IRAC Full-Scale Flight Testbed Capabilities

Jim Lee
Joe Pahle
Bruce Cogan
Curt Hanson
John Bosworth

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Full-Scale Flight Test Overview

- Provide validation of adaptive control law concepts through full scale flight evaluation in a representative avionics architecture

- Develop an understanding of aircraft dynamics of current vehicles in damaged and upset conditions
  
  Real-world conditions
  
  Turbulence, sensor noise, feedback biases
  
  Coupling between pilot and adaptive system

  Simulated damage
  
  “B” matrix (surface) failures
  
  “A” matrix failures

- Evaluate robustness of control systems to anticipated and unanticipated failures
RFI Objectives

- Objective 1: To validate adaptive control technology using manned flight experiments
  - Experiments addressing:
    - Challenges that can only be addressed by manned flight
    - Address barriers to implementation
    - Sufficiently large (meaningful) failures

- Objective 2: To examine the benefits of manned Vs autonomous recovery from upsets or failures
  - Experiments addressing:
    - Types of pilot input to system
    - Separate, backup, or primary flight control implementation
    - Pilot Interaction with the adaptive system
RFI Objectives

- Objective 3: To test and validate system-level reasoning for flight control reconfiguration
  - Experiments addressing:
    - Detection, diagnosis, prognosis, and isolation technologies for control reconfiguration and envelope limiting controls
NASA F-18 Full-Scale Test bed

- Extensive Structural Instrumentation
  - Strain Gages
  - Accelerometers
  - Optical Flight Deflection Measurement System

- Quadruplex Research Flight Control System (RFCS)
  - Safety Monitoring and Mode Transitions
  - Full Command of Surfaces/Throttles
  - On-Board Excitation System
  - Simulated Failures

- Dual Airborne Research Test System (ARTS IV) Computers
  - Commands Surfaces and Engines through RFCS
  - Capability for Interfacing to Structural Instrumentation
  - Additional Payload I/O
Instrumentation

TOTAL PARAMETERS – over 1669

A/C 1553 DATA BUS – 1092
GPS/INS 1553 DATA BUS – 170
FIBEROPTIC SHAPE SENSORS (In work)

RH WING
PARAMETERS-168
107 - FULL BRIDGE STRAIN GAGES
18 – ACCELEROMETERS
8 – POSITION SENSORS
10 – VOLTAGE SENSORS
3 – TEMPERATURE SENSORS
22 – PRESSURE SENSORS

LH WING PARAMETERS-155
77 - FULL BRIDGE STRAIN GAGES
18 – ACCELEROMETERS
8 – POSITION SENSORS
10 – VOLTAGE SENSORS
4 – TEMPERATURE SENSORS
22 – PRESSURE SENSORS
16 – FDMS TARGETS

FUSELAGE
PARAMETERS-70
6 - MOTION PAK
7 – ACCELEROMETERS
7 – TEMPERATURES
8 – FUEL QUANTITY
27 – MISC. A/C PARAMETER
15 – TCG PARAMETERS

EMPENNAGE
PARAMETERS-14
4 – POSITIONS SENSORS
10 – ACCELEROMETERS
RFCS and ARTS IV Architecture

**Instrumentation**
- ARTS IV
- 1553B Ethernet
- Analog Discrete RS-422

**Payload**
- Pilot Inputs, INS, Air Data
- 1553B Commands

**RFCS / 701E**
- Pilot Stick and Rudder
- Air Data
- Rates Accels

**Pilot Stick and Rudder**
- Stabilators
- Ailerons
- Rudders
- Leading-Edge Flaps
- Trailing Edge Flaps
- Throttles

**Optional Experiment**
- Baseline Experiment
- F-18 Infrastructure
F-18 701E/RFCS integration

- F-18 Production FCS used for T/O, getting on condition, and landing
- Robust backup in case of RFCS failure or departure
- RFCS control laws completely separated from production control laws
- RFCS experiment can be point design, single axis or full-envelope, all axis design (initially will be limited to the Class B envelope)
ARTS IV Hardware

Flight unit

Lab unit

Portable test computer
ARTS IV Capabilities

• The ARTS IV can be given full control of the aircraft’s control surfaces and engines via the RFCS.

• It is time-synchronized with the RFCS and designed to minimize time delays in the control path.

• The ARTS IV experiment software is mission-critical for rapid prototyping capability. The quad-redundant RFCS handles safety-critical envelope checks, fault detection and mode transitions.

• The ARTS IV consists of fully redundant dual hardware for potential future experiments requiring fail-safe capability.

• Provisions for external high-speed data links to support instrumentation feedback (structural, IVHM, etc.) into flight control experiments as well as allow an interface to each engine.
ARTS IV Capabilities (Cont.)

- Classes of potential experiments include, but are not limited to:
  - Direct and indirect adaptive inner-loop control
  - Integrated aerodynamic and propulsion flight control
  - Adaptive mission planning and guidance
  - Integrated vehicle health monitoring
  - Multiple (up to 8) experiments can be loaded at once prior to flight (only one can be controlling at a time, but the others can be running as well)
  - Adaptive control with structural constraints (potential future capability)
  - ARTS IV is based on 1Ghz PPC processor technology enabling computationally intensive experiments

- Examples of these experiments are illustrated on the next slide
Controls-Centric Capabilities

Command Augmentation
- System Identification
- Reconfigurable Retrofit
- Persistent Excitation

Outer-Loop Control
- Piloted
- Experimental Autopilot
- Surrogate UAV

Inner-Loop Control
- F-18 Replication (RFCS)
- User-Specified (ARTS)

Simulated Failures
- Single Surface Lock
- Multi-Surface Lock
- Throttles-Only
- “Damaged Wing”
- User-Specified

IVHM
- Real-Time
- Off-Line

Outer-Loop Control
- Pitch Stick
- Roll Stick
- Rudder Pedals
- Throttle Levers

Inner-Loop Control
- Stabs
- Ailerons
- Rudders
- Flaps
- Throttles

IVHM
- Inertial, Air Data Structures, etc.
ARTS IV Capabilities (Cont.)

• Flying an experiment
  – Experimenter’s handbook details procedures to get experiment in the ARTS IV
  – Experiment can be delivered as a Simulink model or as “C” code
  – Verification and validation of candidate experiment done at DFRC using HILS Test Bench and piloted sim
  – Rapid prototyping of potential experiments and quick path to flight

• A non-controlling experiment can be flown anywhere in the F-18 envelope

• A controlling experiment will not result in structural damage in the event of a control surface hard-over when flown in the Class B envelope (see next slide)
“Controlling Experiment” Flight Envelope

Controlling Experiment (Class-B) Envelope

Altitude, ft

Mach

$4 \times 10^4$

3.5

3

2.5

2

1.5

1

0.5

0

0

0.1

0.2

0.3

0.4

0.5

0.6

0.7

0.8

0.9

250 KIAS
DFRC Flight Research Support Capabilities

• Real-time Piloted F-18 Simulator
  – Allows advanced analysis of experiments, including flight planning and piloted evaluations
  – Includes S/W models of the RFCS and ARTS IV subsystems
  – ITAR restrictions apply to most simulation models

• F/A-18 Hardware-in-the-loop (HIL) Test Bench
  – Allows flight qualification testing of experiments
  – Exhibits many of the same difficult to model constraints encountered on the A/C, including timing issues and system noise
  – Provides capability to rapidly advance experiments to flight and make quick turn arounds between flights

• Real time Control Room Monitoring
  – Critical disciplines generally include loads, flight controls, flight operations
  – May also include aerodynamics, propulsion, structural dynamics, and others as needed
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Contact Information

Jim Lee
james.a.lee-1@nasa.gov
661 276 3385

Joe Pahle
joe.pahle-1@nasa.gov
661 276 3185

John Bosworth
john.t.bosworth@nasa.gov
661 276 3792

Curt Hanson
curtis.e.hanson@nasa.gov
661 276 3966

Bruce Cogan
bruce.r.cogan@nasa.gov
661 276 2627
Questions?