USAF F-16A/B FUEL SHELF JOINT STRUCTURAL RISK ASSESSMENT

Kevin M. Welch
Lynette L. Hajovsky
Matthew S. Edghill
Tim C. Jeske
F-16 Structural Integrity Team - Lockheed Martin Aeronautics Company - Fort Worth, Texas

Robert Kidd
Aeronautical Systems Center - USAF (312 AESG/ENF)

Robert McCowin
Formerly Ogden Air Logistics Center, USAF (501 ACSS/GFFBS)

ABSTRACT

Lockheed Martin Aeronautics Company (LM Aero) was tasked by the Ogden Air Logistics Center F-16 Program Office to perform an extensive fail-safe analysis and overall risk assessment of the USAF F-16 A/B fleet. The analysis process involved:

- Updating the USAF F-16 A/B durability and damage tolerance analysis
- Developing new individual aircraft tracking models
- Performing residual strength and residual life analyses
- Performing structural risk analysis
- Reporting results using hazard matrix terminology

Five airframe areas that had not received designated modifications for improving service life were considered for risk assessment:

- Fuel shelf joints
- Lower FS 446 bulkhead
- Upper center fuselage skins
- FS 479 bulkhead vertical tail attach pads
- Upper and lower wing attach fittings

As a result of this effort, convincing data was provided to USAF operational authorities which resulted in decisive force management actions.

This paper will describe the above effort for the Fuel Shelf Joint (FSJ) Area with emphasis on the risk assessment results. Development of the FSJ fail-safe scenario will be described, inputs for the risk assessment will be identified, a summary of IAT results will be presented, the risk vs. flight hours results will be shown, and fleet projections provided.

The risk assessment was performed using the LM Aero software program identified as PC-based Structural Tracking Risk Assessment Procedure (PCSTRAP). PCSTRAP is used to perform tailored structural risk assessments, stochastic structural maintenance planning and structural maintenance scenario comparisons based on Individual Aircraft Tracking (IAT) data and analysis results. PCSTRAP is a stochastic fleet management tool intended for use by depot-level

structural engineers or structural maintenance planners with appropriate technical understanding. Most of the required user inputs are items familiar to depot engineers or maintenance planners with most of the statistical information developed from data supplied directly from aircraft structural tracking programs.

BACKGROUND

USAF leadership had become concerned that the USAF F-16A/B fleet had flown beyond analytical service life predictions at multiple critical locations and consequently requested a risk assessment to verify and communicate concerns. For these aircraft, some critical structural safety inspections were based on fail-safe capability. The fail-safe force management approach depends upon adequately defined and properly performed inspections, accuracy of the fail-safe analysis, and understanding of the risks involved with this approach. USAF therefore tasked LM Aero to perform an extensive fail-safe analysis and overall risk assessment of the USAF F-16A/B fleet, specifically aircraft that had not received service life extension program modifications.

Because this assessment addressed aircraft which had not received service life extension modifications, and because of similarities in the Block 15 and lock 25/30 structure, risk assessments are recommended for Block 10/15/25/30 international operators without near-term plans to incorporate service life modifications.

TECHNICAL APPROACH

A current force management data package is the foundation for a sound risk assessment. If the underlying deterministic analyses and force management data are not valid, then risk assessments based in this information are questionable. Therefore, one of the first steps of this effort was to obtain current and accurate force management data. Next, for the affected structural areas, we updated the load spectra, and the durability and damage tolerance analyses. We then performed residual strength and residual life analyses. Once these analyses had been accomplished, we had a solid basis for the risk assessment. Figure 1 illustrates the technical approach used for this assessment.

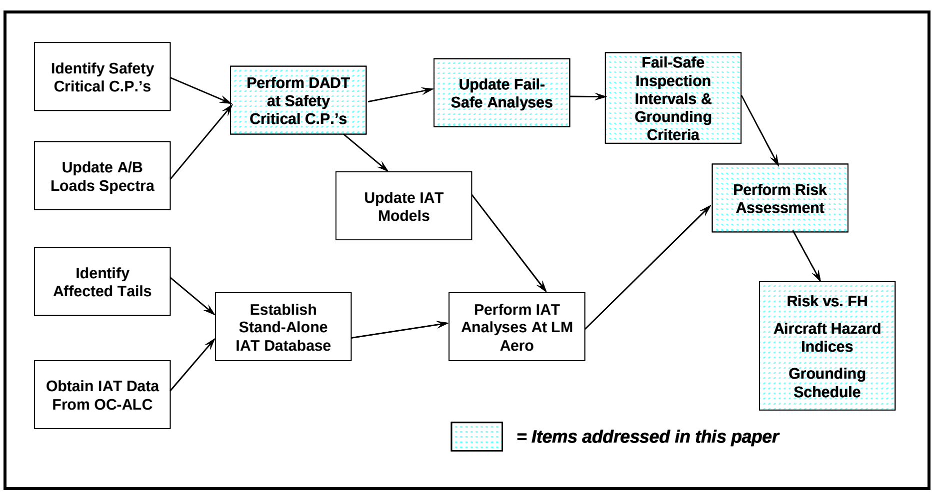

Figure 1 – F-16A/B Risk Assessment Technical Approach

FUEL SHELF JOINT FAIL-SAFE ASSESSMENT RESULTS

F-16 Fail-Safe Approach

MIL-STD-1530C (Reference 1) identifies two damage tolerance approaches: fail-safe and slow damage growth. The fail-safe approach applies to structure with multiple load paths or damage arrest features after a failure or partial failure. The results of the durability and damage tolerance analyses (DADTA) provide the basis for the primary and secondary structure locations for a fail-safe analysis. The fail-safe analysis assumes initial damage is present in both the primary and secondary structure. The secondary structure is analyzed for the number of flight hours equal to the predicted life of the primary failure. After the primary failure occurs, the stresses in the secondary structure are increased due to the load redistribution caused by the primary failure, then the analysis continues until failure.

There are two criteria the F-16 airframe is required to meet in order for the aircraft to be considered fail-safe, and thus maintained by one of the five degrees of inspectability applicable to fail-safe structure, as specified in Section 3.2.2 of MIL-A-83444 (Airplane Damage Tolerance Requirements). The aircraft must be able to react design limit load after the initial failure (static residual strength) and also the aircraft must be able to sustain design limit load in the presence of secondary cracks for a period of unrepaired usage as defined by the fail-safe alternate load path criteria of MIL-A-83444. The period of unrepaired usage necessary to achieve fail-safety must be long enough to ensure the failure or partial failure will be detected visually and repaired prior to the failure of the remaining intact structure.

The total fail-safe capability of the fuel shelf joint structure is the sum of the predicted life of the primary failure plus the predicted residual life of the surrounding structure. Once the aircraft has exceeded the predicted fail-safe capability, the fuel shelf joint area must revert to being maintained by slow damage tolerance crack growth requirements. This stipulates an eddy current inspection of the fuel shelf joint tension bolt holes on all four upper carry-through bulkheads.

Fuel-Shelf Joint Fail-Safe Assessment Details

Two failure scenarios were considered when evaluating the fuel shelf joint fail-safe analysis (see Figures 1 and 2). Scenario #1 focused on a primary failure of the outboard corner of the 16B5252 FS 341 lower bulkhead. This failure was predicted to occur corresponding to the predicted damage tolerance life of the 16B5252 FS 341 lower bulkhead aft inboard stiffener. Scenario #2 considered the simultaneous failure of the 16B5251 and 16B5252 FS 341 upper and lower bulkheads at the outboard tension bolt area. This failure was predicted to occur corresponding to the predicted damage tolerance life of the 16B5251 FS 341 upper bulkhead fuel shelf joint bolt hole. Scenario #2 was selected for the risk assessment as the most likely scenario to occur in the fleet.

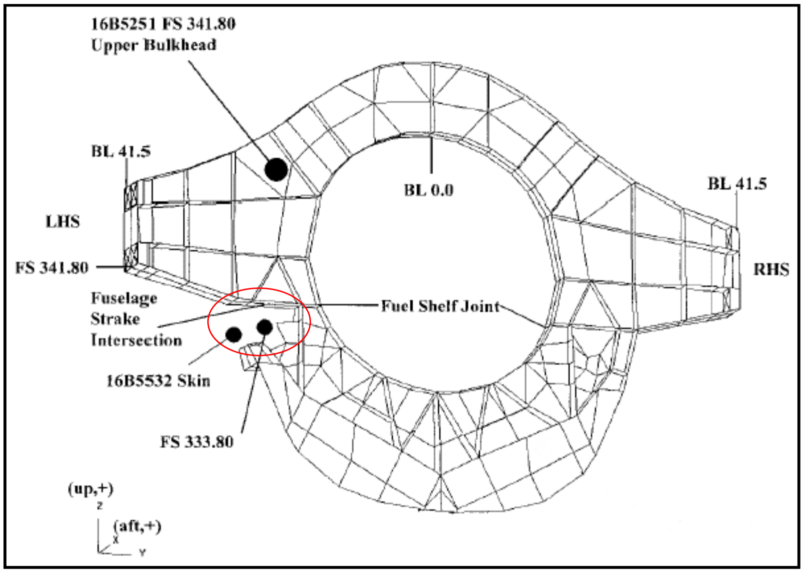

Figure 1 – FSJ Failure Scenario #1

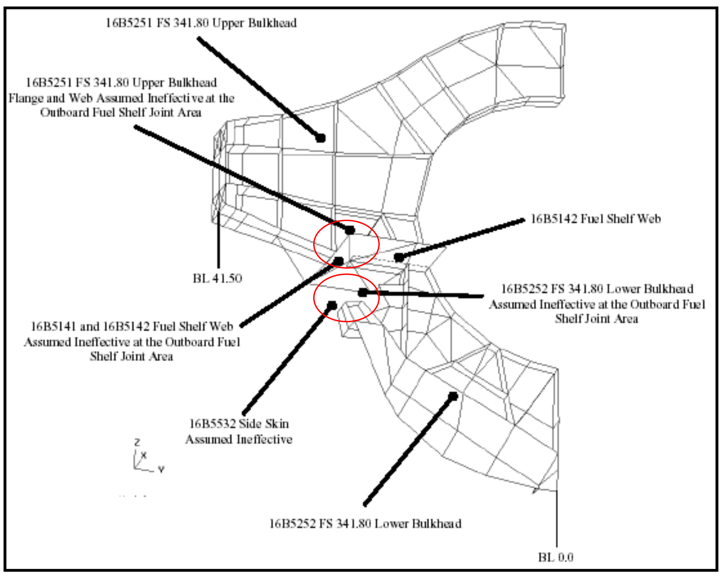

Figure 2 – FSJ Failure Scenario #2

Damage Tolerance Analysis - Predicted Life for Intact Structure

A damage tolerance analysis was performed for the 16B5251 FS 341 Upper Bulkhead Fuel Shelf Joint (FSJ) Bolt Hole at BL 26. The results show that a damage tolerance flaw becomes unstable at 3,800 flight hours. At this point the FS 341 upper and lower bulkheads fail at the outboard FSJ tension bolt area and become an ineffective load path. To model this scenario, the fuel shelf webs at the FS 341outboard FSJ area, in addition to the 16B5532 panel, were assumed ineffective as well. The load carried by this portion of the FS 341 upper and lower bulkheads before their failure is then redistributed to the surrounding structure. For the purpose of this fail-safe analysis it was assumed that the outboard FSJ area of the upper and lower FS 341 bulkheads becomes ineffective immediately after the failure of the FS 341 upper bulkhead at the outboard FSJ tension bolt hole location.

The basis for the simultaneous failure of both the FS 341 upper and lower bulkheads at 3,800 flight hours is due to the 16B5252 Lower Bulkhead at FS 341, Panel C Satellite Hole having a predicted durability life of 2,000 flight hours. Scenario #1 evaluated the fail-safe capability of USAF F-16A/B non-SLEP aircraft following a failure of the 16B5252 lower bulkhead at the aft inboard stiffener. The fail-safe analysis of Scenario #1, in effect, includes a failure of Panel C. Scenario #2 evaluates the fail-safe capability of USAF F-16A/B non-SLEP aircraft following a different type of FS 341 structural failure, namely the 16B5251 FSJ bolt hole, and considers a worst case scenario based on analytical service life predictions by assuming a simultaneous failure of the FS 341 upper and lower bulkheads.

Residual Strength Analysis

Residual static strength analysis of the surrounding structure was performed. The purpose of the residual static strength analysis was to show that the airplane could sustain critical design limit load conditions without catastrophic failure once the crack is arrested in the FS 341 upper and lower bulkheads. This was accomplished by reevaluating static margins of safety at selected locations in the surrounding structure. The stress analysis performed shows that the remainder of the FS 341 upper and lower bulkheads have adequate capability to sustain limit load. The minimum margins of safety determined for the upper and lower bulkheads are +0.84 and +0.49, respectively.

Residual Life Analysis

Residual life analyses were carried out to demonstrate that assumed cracks in the surrounding structure under increased stresses due to the simultaneous failure of the FS 341 upper and lower bulkheads would not grow to a size such as to cause failure and possible loss of the aircraft for a minimum period of unrepaired service usage. Four control points were selected for analysis:

- 16B5241 Upper Bulkhead at FS 325.8, Fuel Shelf Joint Bolt Hole at BL 26
- 16B5251 Upper Bulkhead at FS 341.8, Panel XI Satellite Hole
- 16B5261 Upper Bulkhead at FS 357.8, Fuel Shelf Joint Bolt Hole at BL 26
- 16B5262 Lower Bulkhead at FS 357.8, RHS Lower Flange Cutout with Steel Strap (ECP 1910)

When determining the initial flaw size for the surrounding structure of a fail-safe analysis, the structure must be classified as either multiple load path *dependent* or multiple load path *independent*, as specified in Section 3.1.1.3.1 of MIL-A-83444 and defined below:

> ***Multiple load path dependent structure*** *– if, by design, a common source of cracking exists in adjacent load paths at one location due to the nature of the assembly or manufacturing procedures*
>
> ***Multiple load path independent structure*** *– if, by design, it is unlikely that a common source of cracking exists in more than a single load path at one location due to the nature of assembly or manufacturing procedures*

While the basic manufacturing process is similar at all fuel shelf joint locations, it is highly improbable that such operations would result in “rogue” flaw size imperfections. Therefore, the fuel shelf joint structure was classified as multiple load path independent structure. When analyzing a hole or cutout, a multiple load path independent structure classification requires an initial corner flaw of only $a_i = c_i = 0.005$" in the surrounding structure, as specified in Sections 3.1.1.2b of MIL-A-83444.

Following the load redistribution due to the simultaneous failure of the FS 341 upper and lower bulkheads, a stress increase was calculated at each of the secondary locations listed above. The fail-safe analysis was then performed as follows:

- Damage was calculated at the four locations for the intact structure, i.e. prior to the FS 341 bulkhead failures.
- After the simultaneous bulkhead failures, stresses in the surrounding structure were increased accordingly:
    - 41.4% for 16B5241 FSJ bolt hole
    - 121.3% for the 16B5251 shear web panel
    - 43.2% for 16B5261 FSJ bolt hole
    - 36.7% for 16B5262 lower flange cutout
- These stress increases were applied to the applicable input stress histories for the remainder of the crack growth, thus determining the predicted residual life of each secondary location.

Fail-Safe Analysis Results

When classifying the structure as multiple load path independent structure, the results of the Scenario #1 and Scenario #2 fuel shelf joint fail-safe analyses both predict the USAF F-16A/B non-SLEP fleet to have approximately ***x*** flight hours of fail-safe capability. The results are summarized in Tables 1 and 2 below.

Table 1: Scenario #1 Fail-Safe Analysis Results

Control Point Description	Scenario #1		
	Initial Failure	Residual Life	Fail-Safe Capability
16B5252 Lower Bulkhead at FS 341, Aft Inboard Stiffener at BL 25	*x* FH		
Multiple Load Path *Independent* Structure Classification			
16B5241 Upper Bulkhead at FS 325, FSJ Bolt Hole at BL 26		*x* FH	*x* FH
16B5261 Upper Bulkhead at FS 357, FSJ Bolt Hole at BL 26		*x* FH	*x* FH
16B5262 Lower Bulkhead at FS 357, RHS Lower Flange Cutout with Steel Strap		*x* FH	*x* FH

Table 2: Scenario #2 Fail-Safe Analysis Results

Control Point Description	Scenario #2		
	Initial Failure	Residual Life	Fail-Safe Capability
16B5251 Upper Bulkhead at FS 341, FSJ Bolt Hole at BL 26	*X* FH		
Multiple Load Path *Independent* Structure Classification			
16B5241 Upper Bulkhead at FS 325, FSJ Bolt Hole at BL 26		*X* FH	*X* FH
16B5261 Upper Bulkhead at FS 357, FSJ Bolt Hole at BL 26		*X* FH	*X* FH
16B5262 Lower Bulkhead at FS 357, RHS Lower Flange Cutout with Steel Strap		*X* FH	*X* FH
16B5251 Upper Bulkhead at FS 341, Panel XI Satellite Hole (RHS)		*X* FH	*X* FH

FUEL SHELF JOINT RISK ASSESSMENT RESULTS

F-16 Structural Risk Assessment Model

The stochastic model used by LM Aero for F-16 structural risk assessments defines a relationship among maintenance criteria, risk level, calendar date, and aircraft flight hours. In its simplest form the basic model is expressed as: $D^* = \frac{T^*}{R}$ with the * notation denoting a difference between a value and a reference value, i.e., $X^* = X - X_{Ref}$. In this model, D^*, T^* and R are lognormal random variables defined as follows:

- D^* - Elapsed calendar time to attain a specified maintenance criteria. The distribution may be calculated from the model or maintenance criteria dates may be specified by the analyst depending on problem set up.
- T^* - Maintenance criteria in equivalent flight hours (EFH). Specified by analyst using crack growth analysis , field failures, test data, etc.
- R - Damage accrual rate in EFH per month. Calculated from IAT data.

This model results from the application of F-16 IAT data (see Figure 3) to the stochastic crack growth approach (SCGA) described in References 2 and 3 (see Figure 4). Figure 4 illustrates the resulting methodology. Reference 2 provides details of this model and its software implementation.

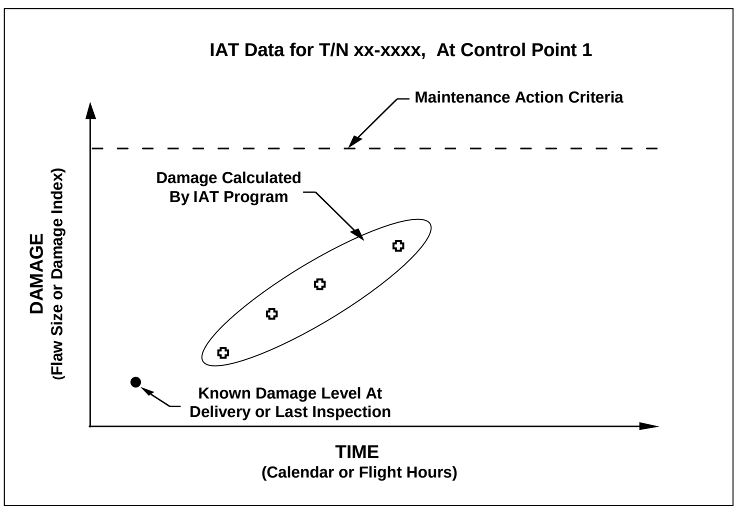

Figure 3 – IAT Data For a Single Aircraft

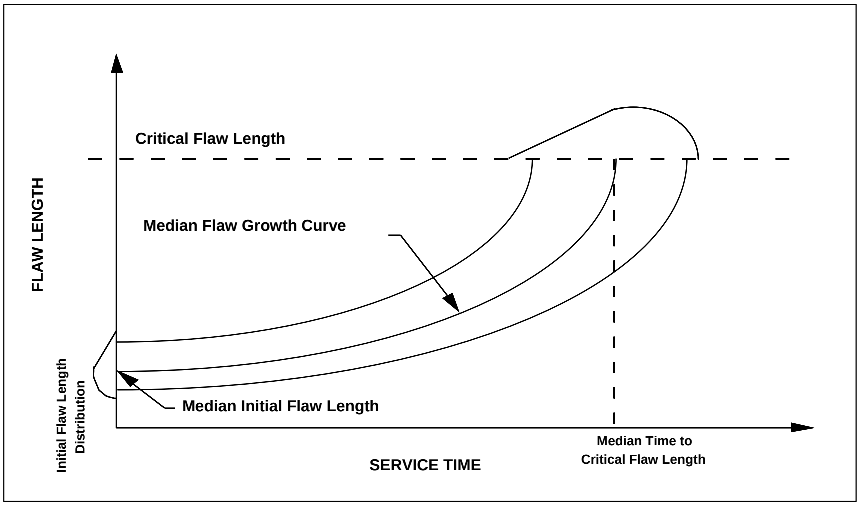

Figure 4 – Generic SCGA Model

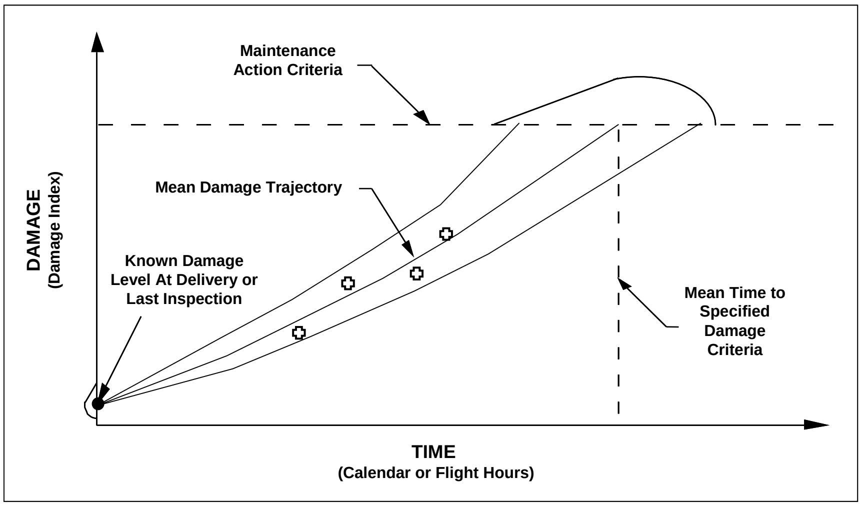

Figure 5 – Resulting Stochastic Aging Model

Risk Assessment Criteria Development

Three criteria for evaluating the hazard level are compared in this effort: fail-safe approach, MIL-STD-882D (Reference 5), and MIL-STD-1530C (Reference 1). The fail safe criteria is the simplest of the three criteria. This criteria uses deterministic crack growth analysis with continuing damage to define a flight hour limit for safe operation. Quantification of risk is not involved. Operation below the flight hour limit is considered acceptable and operation past the flight hour limit is considered unacceptable.

MIL-STD-882D describes a means to classify and index mishap risk using severity categories and cumulative risk levels. The resulting hazard risk index (HRI) is used as a tool for deciding the acceptability of a particular risk, for communicating the severity of a particular risk, and for comparing the severity of different risks. Table 3 illustrates the hazard matrix from the F-16 System Safety Plan. Since structural safety assessment would normally be considered a Category I issue, only the HRI's from that portion of the hazard matrix would be used.

Table 3 – Hazard Matrix Per F-16 System Safety Plan

Probability Level	Cum. Prob. Range	Severity Category (I) Catastrophic	(II) Critical	(III) Marginal	(IV) Negligible
(A) Frequent	> 1.0E-01	1	3	6	13
(B) Probable	< 1.0E-01 > 1.0E-02	2	5	9	16
(C) Occasional	< 1.0E-02 > 1.0E-03	4	7	11	18
(D) Remote	< 1.0E-03 > 1.0E-06	8	10	14	19
(E) Improbable	< 1.0E-06	12	15	17	20

Hazard Risk Index	Acceptability Criteria
1 - 6	Unacceptable
7 - 11	Undesirable
12 - 20	Acceptable

MIL-STD-1530C uses single flight risk to classify a particular risk. as Acceptable, Mitigation Needed, or Unacceptable based on risk level alone. Table 4 illustrates the MIL-STD-1530 criteria. While the MIL-STD-882D criteria and the MIL-STD-1530C as defined cannot be intuitively compared, a reasonable expectation is that the MIL-STD-1530C Mitigation Needed risk is approximately equivalent to HRI = 8.

Table 4 – Hazard Matrix Per F-16 System Safety Plan

Description	Level	SFH Prob.
Unacceptable	High	> 1.0E-05
Mitigation Needed	Moderate	1.0E-05 to 1.0E-07
Acceptable	Low	< 1.0E-07

Since MIL-STD-1530C was not available at the time of this analysis, the original risk assessment task used MIL-STD-882D criteria to evaluate the FSJ risk and to report the results to USAF. Results for MIL-STD-1530C criteria were produced later to support the comparison shown herein. The results shown in the reaming sections are for two purposes: 1) to provide a practical example of a risk assessment that resulted in important force management decisions, and 2) to provide a comparison of fail-Safe, MIL-STD-882D, and MIL-STD-1530C criteria. This assessment process may also set a precedent for deciding when individual F-16 aircraft has reached the end of its operational life.

FSJ Risk Assessment Inputs

The following inputs were needed for this risk assessment:

- Mean Time To Failure (MTF)
- IAT Analysis Results
- IAT Control Point (CP) To Serve As The EFH ‘Clock’ And To Provide Data For The Stochastic Model

FSJ failure Scenario #2 describes a sequence of events leading to loss of adequate residual strength. One of the inputs for the risk model is the MTF for this sequence of events. Since F-16 durability analyses attempt to represent average service life for a control point, the MTF for this sequence of events was determined by calculating the crack growth for scenario #2 using durability criteria.

Because the force management data package for these aircraft was considered out of date and unreliable, new loads spectra were developed and crack growth analyses were performed to provide an updated DADT and new IAT models. The updated IAT models were then used with the accumulated flight recorder data and daily flight records to calculate new IAT control point damage for the affected aircraft.

Since the new IAT models were developed directly for the control points being analyzed in this scenario, selection of an IAT control point to be the EFH 'clock' and provide data for the stochastic model was straightforward. The selected control point was located at the 16B5261 FS 357 upper bulkhead FSJ Bolt Hole.

IAT Results

Prior to performing the detailed risk assessments, the IAT results were evaluated to determine the overall condition of the aircraft. Figure 6 is a scatter plot of EFH vs. Actual Flight Hours (AFH) for each tail number. Because of the low value (0.571) of the correlation coefficient for this population, AFH is a poor predictor of EFH, (accumulated damage); therefore,

- the risk vs. AFH function is not reliable
- use risk vs. EFH to set EFH-based maintenance action criteria
- schedule aircraft for maintenance action using projected date to attain specified EFH

For deterministic fail-safe criteria, the above information would be used for force management decisions. Since there would not be any quantification or assessment of the risks for the above approach, there is no way to determine "how safe" is the calculated fail-safe limit.

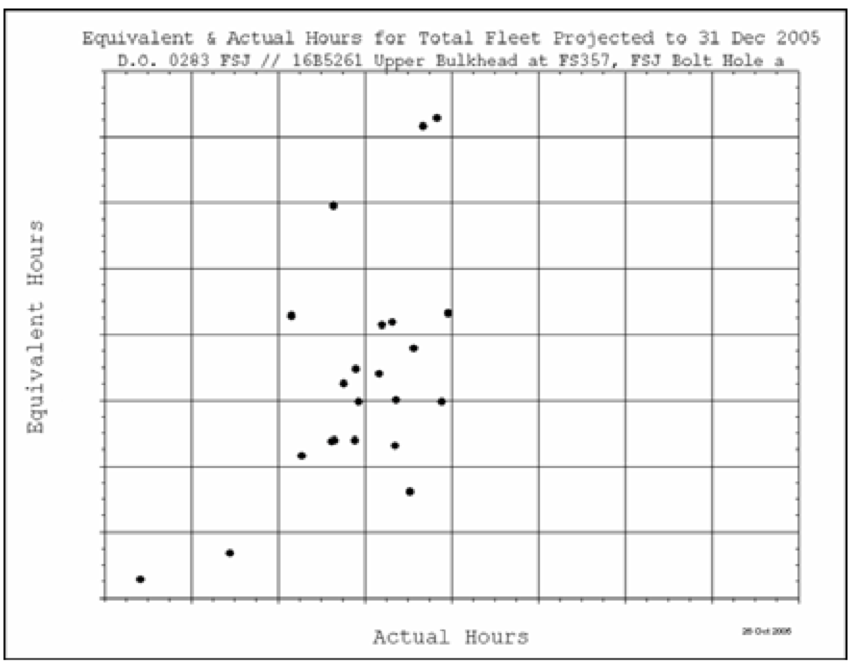

Figure 6 – IAT Results for the FS357 FSJ Bolt Hole

Risk Vs. Flight Hours Results

Figure 7 shows the cumulative risk vs. EFH function annotated to indicate the average flight hours, the fail safe limit, and the hazard levels defined by the MIL-STD-882D criteria. Figure 8 shows the single flight hour risk vs. EFH function similarly annotated except the hazard levels are those defined by MIL-STD-1530C. (The F-16 risk model software calculates single flight hour risk rather than single flight risk).

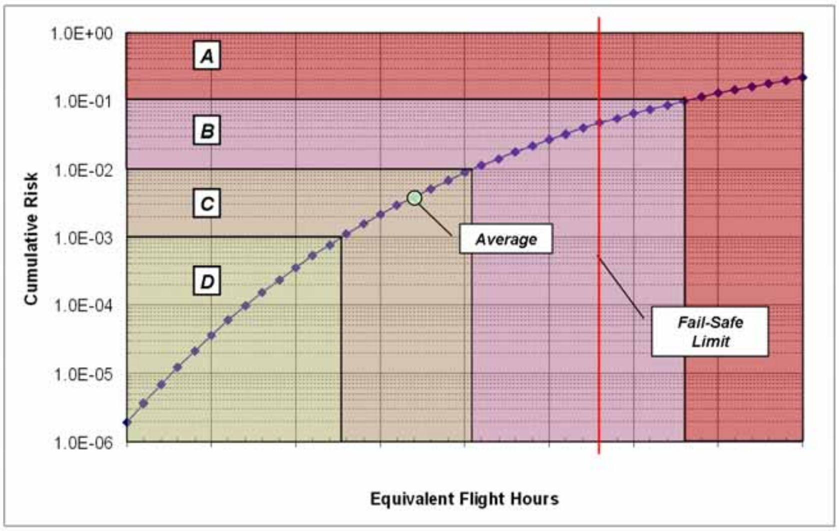

Figure 7 – Cumulative Risk vs. EFH (-882D Criteria)

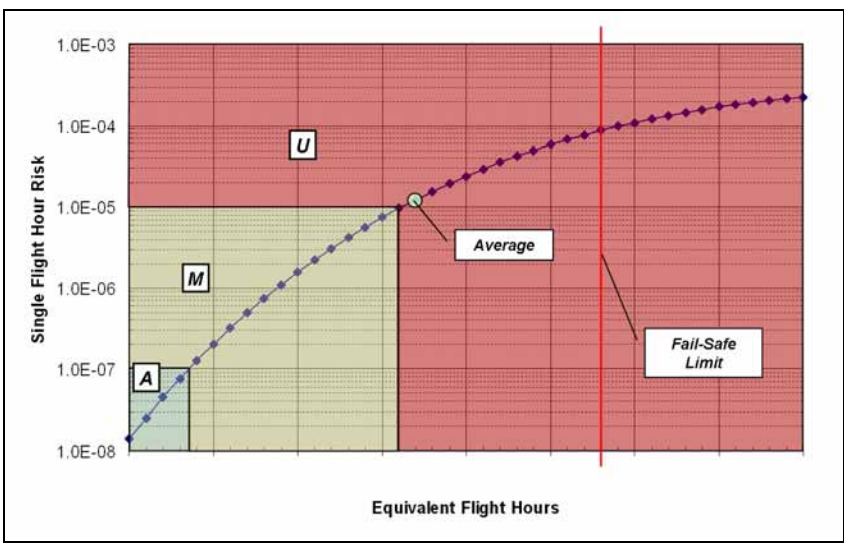

Figure 8 – Single Flight Hour (SFH) Risk vs. EFH (-1530C Criteria)

From these functions, flight hours corresponding to the various hazard levels can be determined and used to compare the MIL-STD-882D criteria with the MIL-STD-1530C criteria. Figure 9 shows this comparison for the cumulative risk vs. flight hours and Figure 10 shows this comparison for the single flight hour risk vs. flight hours. Of particular interest is the flight hour range for the MIL-STD-882D "undesirable" zone compared to the flight hour range for the MIL-STD-1530C "mitigation" zone. Table 5 provides such a comparison. These comparisons show that for this particular analysis, the two criteria are comparable but do not correspond exactly.

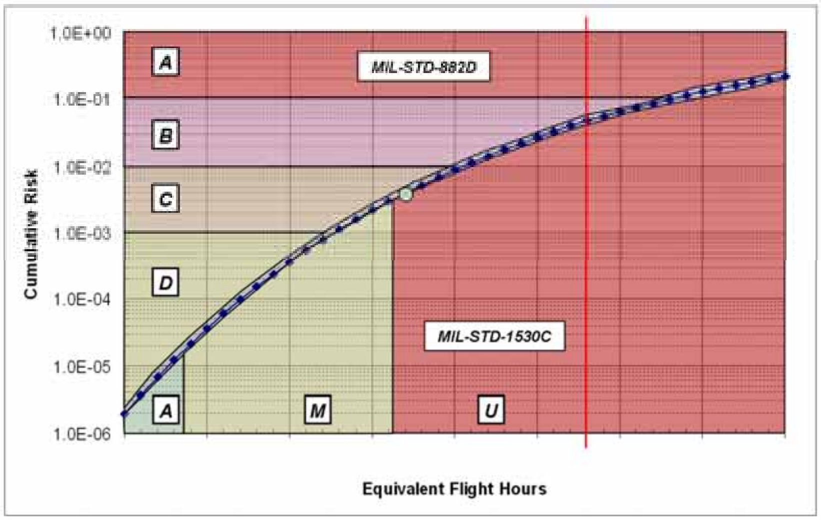

Figure 9 – Cumulative Risk vs. EFH -882D and -1530C Criteria Compared

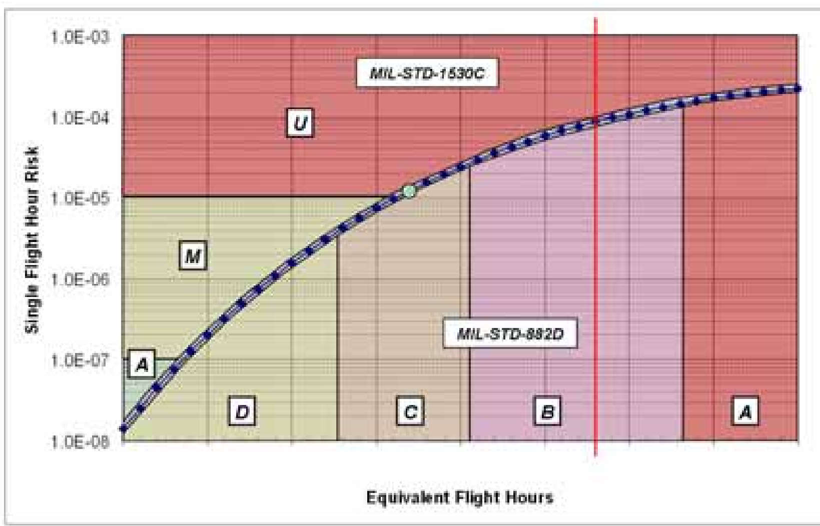

Figure 10 – SFH Risk vs. EFH -882D and -1530C Criteria Compared

Table 5 – EFH and Risk Levels for -882D and -1530C Criteria Compared

-882D Criteria			-1530C Criteria		
Cumulative Prob.	Level	EFH	EFH	Level	SFH Prob.
< 1.0E-06	E			A	< 1.0E-07
1.0E-06 to 1.0E-03	D			M	1.0E-07 to 1.0E-05
1.0E-03 to 1.0E-02	C				
1.0E-02 to 1.0E-01	B			U	> 1.0E-05
> 1.0E-01	A				

The Cumulative Probabilities Corresponding to the -1530C 'M' Range are 1.64E-05 Thru 3.02E-03

Schedule Projections

Table 6 and Figure 11 show projected dates for each aircraft to attain the MIL-STD-882D hazard levels (as noted earlier, the original analysis was performed prior tot release of MIL-STD-1530C.) This schedule projection was a key element in communicating the urgency of the problem. This data showed that all aircraft are at or above level D.

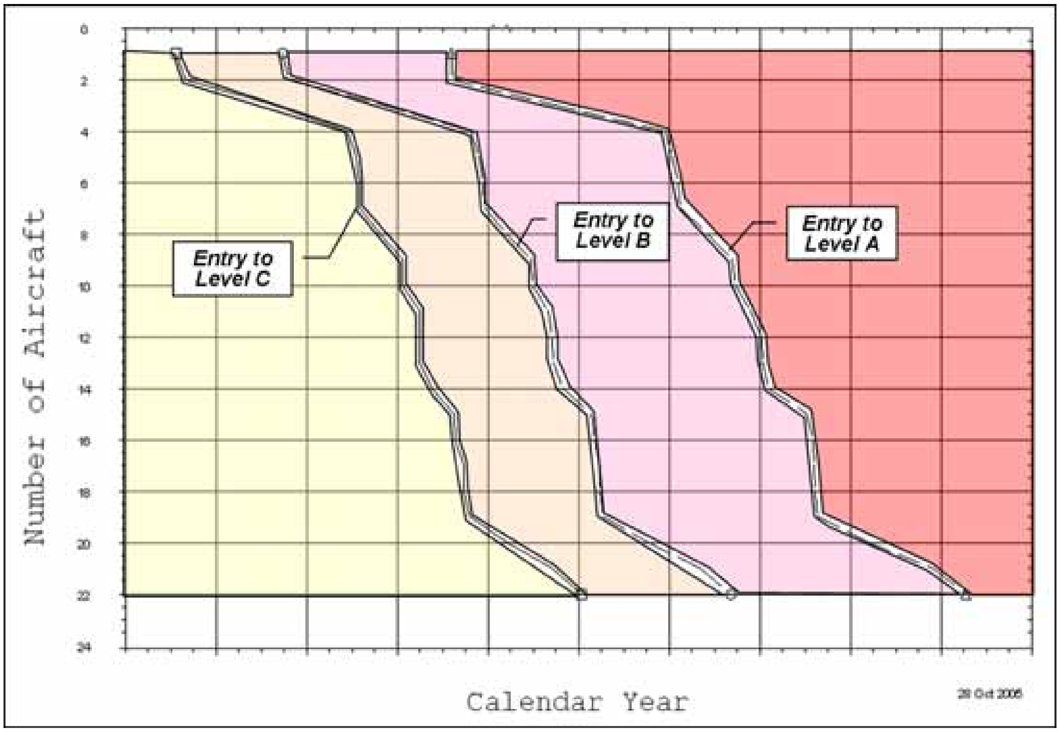

Figure 11 – Schedule Projections (-882D Criteria)

Figure 12 shows a comparison of the schedule for the 22 aircraft to enter the unacceptable risk levels for MIL-STD-882D and MIL-STD-1530C criteria. This comparison shows that, in general, the aircraft attain unacceptable risk later for the MIL-STD-1530C criteria. Similar to the risk vs. flight hours comparison, these schedule projections also show that for this particular analysis, the two -criteria are comparable but do not correspond exactly.

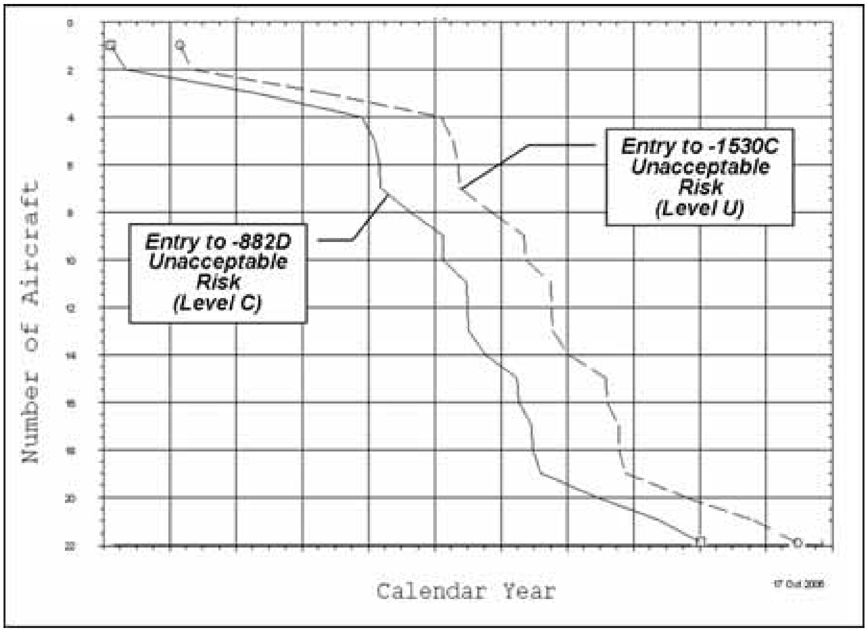

Figure 12 – Schedule Projections -882D and -1530C Criteria Compared

Sensitivity To Mean Time To Failure

Experience has shown that the variable which causes the most variation in the results for this risk assessment model is the MTF. The model output is actually more sensitive to changes in the monthly flight rates, but for a particular F-16 fleet, this value tends to be very stable. The model is moderately sensitive to MTF, but in many cases there is a range of reasonable MTF values depending on the assumption used for the crack growth modeling and whether there is field data or test data available. Once the sensitivity of a particular analysis to MTF has been determined, those results provide guidance for deciding whether to perform further analysis and determining contingencies to consider in the mitigation plans

For this analysis the SFH risk vs. EFH for the MIL-STD-1530C mitigation range was calculated for +/- 5% changes in the MTF (see Figure 13). The results show that at a SFH risk of 10^{-7}, a 1% variation in MTF results in a 1.24% change in EFH and a 1.0 hour variation in MTF results in a 1.75 hours variation in EFH. For a SFH risk of 10^{-5}, a 1% variation in MTF results in a 1.19% change in EFH and a 1.0 hour variation in MTF results in a 1.40 hours variation in EFH.

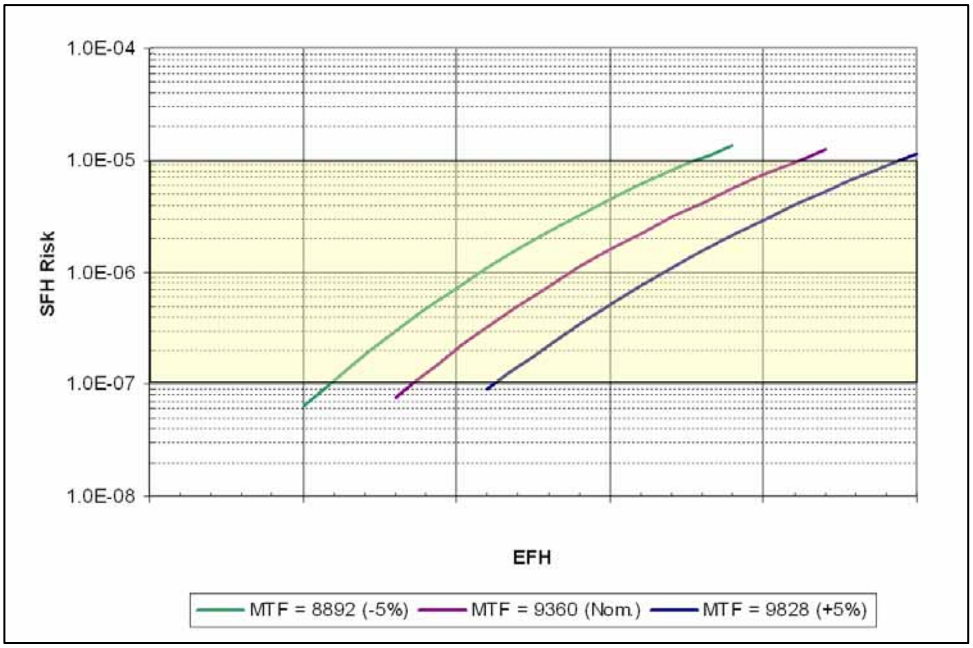

Figure 13 – Sensitivity of SFH risk to MTF

CONCLUSIONS

This effort was important for a number of reasons: the results effectively addressed USAF concerns for this situation, the technical approach developed for this effort sets a precedent for deciding whether and when to retire specific F-16 tail numbers for structural safety issues, the opportunity to quantitatively compare risk acceptance criteria. In addressing USAF concerns for structural safety, use of HRI effectively communicated the significance of the risk assessment results to management decision makers and worked as a common language to quantify the significance of complex engineering issues. USAF had the following comments about this work:

- From Aeronautical Systems Center: "The results of this work have alleviated concerns expressed by USAF senior engineering leadership and exceeded the F-16 ASIP manager's needs to safely manage F-16 aircraft."
- From Ogden Air Logistics Center: "As a result of this effort, convincing data was provided to USAF which resulted in decisive force management actions.

For this particular analysis, comparing the use of the undesirable/mitigation-needed risk level criteria from MIL-STD-882D and MIL-STD-1530C showed comparable, but not identical results. In contrast, use of deterministic fail safe criteria resulted in higher operating at undesirable risk levels and did not provide a means to effectively communicate the need for urgent action. The purpose of comparisons among these three criteria is to increase confidence in relying on the MIL-STD-1530C criteria for structural safety decisions. For this assessment the MIL-STD882D criteria and the MIL-STD-1530C criteria compared favorably, the differences found would not have alter the force management decisions made for these 22 aircraft. However, sole application of deterministic fail-safe criteria would have resulted in a less effective response. Since, this assessment this is only one example, similar comparisons should be performed for other situations and programs. When situations arise where the two risk level criteria do not compare favorably, significant differences need be to understood and reconciled.

An assessment of the three structural safety risk acceptance criteria discussed herein could be summarized in a "Goldilocks and The Three Bears" conjecture:

- The deterministic fail-safe criteria appears too simple in that it does not quantify "how safe" or "how unsafe" are the resulting force management decisions or the rate at which aircraft move from "safe" to "unsafe
- the MIL-STD-882D criteria appears too elaborate in that structural risk assessment is only concerned with a small portion of the hazard matrix
- The MIL-STD-1530C criteria appears to be just right in that the acceptable/mitigate/unacceptable approach has an appropriate complexity level for force management decision-making and the resulting force management decisions are expected to be consistent with those arrived at from using MIL-STD-882D criteria.

REFERENCES

1. MIL-STD-1530C, Department of Defense Standard Practice for ASIP, 1 November 2005
2. Yang, J.N. and Manning, S.D., "Stochastic Crack Growth Methodologies for Metallic Structures", Engineering Fracture Mechanics, Vol. 37, No. 5, 1990, pp. 1105-1124.
3. Yang, J.N. and Manning, S.D., "Demonstration of Probabilistic-Based Durability Analysis Method for Metallic Airframes", Journal of Aircraft, AIAA, Vol. 27. 2, February 1990, pp 169-175.
4. Welch, K.M. and Rush, G.D., Lockheed Martin Aeronautics Company, "Overview of a Stochastic Fleet Management Software Program", Fourth Joint DoD/FAA/NASA Conference on Aging Aircraft, 15 - 18 May 2000.
5. MIL-STD-882D, Department of Defense Standard Practice for System Safety, 10February 2000