Force Life Management of the F-16 of the Royal Netherlands Air Force

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Force Life Management – Why?

RNLAF F-16 Force Life Management

- How?
- Benefits
Force Life Management (FLM) - Why?

- Fatigue in metal parts still considered to be the major threat to safety of military aircraft
  - USAF report ASC-TR-2010-5002 (Tiffany et al.)

- Two structural integrity (SI) concepts are currently in use for structural design and maintenance of military aircraft
  - Safe Life
  - Damage Tolerance

- Damage Tolerance philosophy
  - Slow Crack Growth DamTol design  \(\leftrightarrow\) most common
  - Fail-Safe DamTol design

Safety-by- Inspection
• During design /development, an estimation of the expected usage is made by the OEM – “design usage”

• Based on design usage, service lives and inspection intervals are derived to accomplish acceptable level of safety

• The “operational usage” is always different and will continue to differ throughout deployment phase
  - this will affect fatigue crack growth

• Service lives & inspection intervals therefore may ($$$$) or have to (safety) be adjusted
Basic FLM schema

Design usage is (initial) baseline

Actual operation may be less/more severe than baseline

- Monitoring
- Severity
- Measures
- Implication

Actual operation may be less/more severe than baseline?
"Force Management Programs" as part of USAF integrity programs (ASIP/ENSIP) determine the difference between assumed design and actual usage.

(Damage) indicators are used to quantify the effects of severity of operations:
- CSI for airframe F-16
- CCY/HS3 F100 engine

"What happened up there?"
USAF/ASIP – “5 pillars/tasks”

MIL-STD-1530C (USAF/ASIP):

5.5.1 Individual Aircraft Tracking (IAT) Program.

The IAT Program shall be used to adjust the inspection, modification, overhaul, and replacement times based on the actual, measured usage of the individual aircraft. The IAT Program shall be used to determine damage growth in the appropriate environment as a function of the total measured usage and to quantify changes in operational mission usage. The IAT Program shall also determine the equivalent flight hours (or other appropriate measures of damage such as landings, pressure cycles, etc.) and adjust the required maintenance schedule for all critical locations on each individual aircraft. The IAT Program shall forecast when aircraft structural component life limits will be reached. Data systems should comply with the requirements of AFPD 63-14 and AFI 63-1401.
RNLAF F-16 FLM - How?

F-16 FLM with FACE
- flexible data recorder → each aircraft can be used as test aircraft
- dedicated measurements for load monitoring
  - master signal / slave signals
  - peak-valley-peak data reduction
  - time at level
- NLR/RADA design

Measured FACE data for F-16
- flight parameters (from digital data bus)
- dedicated load parameters (5 strain gauges)
- engine data (Engine Digital Control / Unit)
- discretes (e.g. Weight on Wheels)
RNLAF F-16 FLM - How?

Analog signals (strain gauges)

- FS 462 vertical tail bending
- FS 325 (MSR) wing root bending
- FS 479 horizontal vertical tail bending
- FS 374 fuselage bending
- BL 120 wing tip bending

EDU/DEEC
- Discrete signals
- WOW-switch
- Wheels-position-switch

Avionics MUX-BUSES

VADR

Hi8 VTR cassettes
Measured FACE data

Logistic Debriefing Station at SQN

Flight Admin data SAP/OMISKLu

Debriefing at SQN

Damage Indicators

CSI – Airframe
- relative damage indicator
- load sequence effects
- developed at NLR

CCY/HS3 – Engine
- according to P&W algorithms

Centralized F-16 Loads and Usage monitoring information system at NLR (Oracle Database)

Routine status reports airframe/engine

Ad hoc/ additional detailed analyses

Damage Indicators

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FACE has proven to be a valuable instrumentation package for F-16 FLM management purposes (ASIP & ENSIP)

• Loads/Environment Spectrum Survey (L/ESS) data for update FSMP
  • provided OEM with hi-fidelity RNLAF usage
  • also used in NL for development of load sequences for structural testing purposes (TukLoc, Wing Durability Test)

• Insight in Remaining Useful Life
  • optimization of life consumption
  • maintenance planning
  • selection of aircraft & engines for modif. programs / decommissioning

• FACE used for ad hoc purposes
  • valuable source for mishap investigation
  • detailed engine FAULT-code recordings
  • canopy sill longeron DI
RNLAF F-16 FLM - Benefits

Other benefits

• Military Flight Operations Quality Assurance (MFOQA)
  • limit exceedances of Mach, CAS, AoA, g, GW
  • no separate data recorder needed

• Fuel consumption monitoring

• Limit Cycle Oscillations (LCO) monitoring

• Landing gear DI

• Information system frequently used as study for development of next generation decision support tools

• FACE is a very flexible instrumentation package
  • each aircraft in theory “unique” test a/c

• Supportive test programs
  • WAF bolts, TukLoc program, Wing Teardown & Durability Test
  • source data obtained from FLM program
F-16 TukLoc fastener

- Evaluation of TukLoc fastener system intended to be used in the RNLAF F-16 PACER wing modification program

- USAF, BAF, RDAF, RNoAF already flying with installed TukLocs and experienced problems (loose bolts, loss of clamp-up torque)

- TukLoc performed worse than old bolts, so keep old bolts. Saved RNLAF money.

- Results prompted Lockheed Martin to perform additional risk analyses and recalculate safe life of wing!
F-16 wing teardown

- RHS wing of RNLAF F-16 Block 15
- 4,200 Operational Flight Hours
- Objective: assess current fleet status
F-16 wing test

- LHS wing of RNLAF F-16 Block 15
- 4,200 Operational Flight Hours (with known history)
- Durability test to failure or 2x design life (whichever comes first)

Objectives
- determine if wing has damage not accounted for in early durability test / DADTA
  - undetectable damages will become detectable
- establish crack growth curves for critical locations & relevant load spectrum
  - feeds back into inspection program & required modific./wing acquisition program
- validate fail safe scenarios
- provide inputs for risk assessment studies
- validate cgFEM

Test definition & execution completely independent of LM aero
F-16 wing test
F-16 wing test
F-16 wing test results

- Wing survived Limit Loads after more than 2x design life
- Formation of large fatigue cracks
  - no unexpected locations
  - crack growth rates measured
- Validated cgFEM
  - used in combination with measured crack growth rates to establish RUL
- Based on results, DMO decided NOT to acquire new wing sets
  - 30M€ saving
Questions ?