F/A-18E/F FULL SCALE STRUCTURAL FATIGUE TESTING

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Full-Scale Fatigue Testing

- **Test Articles**
  - FT50 represents the entire F/A-18E/F airframe
  - FT76 represents the new F/A-18E/F forward fuselage
  - FT77 represents the new F/A-18E/F wing

- **Test Requirements**
  - FT50 & FT77: Complete 18,000 simulated hours of fatigue cycling (3 lifetimes)
  - FT76: Complete 12,000 simulated hours of fatigue cycling (2 lifetimes)
Tension-Compression Load System
## FT50 Fatigue Test Setup

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Strain Gages at Test Start</td>
<td>1643</td>
</tr>
<tr>
<td>Deflection Transducers at Test Start</td>
<td>89</td>
</tr>
<tr>
<td>Load Controllers</td>
<td>182</td>
</tr>
<tr>
<td>Lines per 1000 Simulated Flight Hours</td>
<td>448,492</td>
</tr>
<tr>
<td>Total Spectrum Lines in 2 Lifetimes</td>
<td>5,786,042  (including make-up cycling)</td>
</tr>
<tr>
<td>Pretest Surveys</td>
<td>27</td>
</tr>
<tr>
<td>Continuously Monitored Data Channels</td>
<td>1560</td>
</tr>
<tr>
<td>Maximum Lines Per Minute</td>
<td>14.1</td>
</tr>
</tbody>
</table>
FT50 Fatigue Test Spectrum

• Symmetric maneuvers included both steady state and abrupt conditions from -2.5g to 8.5g

• Abrupt maneuvers only occur for positive Nz events

• Asymmetric maneuvers included 40%, 60%, 80%, and 100% lateral stick deflections and consist of -1g rolls, +1g rolls, and Rolling Pull-Outs (RPOs) up to 8.5g

• Negative 1g rolls were limited to rolling through 180 degrees and positive 1g rolls continued through 360 degrees

• Rolling angles (bank to bank) were dependent upon the entry g level for RPOs at Nz greater than 1g
FT50 Fatigue Test Spectrum

- Ground-Air-Ground Cycles: 15750
- Field Taxi Runs: 8750
- Catapult Launches: 2250
- Landings
  - Arrested: 2250
  - Touch and Go: 450
  - Field Carrier Landing Practice (FCLP): 6450
  - Field Mirrored Landing Practice (FMLP): 6600
Extensive Assessment Of Loading Accuracy of Full-Scale Fatigue Test

\[ LR = \frac{N_{\text{Test}}}{N_{\text{Test}}} \]

Design Life:
- FT50 = 16,000
- FT77 = 16,000
- FT76 = 24,000

Test life at the design stress level:
- Overtest if LR > 1.15
- Undertest if LR < 0.85

N_{\text{Test}} \quad \frac{24,000}{12,000}

TM = Test Margin =
Results of FT76 Fatigue Test Accuracy

- Original FT50 Data
- Life Ratios
  - Overtest: LR > 1.15
  - Equivalent
  - Undertest: LR < 0.85

- Test Margins
  - Elevated Risk: TM < 1.33
  - Minimal Risk: TM >=1.33

LR values and TM values for various test specimens are shown on the diagram.
Extensive coordination with United States Navy to define expectations and processes

Eddy Current used as the primary NDI technique

Looking for cracks that are 0.030” or larger
FT50 keel longeron Y555 cracks at 10,000 SFH

FT50 10000 SFH
View Lkg Outbd at LH 74A328120-2005
Keel Longeron at Y555

Y555 Drop Out Link & APU Cover Support Angle Removed

Crack

Eddy current indication in this hole

Crack

Y555 Drop Link & APU Cover Support Angle Removed
FT50 right-hand outer wing electrical cut-out cracks at 16,410 SFH

FT50 at 16410.7 SFH
View Looking Outbd at 74A140313-2001 L/H Outer Wing Rib

.030” crack indications
.030” crack indications

Hole not shown has similar crack between screw hole and connector but no crack emanating away from screw hole.

.030” crack indication
.030” crack indications

Cracks

Crack

Up

Fwd
FT50 Leading Edge Extension (LEX) cracks at 15,000 SFH
17” Crack on FT50 Right Wing Root Lower Surface
Failure analysis example (wing root failure)
Detailed models were constructed to characterize the stress field at the countersink holes.
Failure surface of crack emanating from flaw at fastener hole in wing root lower skin.

Fracture A

Disturbed hole wall at origin

0.005: from origin

Between 104 to 129 thousand striations per inch
• Probability analysis was performed early in the F/A-18E/F program to determine the scatter factor that was to be used during fatigue analysis of structural components.
  - A scatter factor of 1.0, i.e., design for 12,000 SFH and test for 12,000 SFH, would correspond to a 50% probability that a crack will initiate after two lifetimes (12,000 SFH) of testing.

• The E/F program incorporated a scatter factor of 1.33 (design for 16,000 SFH) into all fatigue design allowables which corresponds to an 18% probability that a crack will initiate after two lifetimes.
• Stretch testing the FT50 test article to three lifetimes (18,000 SFH) corresponds to an effective scatter factor of 0.89 since the structure was only designed for 16,000 but was tested for 18,000 SFH.

• This scatter factor corresponds to a 65% probability that a crack will initiate after two lifetimes.

• Therefore, the number of cracks identified on the FT50 test article is not unexpected.
Summary of cracks on FT50 at completion of 18,000 SFH of testing

<table>
<thead>
<tr>
<th>FT50 Component</th>
<th>Parts</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wing</td>
<td>43</td>
<td>641</td>
</tr>
<tr>
<td>Forward Fuselage</td>
<td>53</td>
<td>492</td>
</tr>
<tr>
<td>Center Fuselage</td>
<td>133</td>
<td>1119</td>
</tr>
<tr>
<td>Aft Fuselage</td>
<td>56</td>
<td>293</td>
</tr>
<tr>
<td>Mechanisms</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Vertical Tail</td>
<td>9</td>
<td>45</td>
</tr>
<tr>
<td><strong>Totals --&gt;</strong></td>
<td><strong>296</strong></td>
<td><strong>2593</strong></td>
</tr>
</tbody>
</table>
Many Parameters Required To Successfully Complete Test Program

Certification

SUCCESS

- Structural Technology
- Failure Analysis
- Coordinated Teardown Plan
- Define Teardown Criteria
- NDI Capability
- Analytic Tools
- Strain Surveys
- Perform Over/Undertest Analysis
- Customer Coordination

Global Strike Systems
F/A-18E/F Test Conclusions

- The F/A-18E/F full-scale fatigue test programs are a solid success as expressed by United States Navy
  - “Superb” technical performance expressed by customer
  - FT50 2nd lifetime testing completed ahead of schedule

- Comprised multiple full scale fatigue test articles that certified the airframe to meet the intended design life

- Successful in identifying structure that is capable of exceeding the intended design life

- Success of the F/A-18E/F airframe continues to be realized by utilizing the E/F structural platform as the foundation of the EA-18G program
  - Next generation of electronic attack aircraft for the United States Navy
EA-18G
Electronic attack variant of the F/A-18E/F