

## Propulsion System Reliability Assessment

### A.1 General

#### A.1.1 Type Design Approval

To establish if a particular airframe-engine combination has satisfied the propulsion system reliability criteria for ETOPS, a thorough assessment shall be conducted by specialists of the responsible airworthiness authority for airframe-propulsion system design utilizing all the pertinent engine and airframe-propulsion system data and information available (includes the APU, if required).

Transport Canada will review these findings as part of the aircraft type design approval activity.

#### A.1.2 Operational Approval

To establish if an operator has demonstrated the capability of ensuring propulsion system reliability targets have been and will continue to be met.

### A.2 Concepts and Criteria

No single parameter by itself, without other data/information, can adequately qualify reliability. There are a number of variables, maintenance and operating statistics and general information about the operational experience of a particular power unit, which characterize propulsion system reliability. Engineering judgement must then be utilized to determine the adequacy and applicability of this data and information to ETOPS and to determine the suitability of the aeroplane for ETOPS. As an aid in making this judgement, statistical analysis will be used to help determine that the desired level of reliability is obtained.

The evidence must be such that it can be shown with high confidence that the risk of total thrust loss or loss to an extent that precludes continued safe flight, is acceptably low, i.e., at an appropriate level less than between  $10^{-8}$  and  $10^{-9}$  per hour during the relevant portion of the cruise.

## A.3 Assessment

To assess adequately the propulsion system reliability for ETOPS type design and operational approval, certain world fleet data and information are required. The Regulatory specialists will maximize the use of existing sources and kinds of data generally available but additional data may be required in certain cases.

### A.3.1 Data Requirements

- a) Type Design Approval – World fleet data and information are necessary to adequately assess propulsion system reliability for EROPS. This data shall include:
  1. A list of all engine shutdown events both ground and in-flight for all causes (excluding normal training events) including flameout. The list shall provide the following for each event: data, airline, aeroplane and engine identification (model and serial number), power unit configuration and modification history, engine position, symptoms leading up to the event, phase of flight or ground operation, weather/environmental conditions and reason for shutdown.
  2. A list of all occurrences where achieved thrust was below the intended level, for whatever reason: the list shall provide the above detailed information.
  3. Data concerning total engine hours and aeroplane cycles (if known, include engine hour distribution, e.g., percent of world fleet of engines at 1,000 hours, 2,000 hours, etc.).
  4. Data listing mean time between failure of the propulsion system and associated components that affect reliability (unscheduled removals).
  5. The amount and frequency of using reduced/de-rated thrust (if detailed data is not available, a representative sampling may be sufficient); and
  6. Additional data as specified by the specialist group.

A.3.1.2 Operational Approval – Data requirements for ETOPS Type Design Approval A.3.1a) limited to operator fleet experience and any experience claimed as compensatory experience (see Engineering Assessment A.3.3).

A.3.2 Experience

A.3.2.1 Type Design – In support of applications for ETOPS type approval, data shall be provided from various sources to ensure completeness, i.e., engine manufacturer, operator and aeroplane manufacturer.

To provide a reasonable indication of reliability trends and significant problem areas, an accumulation of at least 150,000 engine hours is normally required in the world fleet before the assessment process can produce meaningful results. This number of hours may be reduced if adequate compensating factors are established which give a reasonable equivalent data base.

Once an assessment has been completed and the specialist groups have documented their findings, the Director, Airworthiness, will declare whether or not the current propulsion system reliability of a particular airframe-engine combination satisfies the relevant criteria of this document. Transport Canada will specify items required to qualify the propulsion system suitable for ETOPS, such as the recommended propulsion system type design configuration, operating conditions, maintenance requirements and limitations.

A.3.2.2 Operator – Operational experience is required to ensure the operator can and will continue to maintain and operate the particular aircraft-engine combination at an acceptable level of reliability. The assessment of an operator's suitability to be granted an ETOPS approval is routinely made after a minimum amount of operating experience. Operational experience requirements may be reduced if adequate compensatory experience factors exist (see Appendix C ). The accepted basic experience requirements is defined in Chapter 3.

A.3.3 Engineering Assessment

A.3.3.1 An analysis, on a case-by-case basis, of all significant failures, defects and malfunctions experienced in service (or during testing) for the airframe-engine combination shall be addressed. Significant failures are principally those causing or resulting in in-flight shutdown or flameout of an engine but may also include unusual ground failures and/or

unscheduled removal of engines from the aeroplane. In making the assessment, consideration is given to the following:

- a) the type of power unit, previous experience, whether the power unit is new or a derivative of an existing model and the engine operating rating limit to be used with one-engine shutdown;
- b) the trends in cumulative and six and twelve months rolling average, updated quarterly, of in-flight shutdown rates versus propulsion system flight hours and cycles;
- c) the effect of corrective modifications, maintenance, etc., on future reliability of the propulsion system;
- d) maintenance actions recommended and performed and its effect on engine and APU failure rates;
- e) the accumulation of operational experience which covers the range of environmental conditions likely to be encountered; and
- f) intended maximum flight duration, maximum diversion and mean diversion time used in ETOPS.

A.3.3.2 Type Design – An assessment of the corrective actions planned or taken for each problem identified with the objective of verifying that the action is sufficient to correct the deficiency.

When each identified significant deficiency has a corresponding Transport Canada accepted corrective action and when all corrective actions are satisfactorily incorporated and verified, Transport Canada determines that an acceptable level of reliability can be achieved. Statistical corroboration will also be utilized.

Any certification inspections and tests that may be necessary to approve these corrective actions will be the responsibility of the appropriate Design Approval Authority. The required corrective action and modifications will be included in the type design standard necessary for final type approval of the aeroplane for ETOPS.

A.3.3.3 Operations – Transport Canada recognises that a number of potential countable events (eg. IFSDs, flameouts, uncommanded thrust reductions, etc.) are not ETOPS relevant or action has been taken to preclude further occurrences. An operator may request,

through the Regional Airworthiness office to Airworthiness Engineering - Powerplants, that such an event be discounted so that the propulsion system reliability objective is not affected. Any configuration, maintenance or procedural change to satisfy the event discounting must become part of the operators ETOPS CMP criteria. (Credit for optional equipment, eg. ACARS, must be reviewed against MEL criteria.)

## **A.4 Propulsion System Reliability Objective**

- A.4.1 Type Design – A determination will be made that the type design of the propulsion system achieves the desired level of reliability. Transport Canada will determine if the probability of total/unacceptable thrust loss due to design related and/or independent causes meet the criteria of this section.
- A.4.2 Operations – A determination will be made of the propulsion system's ability to achieve the desired level of operational reliability in ETOPS. Transport Canada will determine if the probability of total/unacceptable thrust loss for all independent causes meets the criteria of this section.
- A.4.3 The propulsion system reliability objective will ensure that the propulsion system achieves at least the minimum reliability criteria required of other critical aircraft systems, i.e., navigation, flight control, communications, etc.

Considering the complexity of the entire powerplant system, the approach to determine the reliability has been to use in-service data. This data therefore, not only considers design related failures (Airworthiness Manual Section 525.1309 approach), but also includes maintenance and operational effects on the failure rates

The events to be considered are to include those occurring from the beginning of the take-off roll to the end of the landing phase, though items confirmed as not ETOPS significant will be discounted. Failures considered are, engine in-flight shutdowns (IFSD), any other significant power loss or loss of engine control. The reliability objective used by Transport Canada relates diversion time to the probability of a loss of thrust which precludes continued safe flight.

The target is expressed by the following formula:

$$(10^9)(Pe^2)(t) \leq 1$$

where

Pe = probability of an engine failure (per hour)

t = diversion time (hours)

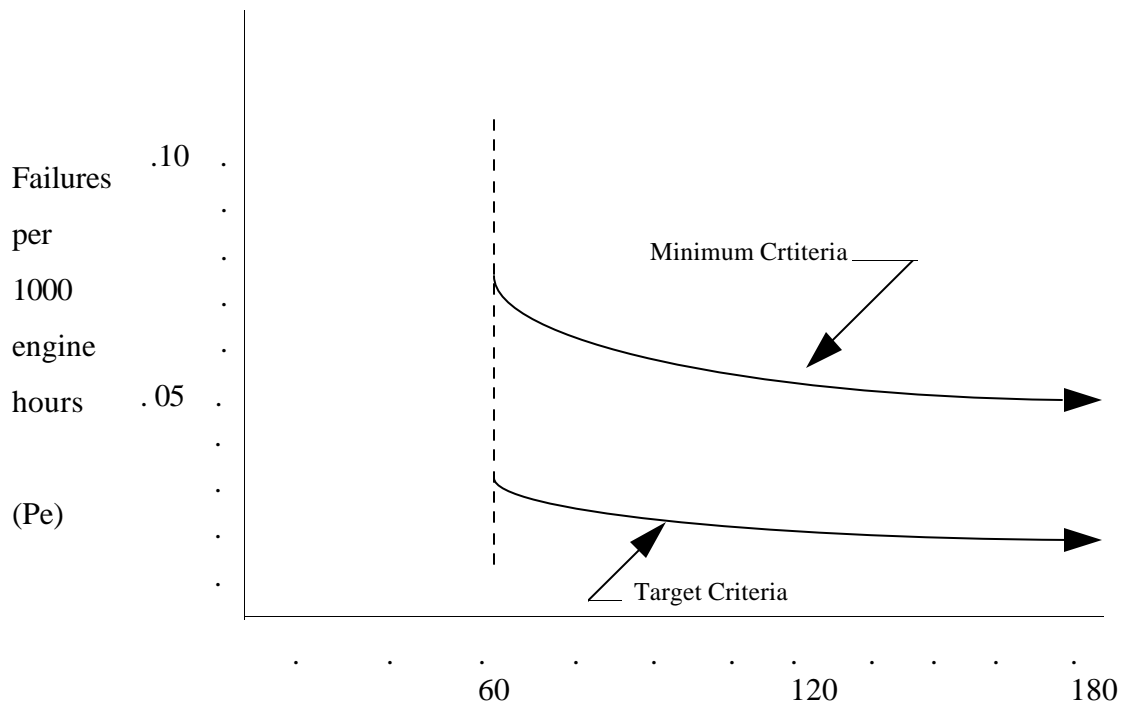
$(10^9)$  represents the life of an entire aircraft fleet (hours)

Transport Canada believes some tolerance is required to account for verified corrective actions and precautionary shutdowns and also to provide for the expected variance over time in propulsion system reliability statistics. Reported occurrences beyond the tolerance will be grounds for withdrawal of ETOPS approval, or reduction in allowed diversion time. The maximum criteria is defined by the following formula:

$$(.25)(10^9)(Pe^2)(t) \leq 1$$

Figure 1

Propulsion System Reliability Objective



Diversion Time (minutes) (t)

## Reliability Table (Engine Failures per 1000 hours)

Diversion Time (t)	Target Criteria	Minimum Criteria
60 minutes	.032	.063
75 minutes	.028	.056
90 minutes	.026	.052
120 minutes	.022	.044
138 minutes	.021	.042
180 minutes	.018	.036