Probability Analysis

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Summary

This analysis has been made in an attempt to compare the ETOPS probabilities with the probability of cockpit smoke and subsequent loss of an aircraft due to interference with the crew to the extent that they cannot successfully follow manual procedures to locate the source and apply corrective action to eliminate the smoke. Failure to promptly apply effective corrective action to eliminate the smoke would exacerbate the situation and could subsequently lead to an inability to control the aircraft.

The ETOPS probability resulting in loss of the aircraft due to ditching or crash is the probability of the first engine failing in the scheduled flight segment followed by the failure of the second engine during the diversion. Since these are independent events, the combined probability is obtained by multiplying the IFSD probability for each event. The combined probability falls within the FAA Extremely Remote range.

The probability of smoke in the cockpit causing diversions is found from available incident reports. The probability of the cockpit smoke causing subsequent loss of the aircraft through crew inability to correct the situation is real; the probability number is inferred. The assumption is that the combined probability of smoke and subsequent loss of the aircraft must fall in the range of Extremely Remote. The inferred probability of the second event spans the range of Frequent to Reasonably Probable.

The conclusion is that smoke in the cockpit, from whatever cause, is Reasonably Probable. The probability of subsequent loss of an aircraft due to the smoke is inferred to be in the range of Frequent to Reasonably Probable. Smoke in the cockpit is a serious matter—and it could lead to loss of the aircraft—or to the hazards of a less than normal landing and the risks associated with passenger emergency evacuation.

Probability Analysis

The probability of an IFSD of a single engine based on .02/1000 hrs is equal to 2 $x10^{-5}$ for the maximum ETOPS category of 180 minutes and the special category of 207 minutes. (Note: Per AC120-42A, 0.02/1000 hrs is the threshold value to be used in the analysis of a 180-minute ETOPS.) This would require diversion to a 180-minute airport under max *normal* ETOPS. For a complete loss of the aircraft (or ditching in the open seas) the second engine would have to fail with the same probability as the first. Since these are unrelated events the total probability is the product of the two independent probabilities.

For the sample case of a 7-hour flight and a 3-hour diversion to the nearest airport, the combined probability would be $(7 \times 2 \times 10^{-5}) \times (3 \times 2 \times 10^{-5})$ or 0.084×10^{-7}. This would be within the FAA guidelines for an Extremely Remote probability of 10^{-7} to 10^{-9}.

Simultaneous Loss of Thrust

The probability of simultaneous loss of two engines due to a common cause (e.g. fuel mismanagement) can be derived from equation (1) of Sec 2(d) of the AC, [AC 120-42A Appendix 1] where the total probability of complete thrust loss is the sum of the probability of complete loss of thrust due to independent causes plus the probability of complete loss of thrust due to common causes.

Using the value of 0.084×10^{-7} and subtracting from 1×10^{-7}, the loss due to common causes must be less than 0.916×10^{-7}, again falling within the Extremely

Remote Category. The AC does not attempt to analyze the likelihood of this common cause.

Cockpit Smoke

To relate to the probability of a diversion due to cockpit smoke, the probability of such an event was determined from available incident reports. The frequency of diversions was based on 7 diversions per 100,000 flights. With a flight duration of 1.75 hours (assumed) the probability of a diversion is 4×10^{-5} per hour. This would make the probability of a diversion due to cockpit smoke just beyond the FAA range of 10^{-3} to 10^{-5} per hr. or a Reasonably Probable event as classified by the FAA, and in the range of Remote. The other data given were that there were 350 diversions in a 10-month period. Basing a probability calculation on these data and 15,000 flights a day of 1.75 hours, the probability of a smoke-caused diversion is 350 divided by the total hours which are equal to (10/12 x 365 x 15,000 x 1.75) or 8×10^{-6}, which yields a probability of 4.4×10^{-5} which again would put it just above the upper limit of the Reasonably Probable Range 10^{-3} to 10^{-5} and again in the range of Remote.

Based on flights rather than hours, the data used give values of 7 and 7.7×10^{-5} as the probability of a smoke diversion per flight.

To directly compare the hazard of a smoke caused diversion with that of an ETOPS ditching or accident, the probability of a crash as a result of the cockpit smoke can be calculated using FAA guidelines for probability of an event. To reach the lower limit of extremely remote probability (1×10^{-7}) the probability of the smoke induced diversion causing the second failure, the crash, must be combined with the incident probability. The total probability of the two events, smoke in the cockpit and eventual crash must reach 1×10^{-7} to 1×10^{-9}.

The calculations have been based on a per hour exposure in accord with the FAA guidelines. Given that the probability of event A, (P_A) smoke in the cockpit, is 4.4 x 10-5, to find the probability of event B, (P_B), subsequent loss of the aircraft, which when combined will equal P_{AB}, (1×10^{-7}) we divide P_{AB} by P_B. Thus (1 x10-7)/(4.4×10^{-5}) = 2.27×10^{-3}. The lower probability of 1×10^{-9} when divided by PB yields 2.27×10^{-5}. These inferred probabilities of a subsequent loss of aircraft due to cockpit smoke fall in the range of Frequent (2.27×10^{-3}) to Reasonably Probable (2.27×10^{-5})[1]

The Author

Paul Halfpenny has 33 years experience with Lockheed aircraft in the design and testing of Lockheed aircraft, systems, and components beginning with the C-130 and the P2V, Navy Patrol Aircraft in 1952 and ending with the L-1011 in 1985.

While employed he served on the AC-9 committee of the SAE and was chairman of that committee in 1983-84. After retiring he was the vice chairman of the National Academy of Sciences (NAS) Committee on Airline Cabin Safety, and a member of the NAS committee on Contamination Limits for Space Station Freedom. He has served as an expert witness in various aircraft accidents involving contamination in the flight station. Included were the Air Canada accident at Cincinnati, the L-1011 Fire at Riyahd, Saudi Arabia and most recently, the Value Jet Accident at Miami.

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[1] FAA Probability Guidelines, Probability Occurrence, 10^{-3}, **Frequent**; 10^{-3} to 10^{-5}, **Reasonably Probable**; 10^{-5} to 10^{-7}, **Remote**; and 10^{-7} to 10^{-9}, **Extremely Remote.**