Technical Airworthiness Authority Advisory (TAA Advisory)	
Title	**Engine Structural Integrity Monitoring Requirements**
TAA Advisory Number	**2016-02e**
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Reference	**TAM Part 3, Chapter 4, Section 2, Annex C**
OPI / Telephone	**DTAES 4-4**
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1 Purpose

1.1 This Technical Airworthiness Authority (TAA) Advisory provides clarification and guidance on how to meet Department of National Defence (DND) requirements for Engine Structural Integrity Monitoring.

2 Applicability

2.1 This TAA Advisory is applicable to all DND owned fixed wing and rotary wing aircraft. For Uninhabited Air Vehicle (UAV) Systems and Leased Aircraft, TAA guidance must be sought to determine if this TAA Advisory is applicable.

3 Related Material

3.1 Definitions.

a. Safety Critical. Parts of an engine whose failure is likely to result in:

(1) substantial damage to the aircraft, a second unrelated system or a second engine system; or

(2) forced landing, loss of aircraft, fatalities or serious injury.

Within the DND/CAF Airworthiness Program, these are considered equivalent to a Hazardous or Catastrophic failure condition. For the purpose of this advisory, reference to components or parts using the term “critical” is taken to mean “safety critical”.

b. In-Flight Shut Down (IFSD). When an engine ceases to function in flight and is shut down, for any reason (e.g., flameout, internal failure, crew-initiated shut-off, foreign object ingestion, icing, etc.), or power reduction, which results in an unacceptable thrust loss. This definition is limited to failure conditions, including forced or precautionary shut downs, but does not include intentional shut-downs, such as loiters.

4 Regulatory References.

4.1 *Technical Airworthiness Manual (TAM)*, C-05-005-001/AG-001.

4.2 Transport Canada TP 6327 – *Safety Criteria for Approval of Extended Range Twin-Engine Operations (ETOPS)* (06/2007)

4.3 FAA AC 33.4-2 – *Instructions for Continued Airworthiness: In-Service Inspection of Safety Critical Turbine Engine Parts at Piece-Part Opportunity*

4.4 QMS AF9000 Procedure EMT 05.006 – *Monitoring of Airworthiness and Aviation Safety Documents (AASD) Within WSM Organizations*

4.5 Report to Congress by the Comptroller General of the U.S. PSAD-80-72 – *Are Management Problems In The Acquisition of Aircraft Gas Turbine Engines Being Corrected?*, September 30, 1980.

5 Discussion

5.1 **Background**.

5.2 A number of high profile catastrophic or near-catastrophic instances of uncontained failure of critical engine components provide graphic illustrations of the need to maintain the structural integrity of engines. Analysis of fifteen years of transport aircraft and incident data shows that the leading cause of engine related accidents resulting in substantial damage or loss of the aircraft for turbofan engines is the uncontained failure of safety critical parts. Various studies suggest incremental improvement with successive generations of engine design. Several Royal Canadian Air Force (RCAF) aircraft types continue to operate with engines that do not benefit from these improvements.

5.3 A causal factor for loss of structural integrity of engines is inaccurate usage tracking due to changing mission profiles. A report by the US General Accounting Office (GAO) (reference 4.5) found that the actual usage of the F404 engine (used in the F/A-18) was significantly more severe than forecasted, necessitating life limit reductions of almost 50%. Similarly, updates to the Cyclic Exchange Ratio (CER) for the CC130E resulted in a 24% increase in the number of cycles consumed per airframe hour for the critical engine components. If increased usage severity is not captured by programmatic review and update, inadvertent exceedance of life limits may occur; conversely, if usage severity has fallen, then critical parts may be retired prematurely.

5.4 From an aging aircraft perspective, the potential increases for difference between the actual engine usage and the design (or baseline) engine usage as the aircraft ages. Therefore, it is essential to ensure the engine critical component life limits and associated assumptions are re-assessed throughout the life of the engine to ensure they are reflective of actual usage.

6 Action/Method of Compliance

6.1 The engine structural integrity monitoring requirements are found in reference 4.1, Part 3, Chapter 4, Section 2 Annex C. The requirement text has been included in this section of the advisory for convenience. Any extracted requirement text is in italics. The TAA guidance material follows the related requirement text.

6.2 **Requirement Text**: Para 2 of the requirement reads as follows:

"2. Basic Requirements. *Each fleet shall establish and document an Engine Structural Integrity Program (ESIP) that meets all requirements herein, with a designate Office of Primary Interest (OPI). ESIP requirements for a specific fleet can be met by developing an Engine Structural Integrity Management Plan (ESIMP) from the requirements specified herein, or by confirming through documentation that other programs already in existence with a specific engine fleet meet all requirements of ESIP. Each engine fleet shall have:*

a. a defined program to, at regular intervals:

(1) re-assess and document actual usage conditions,

(2) compare actual usage conditions against design usage conditions, and

(3) determine life consumption based on actual usage (of critical components, as a minimum) accordingly;

b. […]"

6.3 **Guidance**.

a. This paragraph defines the monitoring activities required for the conduct of an ESIP.

(1) "a defined program". The set of ongoing activities constituting the "defined program" as documented in the ESIMP. The program may be conducted, and the ESIMP developed, by the Weapon System Manager (WSM) or by another organization in the WSM's Weapon System Support Network (WSSN).

(2) "at regular intervals". The reassessment of actual usage and comparison with the design usage (baseline usage) conditions should be based on the role of the aircraft and the likelihood that usage can change over time. Normally, an interval not to exceed five (5) years would be acceptable to the TAA for the low risk of change situations and, more frequently, where there is a potential for significant variation in usage; any change to the Statement of Operating Intent (SOI), change to the Aircraft Structural Integrity Program (ASIP) baseline usage spectrum, or similar change identified by the WSM should trigger a review of usage.

b. "Re-assess and document actual usage conditions." The re-assessment of usage conditions must define the usage spectrum to which the engine has been exposed, so that it may be compared to the baseline usage spectrum. This requires the recording and analysis of operating data:

(1) Recording. There must be some means of recording usage parameters. Parameters may be recorded by hand or digitally, but digitization is necessary for analysis. Parameters must be recorded on a per-flight basis, but on-board recording systems may provide useful real-time recording capability. Engine Original Equipment Manufacturer (OEM) requirements should define the minimum data recording requirement (i.e., parameters and sampling frequency) for usage monitoring.

(2) Analysis. The collected data should be reduced to a statistical data set that is technically representative of the usage spectrum. An OEM or engineering support contractor who performs the comparison should also perform the data reduction analysis.

c. "Compare actual usage against design usage conditions." This is the comparison of the recorded actual usage spectrum against the baseline usage spectrum. If the recorded actual usage spectrum does not fall within the baseline, the baseline usage spectrum must be updated so that the rate of component life consumption may be accurately calculated.

(1) The design usage conditions are the assumed baseline usage spectrum when an engine enters into service on a particular platform, used to determine both life limits and the way in which life consumption is calculated. Given that there are a number of assumptions made during the design stages, the actual usage of the engine may vary from the design usage conditions. Initially, the baseline usage spectrum should be established using the information in the SOI. The SOI may not be updated unless a formal re-role of the aircraft occurs. Usage must therefore be monitored to assess the validity of the baseline.

(2) The engine OEM should be engaged to perform the analysis comparing actual usage to the previous baseline using all recorded usage data (no data reduction) and with reference to any previous usage assessments. If necessary, the OEM will make recommendations on any need to alter the life consumption rate or life limits as

appropriate. If OEM support is not possible, the WSM may employ other elements of the WSSN to perform this analysis.

(3) The process and engineering methodologies used to establish and maintain the baseline usage spectrum must be documented in the ESIMP. The baseline usage spectrum established for the ASIP provides some useful data for the engine baseline, but additional information is required to assess engine usage.

d. Determine life consumption based on actual usage (of critical components, as a minimum) accordingly. If it is found that there has been a change to the baseline usage spectrum such that either the life limits or the calculation of life consumption changes, the results must be incorporated into the approved maintenance program. If a reduction to life limits is identified, fleet records are to be reviewed to determine if any in-service components exceed life limits as a result.

Note

Any change (increase or decrease) to life limits, and/or the means of calculating life consumption, of engine components is considered a major design change.

6.4 **Requirement Text**. Para 2.b. of the requirement reads as follows:

"[…]

b. documentation providing:

(1) a valid and up-to-date listing of all critical engine components,

(2) defined maintenance, inspection and usage monitoring requirements, as applicable, and

(3) defined service life for all critical engine components reflecting actual usage conditions; and

c. […]"

6.5 **Guidance**.

a. Documentation. The recording of this information must be included or referred to in the ESIMP, as described in para 6.8 of this TAA advisory.

(1) The listing of critical engine components (as defined in para 3.1.a of this advisory) includes, but is not limited to, life limited components in the engine. The listing should include any components identified by the Systems Safety Analysis (if available) or as a result of in-service experience/mishap as being safety critical even if no life limit has been assigned. Engine critical components usually include (but are not limited to) disks, spools, spacers, hubs, and shafts and high-pressure cases.

(2) Reference must be made to the approved maintenance program to identify maintenance program requirements. The description of usage monitoring must detail the extent and means of data capture of the parameters necessary to meet para 6.3.b of this advisory.

(3) The defined service life for critical components must be included with the listing, where applicable. If a safe-life philosophy is not used, the design philosophy applied and any lifing criteria should be identified.

6.6 **Requirement Text**. Para 2.c. of the requirement reads as follows:

"[…]

c. a published Engine Structural Integrity Management Plan (ESIMP) that would satisfy these basic requirements.

[…]"

6.7 **Guidance**.

a. A description of the requirements for an ESIMP is provided in paras 6.8 to 6.13 of this TAA Advisory.

6.8 **Requirement Text**. Para 3 of the requirement reads as follows:

"[…]

*3. **Engine Structural Integrity Management Plan (ESIMP)**. ESIP requirements for a specific fleet can be met by developing an ESIMP from the requirements specified herein, or by confirming through documentation that other programs already in existence with a specific engine fleet meet all requirements of ESIP.*

a. […]"

6.9 **Guidance**.

a. The ESIMP is a living document that records how the requirement is met so as to maintain the structural integrity of the engine fleet, and also records the information necessary to enable the management and accomplishment of the requirement.

b. In all cases, the information necessary to populate the ESIMP may be included directly in the ESIMP with references, or the references alone (electronically linked wherever possible) may be provided.

6.10 **Requirement Text**. Para 3.a. of the requirement reads as follows:

"3. […]

a. The ESIMP shall contain or refer to documentation containing the following engine information:

*(1) **Engine Description**. This section will provide a general engine description, including:*

(a) main operating features, variants, physical and operating characteristics, design service life and a list of design changes that were required to accommodate the configuration; and

(b) pictorial and written description of the engine structure and the critical components or refer to documents containing this information.

*(2) **Acquisition Details.** This section will provide the high level details on the contractual arrangement under which the engine fleet was procured, the contractor support arrangements and timeframe for such support.*

*(3) **Type Certification Information.** This section will provide a high-level description of:*

(a) the certification basis/airworthiness standards of the design on which the engine is based and/or used for the DND basis of certification;

(b) the critical engine components design criteria (safe life, damage tolerance, fail safe) and the maintenance actions related to the selected criteria; and

(c) the documentation of the engine model specification and confirmation that the engine satisfies the model specification.

b. […]"

6.11 **Guidance**.

a. Engine Description. Understanding the physical engine design allows an understanding of the thermodynamic cycle, the effect of usage on thermodynamic and mechanical conditions, and the factors that need to be accounted for in assessing usage and its effect on component life. Design changes with an effect on the physical configuration, including the materials, manufacturing processes, or design assumptions used, can alter the effect of usage. The engine description must include:

(1) The model or variant;

(2) A general written or pictorial description of physical characteristics of the engine along with the nominal operating parameters and the operating limits;

(3) Any unique design changes or modifications required for the Canadian configuration should be detailed.

b. Acquisition Details. This data provides insight into the engine design (the design assumptions and engineering practices used to determine the maintenance program, including life limits, may vary amongst OEMs and other suppliers with design authority such as other militaries), and the configuration of the engine fleet (for instance, if some units were acquired separately), as well as the availability of design data. The description must include:

(1) Initial Procurement. A high level overview of the contractual arrangement for the initial procurement of the engine and the number of units acquired.

(2) In Service Support Details. The engine R&O and engineering support contractors along with the pertinent contracting arrangements and the engine contract details.

c. Type Certification. As per para 2.1.1.1.2 of reference 4.1, it is not the intention for DND to proceed with the type certification of an engine that is separate from the aircraft type on which it is installed. However, the engine certification basis or specifications must be identified. A high level overview is sufficient, as follows:

(1) The applicable certification basis document or specification. This may take many forms, for example: a recognized standard such as the UK's Defence Standard 00-970 Part 11 or Federal Aviation Regulation Part 33; a military specification such as US Military spec MIL-E-8593A; or a combination of standards and specifications. Reference to the certification basis is necessary for approval of any significant modifications and repairs, including any changes to component lives. In assessing the effects of usage, reference to the cert basis allows a verification of factors that were (or were not) taken into account in the original certification.

(2) The design criteria or philosophy utilized to ensure/maintain the integrity of critical components (e.g., -3σ N_i, 2/3 dysfunction life). The maintenance philosophy and any changes thereto should also be documented (e.g., reliability centered maintenance) and an overview provided of the major maintenance activities (i.e., overhaul, hot section inspection, etc.) This provides an indication of the means by which compliance was originally demonstrated (the standards applied to achieve certification); the degree of conservatism of the design; and the way in which changes in usage or component life may relate to reliability and/or inspection cycles.

(3) A reference should be provided for the data that substantiates compliance with the applicable cert basis and/or design specifications.

6.12 **Requirement Text**. Para 3.b of the requirement reads as follows:

"3. […]

b. The ESIMP shall contain the following fleet integrity management information or refer to documentation accessible to DND that contains the following fleet management information:

(1) Description, supported by a figure, of all engine critical components including material type, heat treatment and coatings where not limited by IP constraints;

(2) Maintenance, inspection and usage monitoring requirements, as applicable, either directly or by reference to the required technical documentation. Responsibilities for engine usage monitoring activities should be clearly assigned: identification of all required engine usage parameters, the means to collect them, sampling frequency, the data collection and transfer process and the related DND units and contractor responsibilities;

(3) Description of the engine usage parameters being collated, reviewed and documented and how the results of this process are being used to affect the maintenance program activities and schedule;

(4) Description of the processing being performed on the critical component usage data and how the data is being used for engine airworthiness and fleet management;

(5) Description of the data validation and review process, including frequency, and the means by which the results of the above processes are inserted back into the maintenance program activities and schedule;

(6) Usage statistics for both design usage and actual usage in enough detail to assess life consumption against design life for applicable components;

(7) Discussion of any structural issues (such as modifications, fatigue, repairs, environmental wear and degradation) that require attention or are to be monitored for the upcoming reporting period;

(8) Description of currently on-going or planned projects and special activities related to the engine management, such as sampling inspection, follow-on full-scale/component structural test, coupon testing program, etc.;

(9) In-service failure reviews; and

(10) Listing of component improvement programs, or similar programs.

4. […]"

6.13 **Guidance**. In addition to the information provided in para 6.10 and para 6.11, the following information must be included in the ESIMP.

a. **Guidance on Para 3.b.(1).** A description, supported by figures, of all engine critical components, including:

(1) Part name;

(2) Part Number(s);

(3) OEM-recommended life limit, RCAF service life limit and any field limits, as applicable; and

(4) Material type, including details regarding heat treatment and coatings if available.

b. **Guidance on Para 3.b.(2).** The maintenance and inspection program, and the means by which usage monitoring is accomplished must be described IAW the guidance provided in para 6.5.a.(2) of this TAA advisory. The OPI for the ESIMP must be clearly identified along with their responsibilities. The responsibilities assigned within the WSSN for ESIP activities must also be included.

c. **Guidance on Paras 3.b.(3) to 3.b.(6).** Describe ALL of the parameters recorded to satisfy the requirement described in para 6.3.b. of this TAA Advisory. Any recorded parameters that directly drive maintenance program activities (e.g., exceedances, accumulated cycles, hours) should be described and identified as such.

d. **Description** of how the requirements, described in paras 6.3.b to 6.3.d of Annex C of reference 4.1 are met and, as necessary, results incorporated into the approved maintenance program, at an interval no greater than that described in para 6.3.a.(2), to ensure the defined service life for all critical engine components reflects actual engine usage conditions.

e. **Guidance on Para 3.b.(7).** Any significant structural issues should be documented in the ESIMP. If there is a RARM in place, no reference to the RARM is required. If there is no RARM, then it should be captured as an in-service failure.

f. **Guidance on Para 3.b.(8).** A description should be provided for any projects or activities such as a time between overhaul (TBO) escalation or component testing or trialling that are underway or planned relating to the engine. Any significant upgrades or modifications already incorporated into the engine should be documented or a reference provided.

g. **Guidance on Para 3.b.(9).** The means of documenting in-service failures must be described.

(1) In-service failures for engines include, but are not limited to:

(a) Loss of thrust/power, shutdown or failure of any engine;

(b) Inability to shut down an engine or to control power, thrust or revolutions (RPM);

(c) Engine Structural Significant Issues; and

(d) Failure of engine compressor or turbines.

(2) The use of processes (i.e., reference 4.4, or another process deemed to be equivalent by the TAA) to document in-service failures, should include the following components:

(a) Review and Evaluation of the in-service failure;

(b) A root cause analysis of the in-service failure; and

(c) A follow-up action plan to address the in-service failure.

NOTE

The use and documentation of performance metrics are highly recommended, although not required by the TAM. The Inflight Shutdown Rate (IFSD) provides a good indication of the airworthiness of the engine type. Tracking the rates on both a 12-month and 5-year rolling average will provide a trend indicator on engine airworthiness. With low operating hours, the 12-month rolling average may have too much variability to identify trends. The 5-year rate, while making the trend more visible, is slower to register both positive and negative changes. Both rates, as a result, should be monitored and a narrative provided on a periodic basis to explain any resulting changes. Additionally, a Pareto chart listing the top IFSD causes should be developed and updated on a periodic basis. This information is highly useful for monitoring the frequency and severity of occurrences and for establishing resource priorities.

h. **Guidance on Para 3.b.(10).** Component Improvement Programs (CIP) provide visibility and access to information and data from other users, including technical issues and solutions. They provide an avenue for user input and understanding into the OEM processes for usage analysis and lifing, which facilitates maintaining engine structural integrity. Documenting involvement in such programs ensures that all data sources and avenues of investigation are clearly identified; CIP documents or reports pertaining to ESIP requirements must be registered in the ESIMP. If fleet involvement with a CIP is ending, the WSM should be cognizant of the effect on the engineering support capability within the WSSN.

6.14 **Requirement Text**. Para 4 of the requirement reads as follows:

"[…]

*4. **Reporting.** The ESIMP shall be reviewed at least every two (2) years, with the end of the review schedule such that the review data and results are available for presentation to the Airworthiness Review Board (ARB) for that particular year*."

6.15 **Guidance**: The AAR Technical Report should include the status of the ESIMP Activities since the last reporting period.