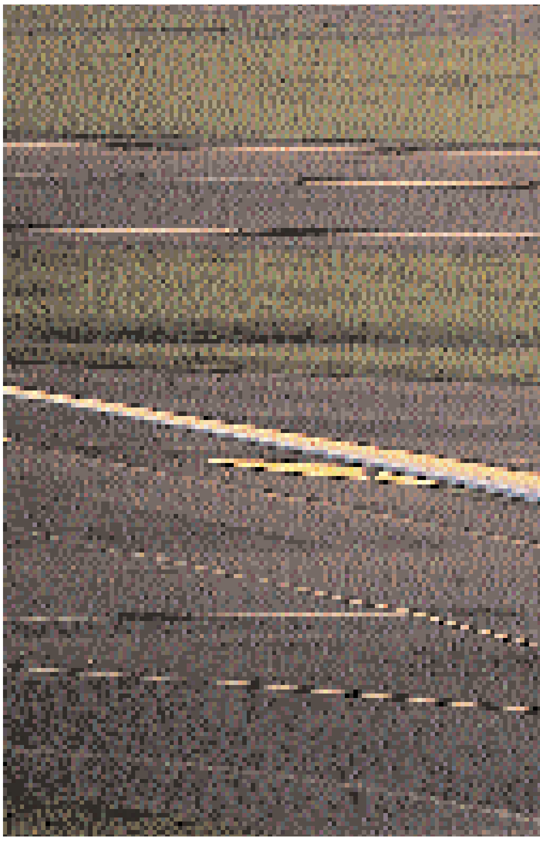
Airlines are now pushing for a 207 minute Etops clearance for trans-Pacific operations. The evolution of Etops reveals how this might be achieved.



Etops for ultra long-range missions

Extended range twin-engine operations (Etops) have been commonplace across the North Atlantic since the 1980s. Trans-Pacific air service agreements are about to experience a similar liberalisation. The demand for 300-seat ultra long-range aircraft will increase as a result. This has prompted airlines to seek a 15% extension to 180 minute diversion rules for twin-engined aircraft. The 777 could then compete more effectively against the four-engined A340 in the north Pacific market.

Ultra long-range

All airframe-engine combinations of twin-engined long-haul aircraft now have an Etops diversion time limit of 180 minutes to a suitable diversion airport. That is, following the shutdown of one engine in-flight, the aircraft must be able to reach a suitable airport within 180 minutes. This is enough for optimum flight paths on trans-Atlantic flights. Because their flight paths are no longer than those of three or four engined aircraft flying across the north Atlantic, fuel burns and seat-mile productivities of twin-engined aircraft are not compromised.

The case across the north Pacific is different. The 180 minute diversion rule for twin-engined aircraft means they may have to fly less than optimum routes. This is because islands with diversion airfields in the north and mid Pacific are spread further apart from each other. These longer flight paths increase fuel burn, can restrict payload and sacrifice revenue, and reduce aircraft utilisation and seat-mile productivities.

The diversion airfields en-route for Etops missions naturally have to be suitable for the aircraft in question. That is, they must have long enough runways and sufficient navigation aids to allow the aircraft to land in poor weather. They must also have adequate safety equipment and emergency services. Finally, there must be a high chance of suitable weather at diversion airfields and and an almost zero chance of two adjacent airfields closed simultaneously due to weather. This is not a problem where there are a large number of diversion alternatives within reach of a position where an in-flight shutdown could occur, as in the north Atlantic.

Three and four engined aircraft are not affected by any diversion rules and so, provided they have the range, can fly the optimum route all the way across the Pacific. Given the long distances involved and the small number of diversion airports, there are large differences between flight paths of twin-engined and four engined aircraft. This makes twin-engined aircraft economically less attractive and puts the A340 ahead of the 777.

For example, the A340-500 was in competition with the 777-200X for an order from Singapore Airlines flying the route between Los Angeles and Singapore. The 777-200X's payload-range was not sufficient to meet SIA's requirement. Had a 15% extension on the 180 minute diversion time been available the 777-200X might have been acceptable to SIA.

Operators of twin-engined aircraft are seeking a 15% extension to the 180 minute diversion time, bringing it to 207 minutes. Optimum flight paths can then be flown across the Pacific and so the 777-200X would be at less of a disadvantage against the A340-500.

An examination of the evolution of Etops will reveal how airlines hope to achieve their objective and so make the 777 an equal competitor to the A340 in the ultra long-range north Pacific market.

Etops regulations

The regulations governing Etops have long been established but are still evolving. The three basic criteria for establishing Etops were the certification of airframe-engine combinations for such missions, approval of the specific airline's operations and the attainment of sufficient engine reliability to maintain Etops clearances.

Certification of an airframe-engine combination requires comprehensive design features for twin-engined aircraft. These, together with special airline operational and maintenance requirements, incur costs unique to twin-engined aircraft. The benefits of using twin-engined aircraft rather than three or four engined aircraft are savings in engine maintenance and inventory as well as fuel and aircraft weight efficiency. Overall there is a net cost reduction from the use of a twin-engined aircraft.

Aircraft design for Etops revolves around the ability to keep an aircraft operational in the event of shutting down an engine. Since aircraft systems

A 15% extension of the 180 minute Etops diversion time would open up the trans-Pacific market to long-range twin-engine aircraft.

ultimately rely on engine power, a 50% loss means redundancy is a key issue. Essential aircraft systems are designed to fail-safe criteria, a high level of system reliability has to be established, the effects of failures have to be determined and there must be sufficient oxygen and control functionality to keep the aircraft operational.

These requirements ensure that the safety of twin-engined aircraft is as good as three or four engined aircraft in the event of a single engine in-flight shutdown.

The design of aircraft for Etops certification is based on the criteria laid out by the Federal Aviation Administration (FAA) and European Joint Airworthiness Authorities (JAA). Although similar, the FAA and JAA have different approaches to Etops.

The JAA will certify aircraft for Etops missions prior to any airline actually operating the aircraft. The FAA will not certify an aircraft for Etops until there is an operator flying the aircraft who applies for Etops capability.

Engine reliability

In order for an aircraft to be first certified for Etops it had to acquire 12 months non-Etops operational experience. This would be on routes which had less than a 60 minute single engine diversion time. During this 12 month period the airframe-engine combination had to establish a level of engine reliability with respect to in-flight shut down (IFSD) rate.

This is because an increase in diversion time would only be granted if it could be established that the probability of an airframe-engine combination requiring an in-flight shutdown was low enough. Under both JAA and FAA regulations a new engine had to demonstrate a mature in-flight shutdown rate (IFSD) of no more than 0.05 per 1,000 engine flight hours (EFH) to gain clearance for 120 minute single engine diversion. That is, only one in-flight shutdown for every 20,000 EFH.

The in-service experience required to demonstrate this level of mature engine reliability differs between the FAA and JAA. The FAA requires an accumulation of more than 250,000 EFH for a new engine and in-service experience of 12 months. A significant portion of these 250,000 EFH would have to be gained on the candidate aircraft. This accumulated experience would therefore be enough for about 12 in-flight engine shutdowns if the target IFSD rate was being met.

The JAA requires only 100,000 EFH and 12 months in service experience for a new engine. This would be enough for five in-flight shutdowns. This policy was also followed by the UK Civil Aviation Authority.

Both authorities agreed that the in-service experience could be reduced to 50,000 EFH for a derivative engine.

To gain clearance for 180 minute single engine diversion time another 12 months operations and a mature IFSD rate of 0.02 per 1,000 EFH has to be reached under both JAA and FAA rules. The probability of an engine in-flight shutdown therefore has to be less than one in every 50,000 EFH.

These levels of reliability have to be achieved by the global fleet. An in-service experience of 250,000 EFH means an aircraft flight hour (FH) accumulation of 125,000 FH. Considering a typical airline long-haul aircraft annual utilisation of 4,000 FH this experience equals a year's operation with about 30 aircraft using the same engine. This would be reduced to 12 aircraft under the JAA regulations and just six aircraft in the case of clearing a derivative engine.

The engine reliability IFSD rates of 0.05 and 0.02 per 1,000 EFH are targets. Not only do the IFSD rates have to be achieved, they also must be maintained.

Airline approval

These IFSD rates are targets for the global fleet but still have to be achieved by each airline. For an airline with a large fleet, reaching the required in-service EFH experience to demonstrate the IFSD target is not difficult. For a carrier with a fleet of just two or three aircraft it could take years to accumulate the required experience for 120 minute Etops clearance. The aircraft might have been originally acquired specifically for these missions and so there was pressure to grant Etops clearance with less in-service experience.

The basic requirements of the FAA and JAA are that an airline can establish and maintain the required level of IFSD

The 767 pioneered Etops across the Atlantic. Its experience contributed greatly to accelerated and instant Etops.

reliability. When a small airline's in-service experience with an engine is small the authorities would take all operational factors into consideration. Etops clearance could be given and any subsequent in-flight shutdowns would be reviewed on a case-by-case basis.

Besides certification for the aircraft, airlines must have approval to fly Etops missions. To achieve this an airline must prove to its local authority that it has achieved the required level of mature engine reliability and IFSD targets. In addition the airline has to achieve the overall objective of meeting all the maintenance, flight planning and operational requirements. The airline also has to have a more extensive minimum equipment list on its aircraft.

This takes considerable time. Even then an airline has to accumulate extensive operational experience of Etops missions before an aviation authority grants an airline an Etops certificate.

Flight planning is of particular importance. In-flight shutdowns on Etops missions require immediate diversions to the nearest suitable airport. Airline operations departments are therefore required to keep accurate weather records for diversion airports and keep informed about changes to airfields' status, maintenance and navigation aids.

Airlines also have to maintain an appropriate flight crew training programme. This involves courses on Etops regulations, flight and route planning, aircraft performance, diversion procedures and use of emergency equipment.

Airline approval for Etops missions means a request has to be filled by the carrier with its local authority at least three months prior to the start of operations. To be granted an Etops certificate an airline must be able to achieve and maintain the target level of engine reliability.

Accelerated Etops

When 180 minute Etops clearance was established for all twin-engined types, Airbus pressured the authorities to accelerate the approval process. This led to the reconsideration of airline approval for Etops and the possibility of a shorter one year approval period for 180 minute Etops.

The method of achieving this is specified by the JAA and FAA. Accelerated Etops certification would be approved by using compensating factors. These were verification of aircraft system reliability, aircraft altitude clearance capability over high obstacles and reviews of the possibility of maintenance errors and the stress on flight crews.

The engine reliability criteria were also reviewed. It took six years for the A300 and A310 to establish a reliability level that would allow them a 180 minute Etops clearance. The 250,000 EFH required has now almost been reduced to zero when there is a considerable level of commonality between the engine in question and other powerplants. One year of service experience with the A340 contributed to early Etops approval for the A330. The A340's contribution was the verification of its systems reliability, which are identical to the A330's. The acceleration of Etops approval was based on in-service experience substituted by a series of operational actions to satisfy the authorities. Since the probability of an in-flight shutdown had not been assessed, authorities had to be convinced that the safety of a diverted flight would not be jeopardised, and this would be achieved with additional safety precautions.

If an airline has external support, usually for maintenance procedures from an experienced airline, then it could commence with a 90 minute Etops clearance. The clearance could then be extended to 120 minutes after another 300 sectors had been flown with a mission success rate of 98% or more.

Instant Etops certification could be given to an aircraft-engine combination derived from another type. For example, the A330-200 received instant Etops certification because it is derived from the A330-300.

An example of accelerated Etops was Aer Lingus' use of the A330-300 across the Atlantic. Aer Lingus' aircraft were some of the first A330's in service and were also some of the first to be powered with the CF6-80E1 engine.

The airline first flew the aircraft on valuation flights over European routes. It established special maintenance procedures in Dublin and Shannon where particular aircraft systems were replaced to ensure that Aer Lingus' maintenance personnel were satisfied with the aircraft.

The Etops clearance gained by Aer Lingus was made in steps and started at 75 minutes, increased to 90, then 120 and finally 180.

Instant Etops

Following accelerated Etops an instant Etops certification was proposed. This was partially as a result of Boeing developing the long-range 777 which depended on the freedom to operate unrestricted on trans-Oceanic routes as soon as it entered service.

Instant Etops, or "Etops out of the box", was a requirement to give an aircraft certification for 120 or 180 minute diversion from the time of aircraft service entry. This meant substitution had to be made for engine service experience and the establishment of system reliability integrity.

Instant 180 minute diversion certification would not qualify the aircraft for immediate Etops missions since this would only be granted if individual airlines had proved the suitability of their maintenance and operations procedures. This was made possible by the extensive experience of launch customer United Airlines.

For instant Etops Boeing argued to the FAA that engine reliability was not the correct basis for assessing aircraft safety. It made the point that the key to Etops safety was system reliability. That is, a common mode failure could lead to the loss of both engines in flight. It therefore proposed that instant Etops certification should be given on the basis of proven system reliability. The particular systems in question are the hydraulics, avionics, electrical, fuel and pneumatic systems.

Because the 777 was a brand new aircraft with new technology and no experience, Boeing had to demonstrate to the FAA that it had been designed extremely well. Boeing had a comprehensive flight test programme with five aircraft and 1,000 flight cycles of testing as a substitute for in service experience. Following the extensive flight test programme Boeing achieved FAA 180 minute Etops certification when the aircraft entered service with United.

Instant Etops is only awarded, however, if the airline already has prior Etops experience and all the required operational and maintenance procedures in place.

Pacific addition

Airlines are now seeking to get a 15% extension on the 180 minute diversion time. This 207 minute diversion time would permit optimum flight paths to be flown on the longest routes across the Pacific and so reduce flight time for the 777.

The issue of diversion times for trans-Pacific operations is compounded by the small number of suitable diversion airports compared to the Atlantic. The Pacific is a harsher environment. The reliability of the weather at these airports is poor, there is minimal technical support and the airfields have basic landing aids.

Longer diversion times are complicated by aircraft system considerations. These include longer fire suppression capability and the effect of an engine windmilling for longer than three hours after being shut down.

Boeing's analysis of the trans-Pacific routes shows that three and four engined aircraft might have to divert for several reasons, and only some are engine related. The data also shows that a four engined aircraft has the same, if not more, need for an in-flight diversion because of engine related causes. Examples of non-engine related causes are crew emergency and unanticipated headwind requiring diversion for re-fuelling. Boeing's argument is that all aircraft crossing the Pacific require good en-route diversion airports for all types of reasons. The diversion airports used by 747s and DC-10s include Adak, Midway, Shemya and Wake. Other diversion airports for Etops missions include Guam and Saipan. Airbus makes the point that many Pacific ocean island airports are ex-US military airfields now in the hands of private ownership and that these airfields have inadequate safety equipment and facilities. It goes on to say that commercial agreements are necessary to make them available as for Etops missions. Overall, Airbus argues that the number of diversion airports in the Pacific is still limited and this makes operations for twin-engined aircraft difficult. Boeing states that many Pacific island airports will become available for en-route diversions for the foreseeable future.

Boeing's argument has been made to founder Airbus' argument of there being an insufficient number of good quality diversion airports in the Pacific. This argument of course adds weight to the A340's case for being the more suitable aircraft for long-range routes across the Pacific. Boeing's analysis also shows that 180 minute Etops clearance is adequate for routes across the north Pacific. Longer clearance than 180 minutes would only be required on the small number of occasions when several diversion airports in the north Pacific might be simultaneously closed.

Boeing's analysis concludes that there are plenty of suitable diversion airports in the Pacific. For example, there are Anchorage and Kushiro for sectors operating between the US and Japan. Historical weather data shows that the probability of two adjacent alternate diversion airports being simultaneously closed is virtually zero. However there is

extra flexibility with respect to alternate diversion airports if Boeing can get a 15% extension on the 180 minute diversion time.

Airbus' analysis shows that the Etops route between New York and Singapore is 360nm longer than the route for a four engined aircraft. This is because the optimum route flies close to the north pole where there are few diversion airfields within 180 minutes flying time. Route maps across the north Pacific appear to show that they have enough diversion airports available to make an Etops mission not far from the optimum routing. If this is the case then a 15% extension to the 180 minute diversion time should be sufficient to make twin-engined aircraft to operate as efficiently as three or four engined aircraft.

Although airlines have applied for this extension it is not clear what requirements they will have to meet. They will probably be related to system integrity of the aircraft for a one engine flight lasting more than 180 minutes. Questions of battery power and durable anti-icing systems will no doubt be considered. AC