IRAC Full-Scale Flight Testbed
Capabilities

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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**

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

A/C 1553 DATA BUS – 1092
GPS/INS 1553 DATA BUS – 170
FIBEROPTIC SHAPE SENSORS (In work)
RFCS and ARTS IV Architecture

- **Instrumentation**
  - 1553B Ethernet

- **ARTS IV**
  - Pilot Inputs, INS, Air Data
  - 1553B Commands
  - Analog Discrete
  - RS-422

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

- **Payload**
  - Optional Experiment

- **Stabilators**
  - Baseline Experiment

- **Ailerons**
  - F-18 Infrastructure

- **Rudders**
  - Leading-Edge Flaps

- **Throttles**
  - Trailing Edge Flaps
• 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

Portable test computer

Lab unit
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

IVHM
- Real-Time
- Off-Line

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

Command Augmentation
- System Identification
- Reconfigurable Retrofit
- Persistent Excitation

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

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

Pitch Stick
Roll Stick
Rudder Pedals
Throttle Levers

Stabs
Ailerons
Rudders
Flaps
Throttles

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 x 10^4

3.5

3

2.5

2

1.5

1

0.5

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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Questions?