T-38 FUSELAGE STRUCTURAL LIFE ASSESSMENT

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AGENDA

- Introduction
- Review of T-38 Fuselage Test
- Variations in Fleet Usage
- Severity of Usages
- Fleet Aircraft and Component Usage Hours
- Statistical Life Evaluation
- Future Flying Scenarios
- Predictions
- Summary
Introduction

• Purpose of this program
  – Determine long-term viability of the T-38 fuselage structure
  – Fatigue test of current configuration aircraft with numerous structural modification
  – Verify current Fatigue Critical Locations (FCL)
  – Determine possible new FCLs
  – Provide information to validate Finite Element Models

• Following slide presents the general process
**Introduction**

1. **Fatigue Test**
   - T-38C IFF

2. **Test and Post-Test Inspections & Findings**

3. **Prior Fleet Usages**

4. **Severity of Usages Related to T-38C IFF**

5. **Fleet A/C & Component Hours in Prior Usages**

6. **Fleet/Test Component Hours in T-38C IFF**

7. **Stat. Eval. of Fleet/Test Component Hours (T-38C IFF)**

8. **Formulate Future Flying Scenarios**

9. **Generate Predictions Using Future Flying Scenarios**

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### Number of Anticipated Dorsal Longeron Maintenance Actions each Calendar Time Increment

<table>
<thead>
<tr>
<th>Calendar Time</th>
<th>AETC SUPT</th>
<th>AETC IFF</th>
<th>AETC ENJPT</th>
<th>AETC Total</th>
</tr>
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</tbody>
</table>

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**1. Fatigue Test**

- T-38C IFF

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**3. Prior Fleet Usages**

**4. Severity of Usages Related to T-38C IFF**

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**7. Stat. Eval. of Fleet/Test Component Hours (T-38C IFF)**

**8. Formulate Future Flying Scenarios**

**9. Generate Predictions Using Future Flying Scenarios**
Review of Fuselage Test

• Four phase program began in July, 2002. Initiated by OO-ALC
  – Phase 1: Test Setup
  – Phase 2: Testing
  – Phase 3: Teardown
  – Phase 4: Analysis

• Aircraft was received from AMARC

• Brought up to current structural configuration at Randolph AFB
Review of Fuselage Test

- Vertical Loads: 14 Hydraulic Actuators (8.25g Max)
- Horizontal Loads: 7 Hydraulic Actuators (0.7g Max)
- Cockpit Pressurization up to 5 psig
- 272 Strain Gage Channels
- New FCLs Found
- Tested Structural Modifications
- 8,500 hours of Simulated Introduction to Fighter Fundamentals (IFF = severe usage)
Review of Fuselage Test

Steel Dorsal Longeron – FS 401-403 (right and left)
• found at 4500 test hours
• found at 5500 test hours
• found at 7500 test hours
Review of Fuselage Test

Cockpit Longeron (CEM) – FS 269 (left and right side); these cracks ended the test
*found at 8500 test hours

Cockpit Longeron Bathtub Fitting – FS 283 (left side)
*appears in strain data at 7200 test hours

Upper Longeron (splice straps and original longeron segment) – FS 291-300 (right side)
*appears in strain data at 7200 test hours
Variations in Fleet Usage

- There has been different usages, utilizing different aircraft configurations, at different gross weights
- Aircraft has been fielded for over 45 years
Severity of Usages

- Need a baseline usage to compare aircraft on a 1:1 basis
- The IFF usage for the fuselage test was chosen for the baseline – IFF (test)
- Most components will have different crack growth curves thus severity is also component specific
- Only need to go back to 1981 when first steel dorsal longeron (SDL) was installed
- Need a crack growth curve (or assumed curve) for each usage for both the SDL and CEM
Severity of Usages

![Graph showing severity of usages over flight hours with different crack lengths for baseline usage and other usages](image)
Due to SDL cracking discovered during the course of testing, a number of fleet aircraft were inspected by TCTO.

Given the release date and rescission date it was assumed that all were inspected in August 2005.

All results negative, no cracks found in the fleet.

Gathered the usages and hours for all aircraft between SDL installation and August 2005.

Gathered usages and hours for all aircraft between CEM/284 Splice installation and August 2005.
## Fleet Aircraft and Component Usage Hours

<table>
<thead>
<tr>
<th>Component</th>
<th>Prior Usage Hours (1)</th>
<th>Test Hours (2)</th>
<th>Prior Usage &amp; Test Hours (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDL</td>
<td>1045</td>
<td>4500</td>
<td>5545</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5500</td>
<td>6545</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7500</td>
<td>8545</td>
</tr>
<tr>
<td>CEM</td>
<td>265</td>
<td>7200</td>
<td>7465</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8500</td>
<td>8765</td>
</tr>
<tr>
<td>284 Splice</td>
<td>265</td>
<td>7200</td>
<td>7465</td>
</tr>
</tbody>
</table>

(1) Equivalent T-38C IFF (Test) Hours  
(2) Times Cracks were Found or Estimated from Fuselage Test  
(3) Total Hours Used for Statistical Life Evaluation
Fleet Aircraft and Component Usage Hours

Steel Dorsal Longeron Equivalent Hours in 2005

Equivalent IFF (Test) Hours

- **AETC IFF**
- **AETC SUPT**
- **AETC ENJJPT**
- **ACC**
- **AFMC**

Aircraft

0 1000 2000 3000 4000 5000
Statistical Life Evaluation

• Inputs-
  – 3 SDL cracks
  – Fleet aircraft inspected, all results negative
  – 2 CEM cracks
  – 1 284 Splice crack
• WinSMITH Weibull software used for the analysis
• The cracks found are ‘failures’
• The longerons on the aircraft inspected are suspensions or censored data (2 longerons each)
• Assumed that CEMs were inspected at same time with no findings (also suspensions)
Statistical Life Evaluation

- Perform Weibayes analysis on 284 Splice assuming same Beta as CEM (due to similarities between the structure and location in airframe)
- Reduced Bias Adjustment (RBA) was employed due to large number of suspensions relative to failures
- Best fit for the SDL was the lognormal distribution
- Best fit for the CEM was the Weibull 2-parameter distribution
Statistical Life Evaluation

- SDL Lognormal - Reduced Bias Adjustment (RBA)
  - SDL Test Data
- CEM Weibull - Reduced Bias Adjustment (RBA)
  - CEM Test Data
- 284 Splice Weibull - Weibayes Analysis
  - 284 Splice Test Data

Probability of Repair/Replacement vs. T-38C IFF (Test) Equivalent Flight Hours
Future Flying Scenarios

• Currently, there are 5 distinct AF fleets based on usage and configuration
• Historical data for the past 3 years were used to determine flying hours by fleet
• Scenarios need to consider configuration and usage
• Assume all AETC aircraft are fully modified by current ongoing TCTOs (higher gross weight = more severe crack growth)
• Some fleets fly a mix of aircraft configuration and/or usages - conservatively assume worst case
Future Flying Scenarios

Steel Dorsal Longeron Hours at: 2005, 2015, 2025

Equivalen IFF (Test) Hours

Number of Aircraft

AETC IFF
AETC SUPT
AETC ENJJPT
ACC
AFMC
Mean Time To Failure (MTTF = 7050)
Predictions

- Can estimate number of maintenance actions (either repair or replacement) need by fleet based on calendar time
- Predictions are dependent on replacement methodology
- Statistical results are based on a single component
- The risk due a component set (left and right sides) is: \( \text{Risk} = 1 - (1 - \text{Risk}_{\text{Left}})(1 - \text{Risk}_{\text{Right}}) \)
- If multiple components are replaced during the same maintenance visit then risk is a function of each component being replaced: \( \text{Risk} = 1 - (1 - \text{Risk}_{\text{SDL}})(1 - \text{Risk}_{\text{CEM}})(1 - \text{Risk}_{\text{284 Splice}}) \)
Predictions

Cumulative Number of Anticipated Dorsal Longeron Maintenance Actions

- AETC SUPT
- AETC IFF
- AETC ENJJPT
- AETC Total
Predictions

Number of Anticipated Dorsal Longeron Maintenance Actions each Calendar Time Increment

- AETC SUPT
- AETC IFF
- AETC ENJJPT
- AETC Total

Calendar Time

Number of Aircraft
Predictions

• Two scenarios
  – All components are repaired separately as needed
  – The SDL, CEM and 284 Splice are all fixed at once
• If all three items are repaired at once then the maintenance action would be needed if any of the six individual components needed replacement
• However, if replaced separately it could mean up to three different times each aircraft must go to depot for maintenance
Predictions

Reduction in Maintenance Actions due to Multiple Replacements

- Maintenance Actions - All 3 Components are Replaced Separately
- Maintenance Actions - All 3 Components are Replaced Simultaneously
- % Reduction in Maintenance Actions
Summary

- Performed fuselage fatigue test
- Used test findings in analysis
- Analysis considered fleet inspection results
- Aircraft historical data was gathered regarding usage, flying hours, component replacement, configuration changes
- Usages compared by severity
- Information was applied across the fleet to predict problems
- Results were presented by T-38 ASIP to AETC for planning purposes
- Proactive effort underway to gather engineering and parts for repair and modification of the fleet
Questions?