of lubrication properties when mixing GP clay thickened greases and lithium thickened greases. In the event this particular mix appears, Airbus advises operators to conform with the above precautionary principle.

**NEW SPECIFICATION**

Currently Airbus and Boeing in conjunction with lubricant manufacturers are compiling a specification for a GP grease operating at −73°C to +120°C which will be restricted to lithium chemistry. The objective of this specification is the qualification of lithium complex greases that will present increased performance due to their water washout capability, improved penetration and their dropping point which is typically > 180°C.

This specification will be issued as an Aerospace Material Standard (AMS) specification through the Society of Automotive Engineers (SAE). This specification being restricted to lithium chemistry will require that all greases qualified are compatible with each other. Compatibility tests are given in the specification. The SAE specification currently known as M-99AD will act as a core specification for Airbus and Boeing who will raise their own in-house material specifications based on the SAE specification and produce documentation giving the products qualified by each company.

For in-service aircraft, Airbus will also recommend operators to use lithium thickened greases wherever possible provided that Airbus recommendations (SIL12-008) regarding the mixing of different types of grease are fully respected.

Following operators’ requests, Airbus will nevertheless maintain a certain flexibility at specification level, which means that operators still have the choice between the two GP grease types, and different suppliers, to maintain the Airbus aircraft systems.

**Conclusion**

It is a design objective of Airbus that the A380 project should use, whenever possible, lithium thickened greases thereby reducing the risk of mixing greases of different chemistry and properties.

On introducing lithium-complex chemistry greases to applications currently employing clay-thickened greases, advantages are to be gained from the increased performance of the lithium complex greases, apart from global rationalisation and harmonisation.

For in-service aircraft, Airbus will also recommend operators to use lithium thickened greases wherever possible provided that Airbus recommendations (SIL12-008) regarding the mixing of different types of grease are fully respected.
On 7 September 1918 Mr Pierre Latécoère a French aircraft manufacturer whose descendants still make parts of Airbus aircraft, proposed to the French government a plan to open air routes to South America. In 1921 he formed an airline and by 1925 had regular services from Toulouse via Casablanca to Dakar.

At 05:10 on the morning of 11 May 1930 the mail left Toulouse. It arrived in Natal, Brazil on the 13th at 08:10 and in Buenos Aires on the 14th at 19:35, finally arriving in Santiago, Chile at 13:30 on the 15th.

During this flight they performed a single engined flight of 3170 km over water, greatly exceeding the 207-minute diversion times allowed today.

However not all flights were as trouble free as that one. Diversions and emergency landings in hostile territory were frequent occurrences. The lucky crews escaped with an engine repair. Some were held hostage for up to four months.
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