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

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Presenting
the
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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
Roll Control Effectiveness Regions

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

![Graph showing OLEF, ILEF, TEF, OLEF & ILEF Alleron, and Stabilator over time in degrees.]

OBES Roll Doublets

AAW Aileron Flexibility

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)

\[ \tau = 0.25 \]
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)
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