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A Survey of Aircraft Structural-Life Management Programs in the U.S. Navy, the Canadian Forces, and the U.S. Air Force

Yool Kim, Stephen Sheehy, Darryl Lenhardt

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Summary

The U.S. Air Force owns and operates approximately 6,000 aircraft to meet its force requirements. The average age of these aircraft is approximately 22 years and is expected to continue to rise. Many of the older aircraft are facing aging issues, such as structural deterioration due to fatigue, and many aircraft are expected to encounter such issues as the Air Force plans to keep aging aircraft in service for many years.

Fatigue is a process in which damage accumulates in material subjected to alternating or cyclic loading. This damage may culminate in cracks, which will eventually lead to complete fracture after a sufficient number of load cycles. Concern is growing in the Air Force that structural deterioration in aging aircraft is increasing the maintenance workload, reducing aircraft readiness, and potentially increasing safety risks (Pyles, 2003).

Since 1958, the Air Force has relied on its Aircraft Structural Integrity Program (ASIP) to achieve and maintain the structural safety of its aircraft. ASIP provides a framework for establishing and sustaining structural integrity throughout the aircraft’s life.¹ The program’s overarching objective is to prevent structural failures and to do so cost-effectively and without losing mission capability. ASIP is a key contributor to the Air Force’s force management processes, and the

¹ Note that the term ASIP applies both to the overall program of the service (and of the Canadian Forces) and to individual programs tailored for particular aircraft types. Each individual program would include the aircraft designator in its name (e.g., the C-130 ASIP).
program’s ongoing viability will be critical as the Air Force continues to operate an aging force to meet operational needs.

In recent years, some issues have been raised about inadequate implementation of ASIP. The concern is that an aging force, budget pressures, diminishing program regulation, and challenges in communicating structural condition and structural needs to decisionmakers may be leading to omission or incomplete performance of ASIP tasks. (See pp. 4–6.)

A further concern is that these factors may result in loss of control of ASIP, lack of visibility into the structural conditions of aircraft, and resource-allocation challenges for ASIP. The effectiveness of ASIP could be degraded, which would adversely affect operational effectiveness, flight safety, and fleet sustainment costs.

This report surveys aircraft structural-life management programs in the U.S. Navy, the Canadian Forces, and the U.S. Air Force to offer insights into how the Air Force could strengthen ASIP, particularly in enabling (1) independent and balanced regulation, (2) clear and timely communications, and (3) adequate and stable resources to achieve ASIP effectiveness. Table S.1 compares the technical and operational backgrounds for each service, and Table S.2 summarizes the key characteristics of each program.

**The U.S. Navy’s Aircraft Structural-Life Management**

The Navy operates approximately 2,000 aircraft, based both on carriers and on land. In part because of the limited space and facilities on carriers for inspection and repairs, the Navy takes a “safe life” approach to structural-life management. Under this approach, airframes are assumed to be “flawless” at the time of manufacture, and aircraft are retired by the time fatigue cracks in the airframe initiate, which the Navy defines as reaching a length of 0.01 inch.

The Navy has an explicit policy on structural-life management. It establishes strict structural-life limits for each aircraft type and, to ensure structural safety, requires that aircraft not exceed these limits.
Table S.1
Comparison of Technical Basis and Operational Factors

<table>
<thead>
<tr>
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<th>U.S. Navy</th>
<th>Canadian Forces</th>
<th>U.S. Air Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force structure</td>
<td>About 2,000 fixed-wing aircraft of 20 types</td>
<td>About 350 fixed-wing aircraft of 12 types</td>
<td>About 6,000 fixed-wing aircraft of 40 types</td>
</tr>
<tr>
<td>Operational</td>
<td>Carrier- and land-based</td>
<td>Land-based</td>
<td>Land-based</td>
</tr>
<tr>
<td>environment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical basis</td>
<td>Safe life</td>
<td>Mix of safe life, damage tolerance</td>
<td>Damage tolerance</td>
</tr>
</tbody>
</table>

These limits are established based on the fatigue-life limit of the airframe and its critical components.

To ensure that the aircraft do not exceed their fatigue-life limits during service, the Navy tracks individual aircraft fatigue life in terms of a standard quantifiable metric, fatigue-life expended (FLE). A centralized program rigorously tracks the FLE for all aircraft and disseminates the information in a formal report to the organizations that support and operate the aircraft. Rigorous and accurate monitoring of fatigue life is critical to the Navy because, under the safe-life approach, there is no routine inspection for cracks to validate the structural condition. The centralized fatigue-life tracking program further has a dedicated funding line to provide independence to its assessments and to ensure that this critical task is carried out.

The Program Manager for Air (PMA) is responsible for the total life-cycle management of the designated fleet. PMA has the ownership and decision authority for structural-life management of the fleet (except for fatigue-life tracking). PMA uses the FLE information in making resource allocation decisions, such as conducting a service-life extension program, force structure planning, and scheduling modifications. The Naval Air System Command’s Structures Division has regulatory responsibility for the technical aspects of structural-life management, providing an independent technical assessment of PMA’s structural-life management decisions. The communications between the principal organizations involved in structural-life management are primarily informal, facilitated by their working relationship and colocation.
Table 5.2  
Summary of Key Characteristics in the U.S. Navy, the Canadian Forces, and the U.S. Air Force’s Aircraft Structural-Life Management Programs

<table>
<thead>
<tr>
<th></th>
<th>U.S. Navy</th>
<th>Canadian Forces</th>
<th>U.S. Air Force</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Structural-life management policies are explicit.</td>
<td>• The policy is broad and is based on the concept of airworthiness.</td>
<td>• Policies are broad and flexible and are based on broad objectives.</td>
</tr>
<tr>
<td></td>
<td>• Authority for the technical aspects of structural-life management is centralized.</td>
<td>• The regulatory structure is independent but organizationally centralized.</td>
<td>• The regulatory structure is flexible and decentralized, with minimal regulation and oversight.</td>
</tr>
<tr>
<td></td>
<td>• A single, standard metric, FLE, conveys structural conditions.</td>
<td>• Regulations exist to ensure communication and sharing of critical information.</td>
<td>• Visibility of ASIPs and structural conditions across a command is limited.</td>
</tr>
<tr>
<td></td>
<td>• Results of rigorous fatigue-life tracking are disseminated frequently, through a formal fatigue-life report.</td>
<td>• Colocation and close working relationships facilitate informal communication.</td>
<td>• Communications with the lead command on ASIP and structural issues are limited.</td>
</tr>
<tr>
<td></td>
<td>• Close working relationships and colocation promote and facilitate informal communication.</td>
<td>• A single authority (the weapon system manager [WSM]) controls funding for structural-life management for the designated fleet.</td>
<td>• A single authority (the lead command) controls funding for structural-life management of the multiple fleets in the command.</td>
</tr>
<tr>
<td></td>
<td>• The structural-life monitoring program has dedicated funding.</td>
<td>• The ASIP master plan provides formal planning for resource management.</td>
<td></td>
</tr>
</tbody>
</table>

The Canadian Forces’ Aircraft Structural-Life Management

The Canadian Forces operate approximately 350 land-based aircraft of 12 different aircraft types. Because they are based on U.S. Navy designs, the Canadian Forces had originally implemented a safe-life approach to structural-life management. As the Canadian Forces have
sought to extend the service lives of their aircraft, however, they have shifted to a “damage tolerance” approach. Damage tolerance assumes that the material of the airframe has flaws at the time of manufacture and that slowly growing cracks in the structure can be tolerated until they are detected and repaired. Structural inspection intervals are determined to ensure that a crack does not reach its critical size without being detected. Unlike the U.S. Navy, the Canadian Forces do not have carrier-based aircraft; thus, implementing a routine inspection for cracks to accommodate the damage-tolerance approach was not restricted by the space limitations on carriers.

The Canadian Forces take a regulatory approach to structural-life management. An independent regulatory authority, the Technical Airworthiness Authority (TAA), provides regulations and oversight for all weapon systems’ ASIPs and assesses compliance. The governing policy regarding structural integrity is broad and is based on the concept of “airworthiness,” in which the airworthiness requirements are defined in each aircraft type’s basis of certification. An aircraft must remain in compliance with its basis of certification throughout its service life to be considered “airworthy.”

The broad regulations allow each WSM to customize an ASIP for the specific weapon system. The TAA evaluates ASIP compliance on a case-by-case basis via formal airworthiness monitoring and approval processes. The approval processes focus on the tasks that are the linchpins of aircraft structural-life management, such as the airworthiness certification and design-change certification processes, to balance the level of regulation.

The regulatory approach requires considerable formal communication. The formal processes require documentation of critical information for traceability and planning purposes, as well as for assessing compliance. Additionally, colocation of key authorities in structural-life management facilitates informal communication among them.

The resource management plan is formally documented in the weapon system’s ASIP master plan. As the funding and decision authority for the fleet’s ASIP, the WSM must approve the plan. The master plan includes the short- and long-term tasks necessary for
maintaining the structural integrity for the fleet. TAA’s regulatory role provides independent assessments of WSM’s resource allocation decisions.

The U.S. Air Force Aircraft Structural-Life Management

The U.S. Air Force operates a much-larger force with a wider range of aircraft types, about 40. The Air Force’s ASIP is based on the damage-tolerance philosophy described earlier. The governing policy on ASIP is broad, focusing on the program’s objectives, to allow tailoring of an ASIP for each aircraft type. Each system program director (SPD) is responsible for implementing an ASIP for its fleet. The lead command has the funding authority for the fleet management of the multiple fleets within the command, including ASIPs. As a result, the lead command has a significant influence on ASIP implementation.

The Air Force has a flexible, decentralized regulatory structure with minimal ASIP regulation and oversight. There is no regulation to enforce certain ASIP tasks or to provide an independent technical assessment of the lead command’s decisions about structural integrity. Because of this broad policy, the U.S. Air Force recommends multiple measures for assessing ASIP compliance, including mishap rates due to structural failure. This measure, however, is problematic because it is a lagging indicator.

The Air Force does not have a standard metric for communicating aircraft structural condition, partly because of the decentralized ASIP implementation. As a result, the lead command has a limited commandwide view of the structural condition of its fleets, and this makes understanding the relative states of the fleets for resource-allocation purposes challenging.

Communication between the SPD and the lead command about ASIP and structural condition is limited because of the limited involvement of the lead command in the ASIP process (other than

\[2\] When more than one major command possesses the same type of weapon system, one of them will be designated as the lead command for that system.
budget programming) and the geographic separation between them. Some lead commands use a technical liaison to facilitate the communication with the SPDs and to better understand the implications of the resource decisions (e.g., risk of structural failure, effects on operational effectiveness, preventing costly repairs).

**Observations About Different Approaches**

Explicit policy on ASIP provides clarity on ASIP compliance but limits flexibility in structural-life management. Broad policy on ASIP, on the other hand, enables flexibility in ASIP implementation for tailoring but risks lack of clarity about what constitutes acceptable ASIP compliance. The policy should be sufficiently explicit to provide general guidance on ASIP compliance but should rely on independent assessment of ASIP compliance on a case-by-case basis to enable tailoring. (See pp. 67–68.)

ASIP regulations can provide checks and balances for structural-life management, enable clear and timely communication, and promote stable and adequate resources for ASIP. Regulations could also lead to complex processes and management inefficiencies. The regulations should thus focus on elements of ASIP that are critical to the program’s viability to ensure a balance between its control and flexibility. (See pp. 68–69, 72–75.)

Centralization enables standardization of program management and a forcewide view of ASIP compliance and aircraft fleet status, while decentralization enables tailoring to a specific weapon system to achieve a cost-effective ASIP. Centralization of a set of selective ASIP tasks, where standardization is useful, could still allow other aspects of ASIP to be tailored for cost-effectiveness. (See p. 71.)

Regulations, communications, and resource-management approaches are highly interdependent and need to complement each other and the context of the program (e.g., safe-life versus damage tolerance) to achieve ASIP effectiveness. Operational factors, such as the force size, may present certain scalability challenges. The U.S. Air Force’s large-scale force with its wide range of aircraft types may pose
some challenges for standardizing and/or centralizing certain aspects of ASIP across the force.

**Options for the Future**

Our survey suggested several options for the Air Force to consider for enhancing ASIP:

- Clarify ASIP policy and extend existing processes to enable independent assessment of ASIP compliance.
- Formalize key ASIP processes and assign an independent assessment authority to continue enforcement of ASIP and enhance communications.
- Facilitate communications between the lead command and the system program office by establishing close working relationships.
- Instill standardization for commandwide view.
- Dedicate separate funding lines for critical ASIP tasks.