Flight Test of the F/A-18
Active Aeroelastic Wing Airplane

David Voracek
Presenting
the
Flight Test Analysis and Evaluation done by:
Robert Clarke,
Michael J. Allen, Ryan P. Dibley,
John Hodgkinson and Joseph Gera

NASA Dryden Flight Research Center

F/A-18 AAW Airplane

NASA Photo: EC04-0361-08

F/A-18 AAW Control Surfaces

- **Trailing edge flap**
  - +45°/-8°
  - 18°/s

- **Aileron**
  - +45°/-25°
  - 100°/s

- **Inboard leading edge flap**
  - +34°/-5°
  - 15°/s

- **Outboard leading edge flap**
  - +34°/-10°
  - 45°/s

- **Rudder**
  - ± 30°
  - 56°/s

- **Stabilator**
  - +10.5°/-24°
  - 40°/s

Flight Test Background

- Phase I - from Nov 02 to Jun 03
  - Flutter clearance, air data calibration, aerodynamic and loads model development
- Phase II - from Dec 04 to Mar 05
  - Boeing & DFRC CLAW designs
- Phase IA - Mar 05
  - Aeroservoelastic research
- Phase IIA - Mar 05
  - CLAW’s at several test points were redesigned
AAW Design Test Points

AAW Phase I Test Maneuvers

• OBES ASE/flutter clearance
• Air data calibration
  – Tower flyby
  – Level accel’s
  – POPU’s
  – Slow $\beta$ sweeps
• Simulated OLEF failure (left OLEF)
• OBES pitch and roll doublets
• Demonstration maneuvers
  – 5-g WUT
  – 1-g bank-to-bank/360° rolls (incremental build-up to full stick or load limit)
  – 4-g RPO
OBES Pitch Doublets
OBES Roll Doublets

Phase I - Lessons Learned

• Phase I flight tests using OBES provided good data for aerodynamic and loads model development, but hindsight showed some of the doublet maneuvers were too small
• Phase I results showed no tendency for aileron reversal (flexibility of the aileron may have contributed to this)
• The AAW airplane was unable to accomplish any testing at two of the highest dynamic pressure test points
• Aileron hinge moment loads were a design driver for the Phase II CLAW’s
Control Law Development and Verification & Validation Testing

• Both Boeing and NASA DFRC teams developed control laws for each design test point
  – Boeing used ISMD design process
  – NASA used CONDUIT® design process
• Verification testing and limited validation testing conducted by Boeing (FAST and piloted HIL)
• Extensive HIL V&V testing conducted at DFRC
  – Aerodynamic modeling issues were examined for safety-of-flight
  – IADS displays were used as part of test (built confidence in them before they were used for flight test)
  – Several errors in the flight code caught and fixed
    • Rudder trim gain had incorrect value
    • Transient free switches caused control surfaces to drift
AAW Phase II RFCS Envelopes

AAW 1-g Phase II Flight Test

• 1-g bank to bank and 360° rolls
  – Tested the primary AAW technology (ability to roll the airplane using only wing control surfaces)
  – Tested the ability of the control laws to achieve acceptable roll performance and flying qualities while maintaining loads within limits

• Learned how well the aerodynamic and loads models predicted the vehicle’s response (issues were linearity and superposition)
Region I - Subsonic 1-g Rolls

Region I - Subsonic 1-g 360° Roll

Region II - Supersonic 1-g Rolls

Region II - Supersonic 1-g 360° Roll

Region III - Subsonic 1-g Rolls

Region III - Subsonic 1-g 360°Roll

Roll Axis HOS/LOS Comparison
Region II - Supersonic (open-loop)

τ = 0.25
Roll Axis HOS/LOS Comparison
Region II - Supersonic (closed-loop)

\[ \tau = 0.22 \]
AAW Phase II Elevated-g Flight Test

• Windup Turn
  – Tested the ability of the control law designs to reduce wing loads (maneuver load control) or replicate basic F/A-18 trim schedules

• Rolling Pull Out
  – Tested the primary AAW technology (ability to roll the airplane using only wing control surfaces)
  – Tested the ability of the control laws to achieve acceptable roll performance and flying qualities while maintaining loads within limits

• Learned how well the aerodynamic and loads models predicted the vehicle’s response (issues were linearity and superposition)
Region I - Subsonic 4-g RPO
Region I - Subsonic 4-g RPO

Phase II - Lessons Learned

- The RFCS worked well in both Phases I and Phase II
- The AAW program was the first program at DFRC to utilize a RFCS in a safety of flight critical envelope
- The IADS® displays worked well for safety monitoring
- Comparison of the flight data and predicted airplane response ranged from fair to excellent