

1. No single person performing simultaneous engine maintenance or servicing
2. Conservative fuel loading requirements
3. Intense rain/hail ingestion engine design requirements
4. Constant adherence to established ETOPS procedures without exception
5. Robust engine condition monitoring program

The FAA incorporated prevention strategies for these types of failures into airworthiness requirements and ETOPS policy as we learned of them. This proposal would codify those prevention strategies for known sources of common cause, cascading and fuel exhaustion failures that have not been incorporated into the regulations.

The ARAC ETOPS Working Group also looked at how the new risk model could be applied to airplanes with more than two engines. For these types of airplanes, the working group had to decide what a critical loss of thrust was in order to determine the impact that engine failure rate would have on overall risk. For a two-engine airplane, the risk model assumes that a loss of both engines is a critical thrust loss. This is because there is a general expectation that the result of such an occurrence would be a catastrophic loss of the airplane; though there are examples of safe landings following the loss of both engines. The working group applied a similar approach to define a critical thrust loss for airplanes with more than two engines.

The operating rules contained in 14 CFR part 121 have minimum performance requirements with two engines inoperative for airplanes that have more than two engines. Using this as a guide, the working group assumed that critical thrust loss for both three and four engine airplanes would be three engines. If three engines fail on either kind of airplane, there is a general expectation that the result would be a catastrophic loss of the airplane. In other words, the risk model assumes the fourth engine on a four-engine airplane provides no additional safety benefit compared to the loss of all engines on a three-engine airplane. As is the case for two-engine airplanes, there are examples where a flight crew was able to safely land a four-engine airplane following the loss of three of the engines. However, the ETOPS risk model makes the conservative assumption that this would result in loss of the airplane.

This assumption for three and four engine airplanes changes the risk model equations so that for these types of

airplanes, the probability of the loss of three engines would be much more remote than the loss of both engines on a two engine airplane. Under this assumption there is a higher probability of losing three engines on a four-engine airplane than on a three-engine airplane. The following example illustrates the concept. A three-engine and a four-engine airplane are in-flight. Both airplanes suffer the loss of two-engines due to independent causes but can reach a diversion airport. However the loss of an additional engine for either airplane at this point would be catastrophic for the airplane. The three-engine airplane has a single engine that could possibly fail while the four-engine airplane has two engines that could possibly fail. In this unlikely situation, the four-engine airplane is at greater risk because the probability of experiencing an engine failure event increases with the number of engines. Assuming that the engine failure rate is the same for each type of airplane, a four-engine airplane would have twice the probability of losing one of the two remaining engines than the three-engine airplane would have of losing the one remaining engine.

Using the available risk model equations with these considerations, the ARAC ETOPS Working Group determined that the in-flight shutdown rate for a three engine airplane would be approximately 0.2 shutdowns per 1,000 engine-hours to have an equivalent risk of critical thrust loss compared to a two engine airplane with an in-flight shutdown rate of 0.01 per 1,000 engine-hours. On a four-engine airplane, the equivalent in-flight shutdown rate would be 0.1 per 1,000 engine-hours.

Because these rates are so high compared to the failure rates currently achieved by today's turbine engines, the FAA does not consider it necessary to specify in-flight shutdown rates for three and four engine airplanes other than as part of an operator's propulsion system monitoring program. Under these programs, the operator must notify the FAA and take corrective action if these rates are exceeded.

#### In-flight Shutdown (IFSD) Rate

Propulsion system monitoring is vital to ensure safe ETOPS flights. A propulsion system monitoring program is intended to detect adverse trends, to identify potential problems, and to establish criteria for when corrective action may be necessary. The certificate holder would have to ensure that its ETOPS airplanes have In-Flight Shutdown (IFSD) rates commensurate with the world fleet's operation for that airplane type. Propulsion system

monitoring at the operator level has been accomplished via the guidance of AC 120-42A which defined specific IFSD rates for ETOPS.

Propulsion system problems and IFSD may be caused by type design deficiencies, ineffective maintenance or operational procedures. It is very important to identify the root cause of events so that appropriate corrective action may be determined. The diverse causes of propulsion system problems require different solutions. For example, type design problems may affect the world fleet of aircraft. If an individual certificate holder experiences a problem caused by a type design issue, it may not be appropriate for the FAA to reduce or withdraw the particular operator's ETOPS authority. However, maintenance or operational problems may be wholly, or partially, the responsibility of the certificate holder. If a certificate holder has an unacceptable IFSD rate risk attributed to maintenance or operational practices, then action carefully tailored to that certificate holder may be required.

The FAA does not use IFSD rate as the sole means to determine a certificate holder's ETOPS authority. The FAA considers the 12-month rolling average standard that occurs for a mature fleet after the commencement of ETOPS. A high IFSD rate could be due to the limited number of engine operating hours used as the denominator for the rate calculation or a small fleet. The effect may be an IFSD rate jump well above the standard rate due to a single IFSD event. The underlying causes for such a jump in the rate will have to be considered by the Administrator. Conversely, there may be occasions when a single ETOPS event may warrant corrective action even though the overall IFSD rate is not exceeded. In such a case, the cause would be certificate holder specific and may require changes to their operational, dispatch or maintenance procedures.

#### Configuration, Maintenance, and Procedures (CMP) Document

The use of a CMP document has been in the ETOPS criteria from AC 120-42, and later 120-42A, from the very first ETOPS airplane approvals. The CMP document defines airplane and propulsion system design configurations, maintenance procedures, and operational procedures required to comply with the ETOPS requirements that are not already a part of the original type design approved by the original issuance of the airplane and engine type certificates.

The CMP document is comprised of service bulletins, service letters,