

FIVE DEACADES OF T-38 WING TEARDOWNS: DATA, INSIGHT, AND IMPACT

Teresa Moran[1], Isaac Grothe[1], Chad King[2], Laura Hunt[1] & Dr. Paul Clark[1]

[1]Southwest Research Institute
[2]United States Air Force

Abstract

Aircraft teardowns completely disassemble retired airframes or components, and use various NDI techniques to find cracks, corrosion, or other defects on the structure. Teardown activities of aircraft can be critical for long-term sustainment. These actions provide opportunities to evaluate areas that are generally not able to be inspected. Information gained from teardowns help in fleet management and maintenance execution for ever evolving airworthiness challenges. This study pulls together decades of teardown lessons learned from the T-38 Talon trainer.

The T-38 Talon, a twin-engine supersonic trainer, has been a foundational part of United States Air Force pilot training since its introduction in the 1960s. Known for its reliability, maneuverability and versatility, the T-38's initial design lifespan has been significantly extended over the years. Changing mission requirements, advancements in aviation science and the costs of new aircraft development have made it essential to extend the aircraft's life span. Teardowns, wing iterations and other service life extension programs have played a pivotal role in ensuring fleet sustainability while meeting modern demands. For five decades, Southwest Research Institute (SwRI), Northop Grumman, and the United States Air Force have performed wing teardowns of the T-38 aircraft starting with production wings in the 1970s and continuing through today. Throughout the history of the T-38 aircraft there have been seven iterations of wing designs installed on the fleet, each incorporating improvements based on fatigue test data, field findings and teardown results. This study focuses on the wings installed in the 1970s to present day, with particular attention to the penultimate iteration of the T-38 wing, which has been flying since 1979. There have been over 40 full and partial teardowns performed on these wings with the first one happening in 1992.

The teardown investigations have been instrumental in shaping the T-38 fleet management. Key contributions include design changes in the updated wings, refining Equivalent Initial Damage Size (EIDS) distributions for risk analysis, improving inspection techniques, capturing wing cracking trends and locations, and validating analytical predictions. The teardown process has allowed reinforcement for current fleet management along with bringing needed attention to fatigue-critical areas. Teardowns have helped bring characterization and attention to previously existing and additional fatigue critical analyzed locations. This has helped provide actionable predictions that directly informed maintenance schedule, enhanced risk understanding, and improved reliability.

The penultimate iteration of the T-38 wing is currently flying and there are a few aircraft that will continue flying with those wings into retirement. Meanwhile the latest wings began being delivered and installed in 2011 and are now deployed across a majority of the fleet and are expected to remain in service until the eventual replacement of the T-38 aircraft and potentially beyond. This fiscal year

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marks a new milestone, with the first condemnation and teardown of the newest T-38 wing iteration underway. The lessons learned from the teardown of T-38 wing iterations will be critical for validating their projected performance and ensuring safe operation beyond their initial design lifespan. These findings may also provide valuable insights applicable to the T-38's eventual replacement, paving the way for more resilient fighter-trainer aircraft designs.

The continuity of this teardown program over five decades presents a rare opportunity to build one of the most comprehensive datasets on aircraft aging and durability, providing insights not only for the T-38 program but also for broader applications in military and civilian aviation. Combined with service life extension programs, the wing teardown and replacement efforts have enabled T-38 aircraft to remain an essential part of USAF pilot training curriculum for 65 years.

Keywords: teardown, failure investigation, damage tolerance analysis

1. Introduction

Destructive teardowns provide critical insight into aircraft structural integrity and an overview of damage present in the fleet. Findings from detailed teardown analyses inform maintenance and inspection intervals, support lifecycle management decisions and guide structural risk assessments. Over the years teardowns of T-38 wings have been accomplished by Southwest Research Institute and Sabreliner Aviation through multiple support contracts with Center for Aircraft Structural Life Extension (CAStLE) at the United States Air Force Academy (USAFA). Teardown activities allow for insight for assuring structure integrity of the penultimate T-38 wing iteration. This data allows the United States Air Force (USAF) to more efficiently manage the T-38 fleet of the penultimate wing iteration and their eventual retirement and replacement with the ultimate wing iteration.

2. Background

2.1 T-38 Talon

The T-38 Talon is a two-seat, twin-engine jet trainer primarily used by the United States Air Force (USAF). It has played a central role in U.S. military pilot training since the early 1960s. In the 1950s, Northrop Corporation developed lightweight fighter and trainer concepts that led to the T-38 and the F-5A. The T-38 entered operational service in 1961, and more than 1,000 aircraft were produced and delivered between 1961 and 1972. The T-38 has trained over 75,000 pilots since its induction into service[1].

The T-38 holds the distinction of being the world's first supersonic trainer to enter operational service. Its design emphasized simplicity, high thrust-to-weight ratio, and relatively low operating costs, enabling student pilots to progress from basic jet handling to advanced maneuvers, formation flying, instrument procedures, and introductory tactical training. The aircraft has been the primary advanced jet trainer for the USAF pilot training for more than six decades. Multiple service life extension programs have been implemented to keep the aircraft in service, including structural replacements and upgrades, avionics and propulsion upgrades, and systems improvements to enhance safety, reliability, and training relevance.

USAF is the primary user of the T-38 as a trainer, but it has been modified and employed for several other capacities. USAF and NASA have used it for test support, chase operations, safety observations and astronaut proficiency flying. US Navy also has their own fleet that they support. Internationally, T-38 aircraft have been loaned to other countries in the past and currently.

The T-38 Talon has served for more than six decades as the USAF's principal advanced jet trainer and as a versatile utility platform for test and astronaut support. Its long service life, extensive modernization, and enduring role in the training of military pilots underscore its historical significance and its impact on jet training doctrine worldwide.

2.1.1 Wing Iterations

Throughout the history of the T-38 Talon there have been seven different wing iterations. These iterations will be referred to as Wing A – Wing G in this report. Wing A and Wing B were installed at aircraft production and delivery, while Wing C, D, and E were produced as spares used in the 1960s and 1970s. Wing F was designed and produced as a full fleet replacement and was installed in the 1980s through the early 2000s. A subset of these, referred to as Wing F+, incorporated enhanced features introduced during production but did not involve a complete redesign. Wing G iterations are still produced and installed today. Wings F and G remain in service and are expected to continue flying into the early phases of T-38 retirement and divestiture. Wing F has been the primary focus of teardown activities, with more than 40 full and partial teardowns completed on this iteration. These have included wings with diverse usages and operational histories.

2.2 Teardowns

Aircraft teardowns involve the complete disassembly of retired airframes or components and the use of various NDI techniques to identify cracks, corrosion, and other structural defects. Teardown activities are critical for long-term sustainment because they provide opportunities to evaluate areas that cannot typically be inspected in service. Information gained from teardowns supports fleet management and maintenance planning in the face of evolving airworthiness challenges. Most teardowns on the T-38 have focused on Wing F. However, the first teardowns were performed on Wing A and Wing B in the 1970s. The current series of wing teardowns, which began in 2012, has been performed exclusively on Wing F iterations. Teardown activities follow procedures established by the CAStLE Teardown and Analysis Protocols [2].

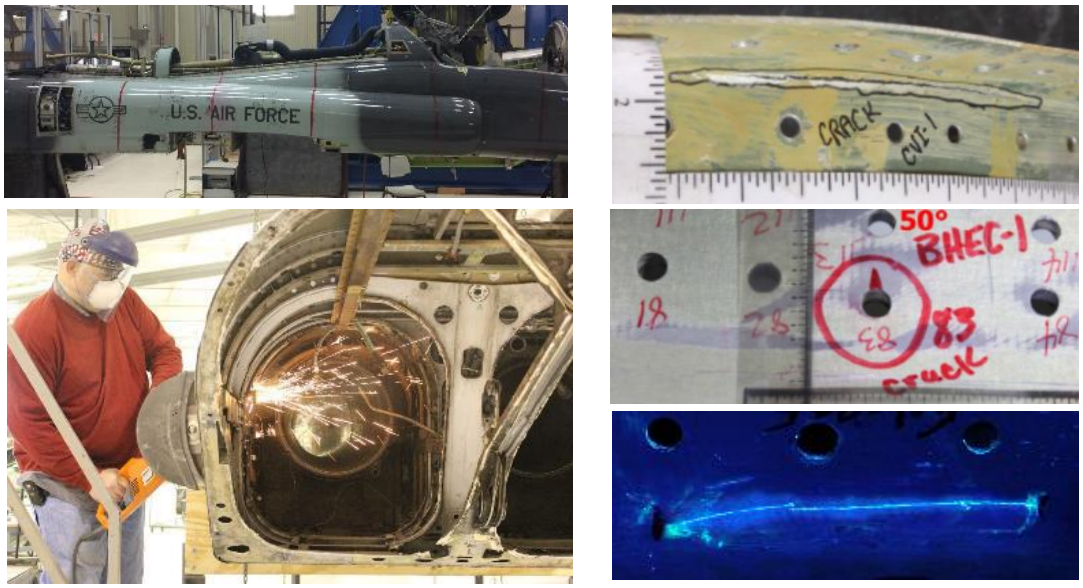


Figure 1 – Process of a teardown

2.2.1 Data

Since 2012, there have been more than 30 full and partial wing teardowns on Wing F, and these efforts are ongoing. From these teardowns, over 10,000 indications have been identified. These indications have been found using NDI methods such as close visual inspection (CVI), fluorescent penetrant inspection (FPI), eddy current surface scan (ECSS), and bolt hole eddy current (BHEC). Figure 2 shows the crack indications that have been found from all teardowns since 2012.

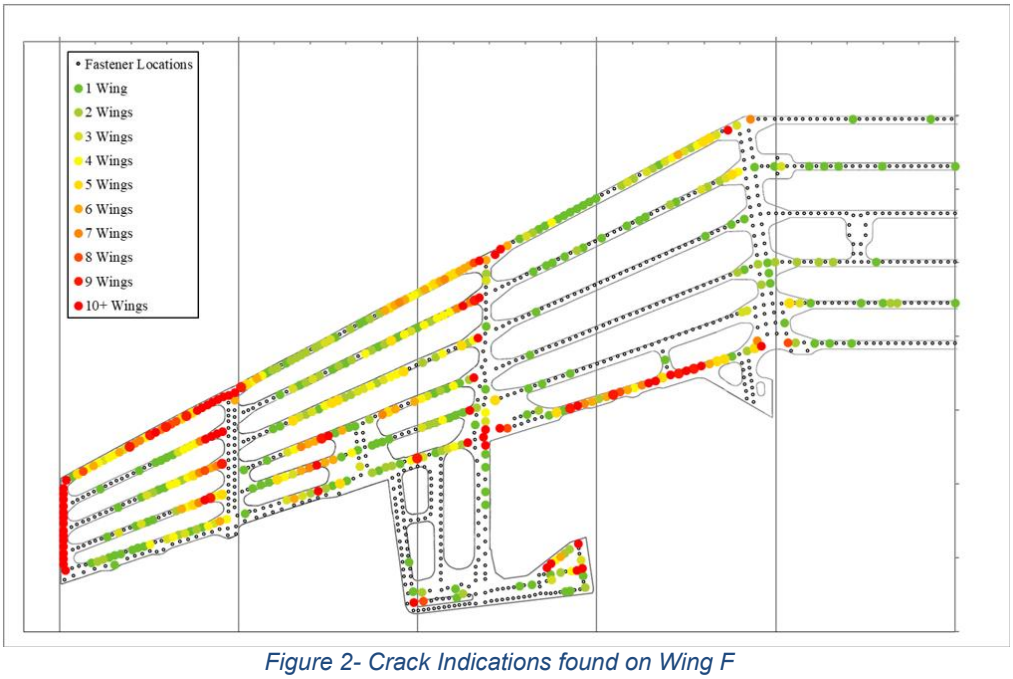


Figure 2- Crack Indications found on Wing F

The indications from all inspections have been down-selected from more than 10,000 to those with sufficient damage or location significance to warrant further study. A prioritization process for these locations is conducted by a team including USAF and SwRI personnel. This selection process has resulted in more than 1,500 full failure analyses. Engineers and scientists perform in-depth inspections and evaluations to determine the root cause of the NDI indications. These inspections and evaluations include, but are not limited to, determining crack origin and propagation, defect size, photographic and microscopic documentation, failure type, and material properties. The failure analyses are grouped into six categories: fatigue, mechanical damage, corrosion, no finding, stress corrosion cracking, and overstress. A large portion of the failure analyses indicate fatigue cracking as the cracking mechanism. Table 1 lists the ten fastener holes with the highest number of fatigue cracks on the wing. Although both upper and lower wing skins and all substructures are evaluated, most of the critical cracked holes are on the lower wing skin.

Table 1 – Top Ten Holes with Cracking

Hole	No. of Fatigue Cracks	Side	Part Description
455	49	RH	Wing Skin, Lower
455	43	LH	Wing Skin, Lower
429	24	RH	Wing Skin, Lower
569	19	RH	Wing Skin, Lower
498	18	LH	Wing Skin, Lower
879	17	LH	Wing Skin, Lower
214	15	RH	Rib, Attach, Wing to Fuselage
500	15	LH	Wing Skin, Lower
879	15	RH	Wing Skin, Lower
709	13	LH	Wing Skin, Lower

2.2.2 Data Storage

The T-38 program office utilizes the NLign product suite as a centralized database for repairs, discrepancies, teardown data, and failure analyses across the fleet. NLign provides an interactive 3D environment that allows users to capture, visualize and store maintenance and engineering data directly on a digital model of the aircraft. This spatially referenced approach enables technicians and engineers to record and observe the exact location of damage, repairs, inspection findings, and failure data, creating a detailed location-based history over the life of the aircraft.

The ability to perform locational searches on teardown and discrepancy data, such as querying all findings in a specific region, has been particularly valuable for fleet maintenance. It supports trend analysis and helps highlight recurring issues in specific areas. As a result, NLign enhances the program office's ability to make data-driven decisions that optimize life-cycle management of the T-38. Figure 3 below shows the teardown data on top of a 3D model of the wing. Each data point shown can be selected to bring up the teardown analysis information that is attached to it.

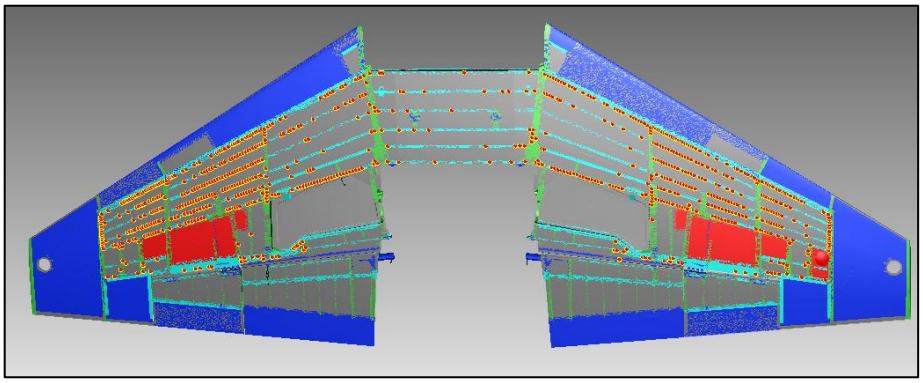


Figure 3 – Wing Teardown Data Shown in NLign

2.3 Aircraft Structural Integrity Program (ASIP) Requirements

MIL-STD-1530 was first introduced as United States Air Force (USAF) as the governing standard for the Aircraft Structural Integrity Program (ASIP) in 1972. Before the advent of MIL-STD-1530 there was no standard for ASIP practices across the USAF, practices were program specific and internally guided. Key features of MIL-STD-1530A (1972) included a definition of ASIP tasks: design, analysis, test, inspection, maintenance planning and data feedback, defined requirements for damage-tolerance design and analysis, enforcement of ASIP processes and deliverables for new aircraft and modifications. Previously the USAF used a safe-life design for fatigue life. MIL-STD-1530C was published in 2005 and introduced formal risk analysis management, changes to nondestructive inspection (NDI) due to advancements, along with further advancements to support the changing atmosphere. MIL-STD-1530D (2016) is the standard that USAF is currently using. MIL-STD-1530D outlines many requirements for design and sustainment of aircraft, with a focus on a continuous, data drive approach to structural integrity. The data and impact of continuous wing teardowns will be discussed in relation to Durability and Damage Tolerance Analysis and Structural Risk Analysis in this report, along with the effects on wing redesigns and replacements.

3. Insight and Impacts

Though the data from wing teardowns has multiple applications this will focus on Durability and Damage Tolerance Analysis (DADTA), structural risk analysis and wing redesigns and replacements.

3.1 Durability and Damage Tolerance Analysis

Sustainment of the T-38 incorporates both durability and damage tolerance philosophies. These philosophies were adopted with the advent of MIL-STD-1530. MIL-STD-1530D requires periodic updates to the Durability and Damage Tolerance analysis. According to MIL-STD-1530D[3] a durability criterion "shall be established to ensure the aircraft structure can achieve the design service life and that in-service maintenance is economically viable." Similarly, a damage tolerance criterion "shall be established to ensure the aircraft structure can safely withstand undetected flaws, corrosion, impact damage, and other types of damage throughout its design service life." The T-38 was not originally designed to these criteria however implementation of these have proven to ensure T-38 flight safety in conjunction with a focused inspection program. Engineering tracks Fatigue Critical Locations (FCL) on the wing and the fuselage with durability and damage tolerance analysis.

Damage tolerance analysis (DTA) is key to airworthiness criteria defined by MIL-STD-1530. Damage tolerance accepts that small cracks and defects exist from manufacturing or may initiate in service. A damage tolerant approach focuses on evaluation of crack growth and ensuring that cracks are detectable by inspection before failure. Characteristics that affect DTA include material behavior, loads and usage, inspection capabilities, and crack and structure geometry. In a DTA a rouge flaw is assumed, and crack growth is analyzed to the critical crack size, conversely durability is assumed pristine and analyzed to the state where damage becomes significant.

Durability correlations are used to create confidence in durability and damage tolerance analysis. A durability analysis is performed with a damage tolerant analysis from a 0.005" initial crack size used to model a pristine condition. That crack curve is plotted along side wing teardown data. The flight hours used for the teardown data points are equivalent flight hours (EFH), EFH hours are baselined to T-38's most severe usage. When teardown data is shown to the right of the durability curve it is meant to be conservative, while if data shows to the left it is meant to be unconservative. These correlations are used to evaluation methodology changes, spectra updates and inspection determinations.

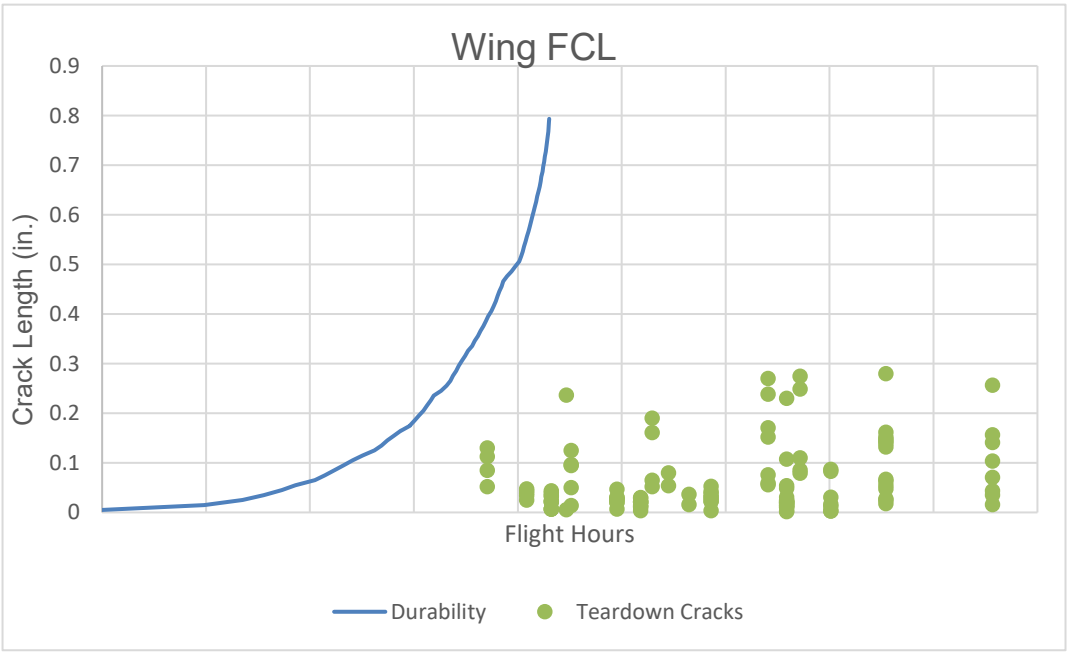


Figure 4 – A Durability Curve Correlation

3.2 Risk Analysis [4]

The primary objective of structural risk analysis is to calculate the Single Flight Probability of Fracture (SFPOF) at an FCL. This is done using probabilistic fracture mechanics. The USAF's Aircraft Structural Integrity Program defines an SFPOF below 10^{-7} is typically acceptable, while one above 10^{-5} is unacceptable, show in Figure 5.

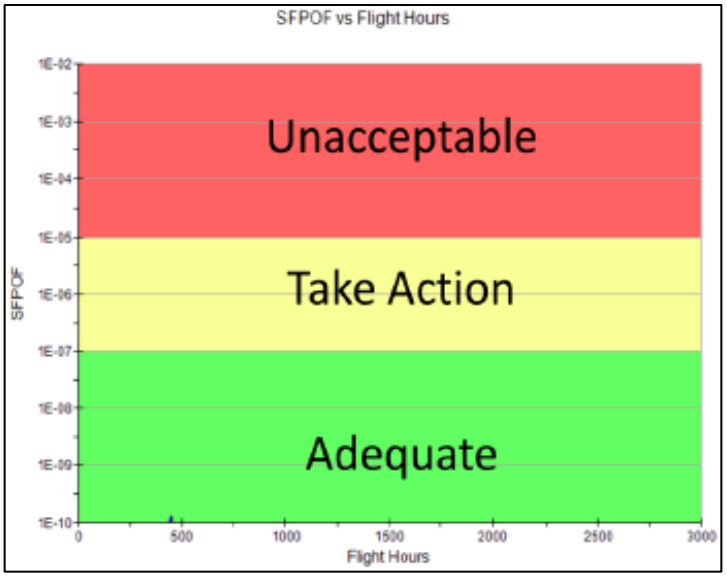


Figure 5 – SFPOF Acceptability Levels

T-38 engineering uses PROF [5] to quantify risk and guide inspection, replacement, and retirement decisions for aging structure. PROF models crack populations while accounting for variability in material properties, usage, inspection, and repair, using DTA based inputs. Stress intensity factors, crack growth curves, inspection intervals, and number of locations are deterministic; fracture toughness, initial/repair flaw sizes, maximum stress per flight, and NDI probability of detection are probabilistic.

Risk analysis requires an initial damage size distribution, which has the largest effect on SFPOF for the T-38. Because real structures experience machining variability and maintenance damage, the Equivalent Initial Damage Size (EIDS) method is used. Observed cracks are extrapolated along a crack growth curve to a hypothetical initial size at entry into service; multiple findings produce an EIDS distribution, this is illustrated in Figure 6.

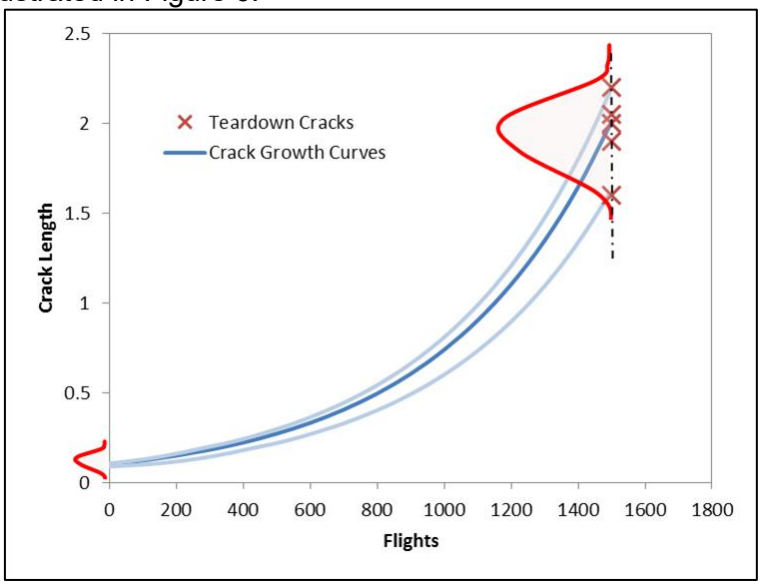


Figure 6 – Illustration of the equivalent initial damage size method

Obtaining high quality EIDS data is difficult because ideal in-service crack characterization is destructive. Before T-38's intensive teardown program, SwRI derived EIFS distributions for T-38 wing

fastener holes from full scale tests, separating coldworked and non-coldworked holes. In the late 2000s, the T-38 program used the expanded teardowns to develop FCL-specific EIDS distributions. It now has ten distributions for the highest-priority wing and fuselage locations and manages the fleet via risk analysis by adjusting inspection intervals, scheduling one-time inspections, and prioritizing part replacement. Figure 7 shows the effect of an FCL-specific EIDS distribution that was created from confirmed crack failure analyses in teardowns.

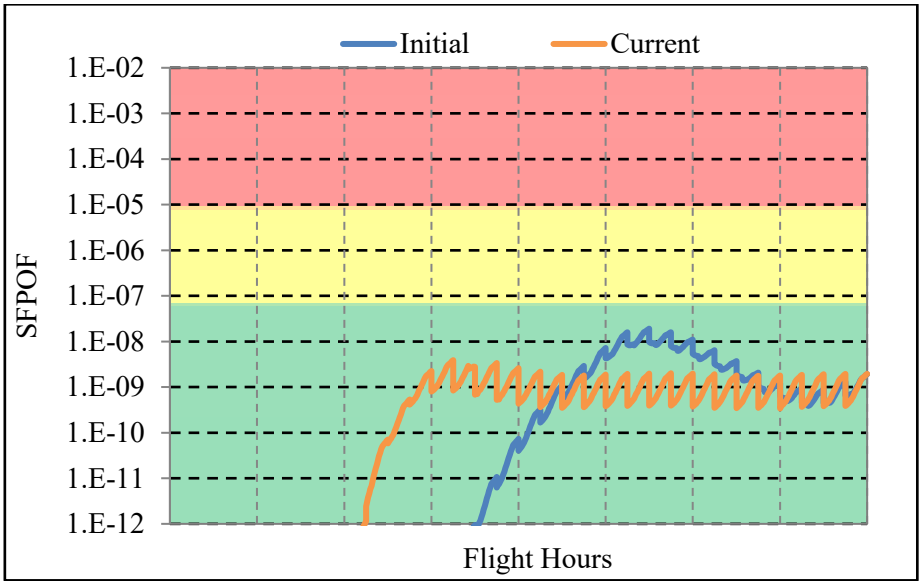


Figure 7 – Risk analysis for initial vs current EIDS distributions

3.3 Wing Redesigns and Enhancements

All T-38 wing iterations have been designed by the Northrup Grumman Corporation. Each redesign that resulted in a new wing iteration has been driven by two objectives economic life and increased recurring inspection intervals. Areas of known cracking are targeted for improvements. Design changes implemented through iterations have included:

- Addition of coldworked holes
- Material upgrades
- Correction of mill pocket issues
- Removal of wing skin mill pockets
- Radius changes of critical areas

Toward the end of the Wing F production run, a subset of wings was built with additional enhancements; these are designated as Wing F+. One of the key enhancements was the addition of coldworked holes. Wing F originally incorporated coldworked holes in its baseline design and production configuration. Further coldworked holes were subsequently introduced as a field maintenance initiative, as shown in Figure 8. Durability curve correlations for Wing F indicated that the analytical life predictions at coldworked holes were conservative. Based on this, additional coldworked holes were incorporated into the lower wing skin of Wing F+ during production, as illustrated in Figure 9.

The progressive evolution from earlier T-38 wing designs through Wing F and Wing F+ reflects a focused strategy to mitigate known cracking, leverage conservative durability behavior at coldworked features, and extend wing life and inspection intervals through targeted structural enhancements. These progressions also continued into Wing G.

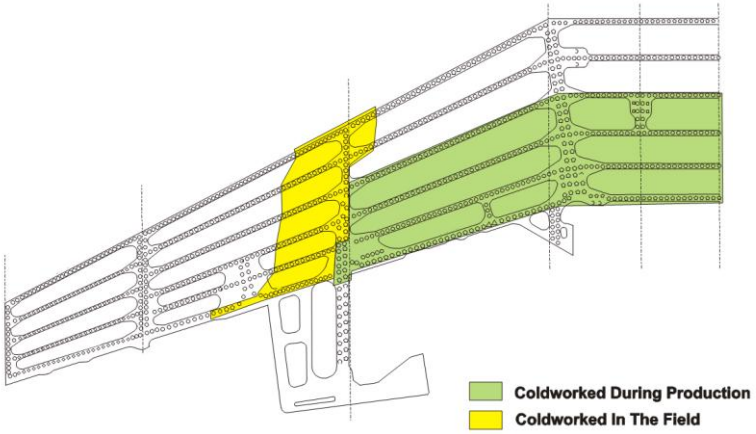


Figure 8 – Wing F Cold Worked Holes

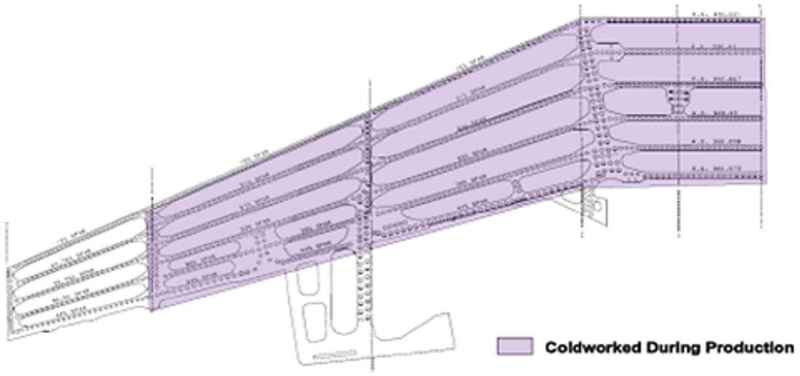


Figure 9 – Wing F+ Cold Worked Holes

4. Conclusion

The T-38 Talon was originally designed for a 20-year service life, yet it is now entering its fourth 20-year service period as it continues to fly toward retirement and divestiture. Sustaining this trajectory has required a coordinated combination of structural redesigns, focused inspections, and service life extension initiatives. Wing teardowns have been central to this effort. In 2026, the first teardown of Wing G, the final planned wing iteration for the T-38, is scheduled, underscoring the program's commitment to continuous planning and data collection to keep the fleet pertinent to USAF needs.

Over five decades, the continuity of this teardown program has produced a uniquely comprehensive dataset on aircraft aging and durability, with implications that extend well beyond the T-38 to military and civilian fleets alike. The systematic collection, analysis, and application of teardown data, combined with targeted wing redesigns, replacements, and other service life extension initiatives, have significantly advanced the understanding of structural longevity in high-usage trainer aircraft. These efforts have directly informed durability and damage tolerance analyses, refined structural risk assessments, and guided practical improvements in inspection planning and maintenance execution.

As a result, the T-38 program has moved from reacting to individual findings toward proactively managing fleet-wide structural integrity based on high-fidelity evidence from actual hardware. The wing teardown and replacement efforts have served as a foundation of this approach, enabling engineers to validate analytical models, calibrate risk analysis, and implement design enhancements focused on known fatigue critical locations. Collectively, this work has not only deepened understanding of aircraft structural behavior over extended service lives but has also enabled the T-38 to remain a vital component of USAF pilot training in support of fifth generation fighters. The methods and insights developed through this sustained effort provide a practical template for managing other aging aircraft fleets as they, too, operate far beyond their original design lives.

5. Contact Author Email Address

Tess.moran@swri.org

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