



# Federal Aviation Administration

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## Memorandum

Date: 21 November 2014

To: Diane Cook, Acting Manager, Engine Certification Office, ANE-140

From: Kim Smith, Acting Manager, Engine & Propeller Directorate, ANE-100

Prepared by: Antonio Cancelliere, ANE-141

Subject: INFORMATION: Equivalent Level of Safety (ELOS) for the GENx-1B and GENx-1B/P1 series engine models

ELOS Memo #: AT03359EN-E-P-1

Regulatory Ref: 14 CFR 21.21 and 33.83

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The Engine & Propeller Directorate established an equivalent level of safety finding for the GENx-1B and GENx-1B/P1 series engine models.

### Background

On June 19, 2012, the General Electric Company (GE) submitted an application to the ECO to amend the GENx series Type Certificate to expand the crosswind restriction from 30 knots to 35 knots for ground operations.

Title 14, Code of Federal Regulations (14 CFR) 33.83 requires vibration surveys to establish that the vibration characteristics of those components that may be subject to mechanical or aerodynamic induced vibratory excitations are acceptable throughout the operating envelope.

Section 33.83(d) requires that the combined vibratory and steady state stresses shall not exceed the endurance limits of the materials.

For the GENx-1B and GENx-1B/P1 the combined stresses in some fan outer guide vanes (OGVs) exceed the endurance limits during unrestricted operation between 30 and 35 knot crosswinds.

GE proposed an ELOS to the vibration requirements of § 33.83(d), using compensating factors in accordance with the provisions of 14 CFR 21.21(b)(1). The ELOS proposal included use of a damage accumulation method to combine the calculated low cycle fatigue (LCF) and high cycle fatigue (HCF) lives of the parts exceeding the endurance limits. The damage accumulation analysis shows that the fan OGVs have a total combined life above the allowable service life. A second compensating factor proposed by GE was redundancy in the Fan OGV assembly, meaning that failure of any or all OGVs that exceed the endurance limit will not result in thrust loss or a hazardous engine effect. GE's proposal also included inspections of the fan OGV assembly as an additional compensating factor.

### **Applicable regulations**

14 CFR 21.21, 33.83

### **Regulation requiring an ELOS finding**

14 CFR 33.83(d)

### **Description of compensating design features or alternative Methods of Compliance (MoC) which allow the granting of the ELOS (including design changes, limitations or equipment need for equivalency)**

To address the use of analysis in lieu of test and the fact that the combined stresses in certain OGVs exceed the endurance limit for compliance with § 33.83(d) by an ELOS, the FAA has identified the following compensating factors for the ELOS finding:

1. The failure of any or all OGVs that exceed the endurance limit does not result in a partial or complete loss of thrust, or any hazardous engine effects, and does not compromise the continued compliance of the engine with Part 33.
2. The HCF methodology contains appropriate correction factors for mitigating uncertainties inherent to HCF life prediction. The combined calculated LCF and HCF lives of the fan OGVs should be above 35,000 cycles.
3. Inspections of the fan OGVs provide means for continued risk control. These inspections should be added into the engine's Instructions for Continued Airworthiness (ICA).

### **Explanation of how design features or alternative Methods of Compliance (MoC) provide an equivalent level of safety to the level of safety intended by the regulation**

The safety objective of § 33.83(d) is to reduce the probability of uncontained rotor failure caused by HCF, and to minimize the likelihood of having multiple engines on the same airplane fail due to the same root cause. This safety objective is met through satisfying the compensating factors described above.

GE's analysis used the most conservative assumptions by selecting the minimum material properties value and applying debit factors for wind velocity data and air temperature variations. The peak operating steady stresses and peak vibratory stresses were assumed to occur simultaneously. The highest crosswind of 35 knots was assumed and the maximum operation time in the crosswind was applied. The predicted minimum life of the limiting fan OGV was calculated to be greater than 100,000 cycles by using the conservative methodology combining both the HCF and LCF capabilities. The comparative analysis showed that a failure of any or all fan OGVs that exceed the endurance limit would not result in thrust loss, a hazardous engine effect, or loss of compliance to part 33. GE also added a detailed inspection of the high stress location in the fan OGV that will be performed at each fan stator module overhaul.

**FAA approval and documentation of the ELOS finding:**

The FAA has approved the aforementioned ELOS finding in GENx-1B and GENx-1B/P1 issue paper P-1. This memorandum provides standardized documentation of the ELOS findings that are nonproprietary and can be made available to the public. The Engine & Propeller Directorate has assigned a unique ELOS Memorandum number (see front page) to facilitate archiving and retrieval of this ELOS. This ELOS Memorandum number will be listed in the Type Certificate Data Sheet under the Certification Basis:

An Equivalent Level of Safety Finding has been made for the following regulation:  
14 CFR 33.83 Vibration Test - (documented in ELOS Memo AT03359EN-E-P-1)

(signed by Ann Mollica)

Manager, Engine & Propeller Directorate  
Aircraft Certification Service

Date 21 Novemeber 2014