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**

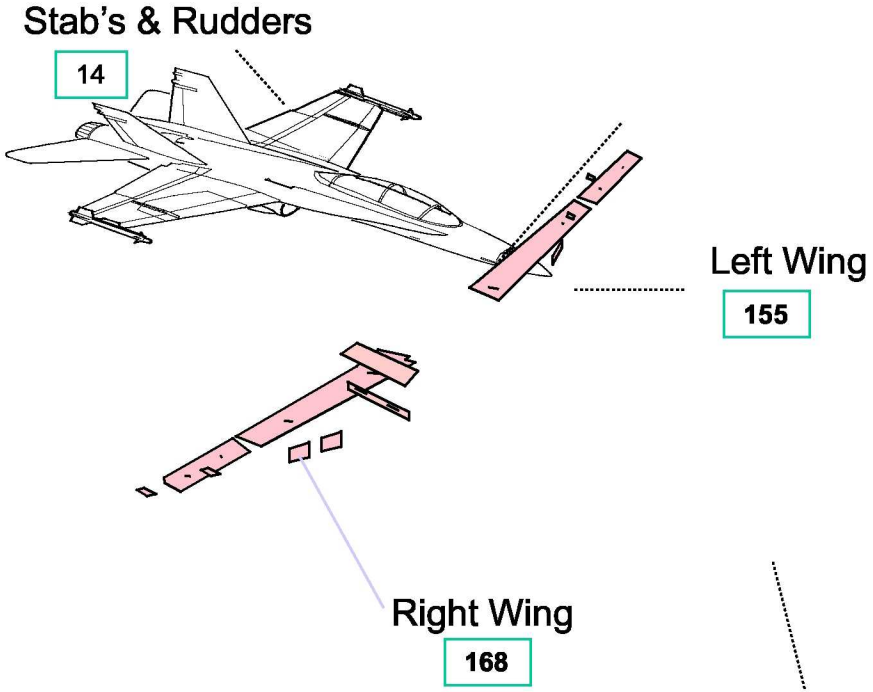
NASA F-18 Full-Scale Test bed

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

T0TAL 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

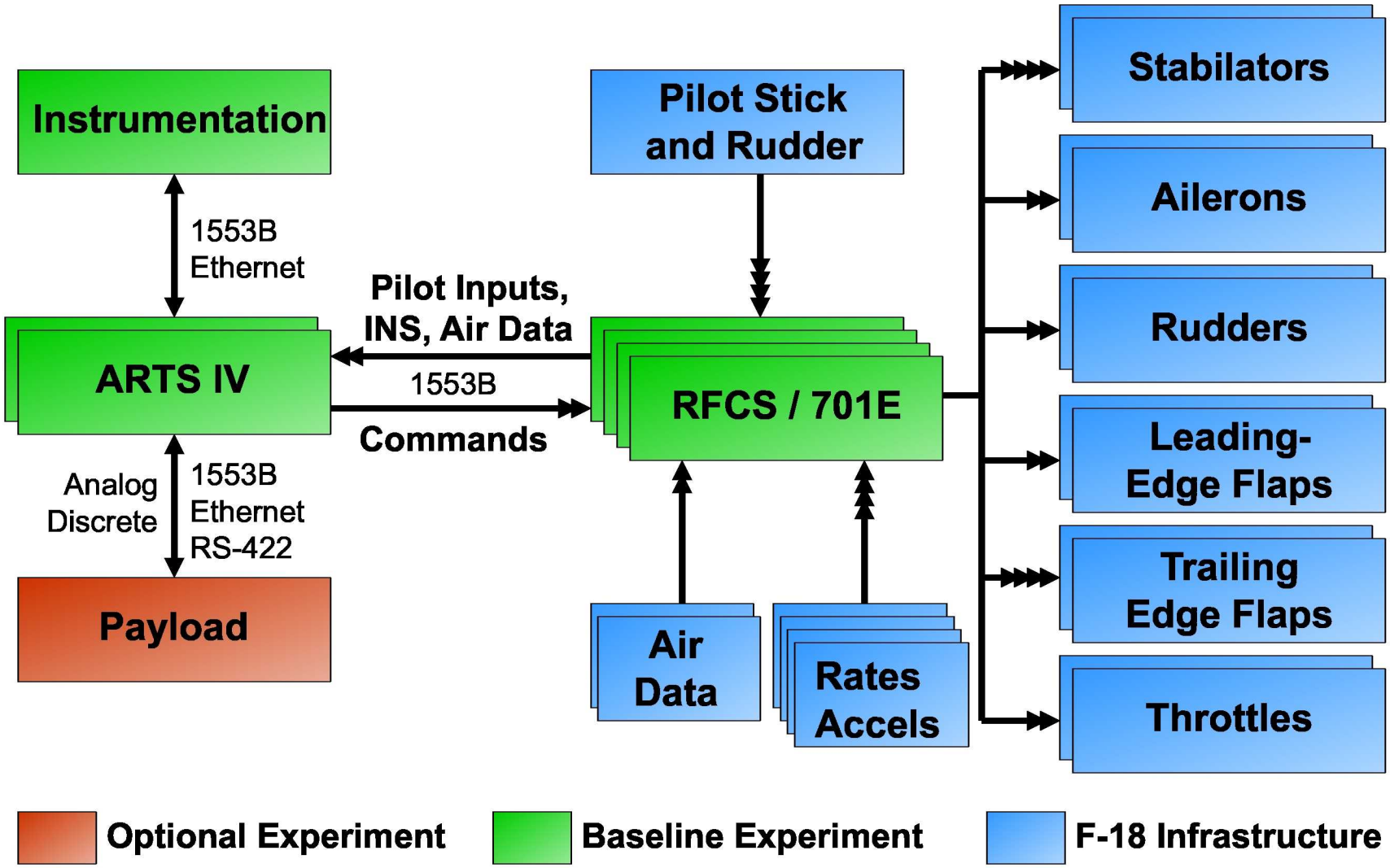
FUSELAGE PARAMETERS-70

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

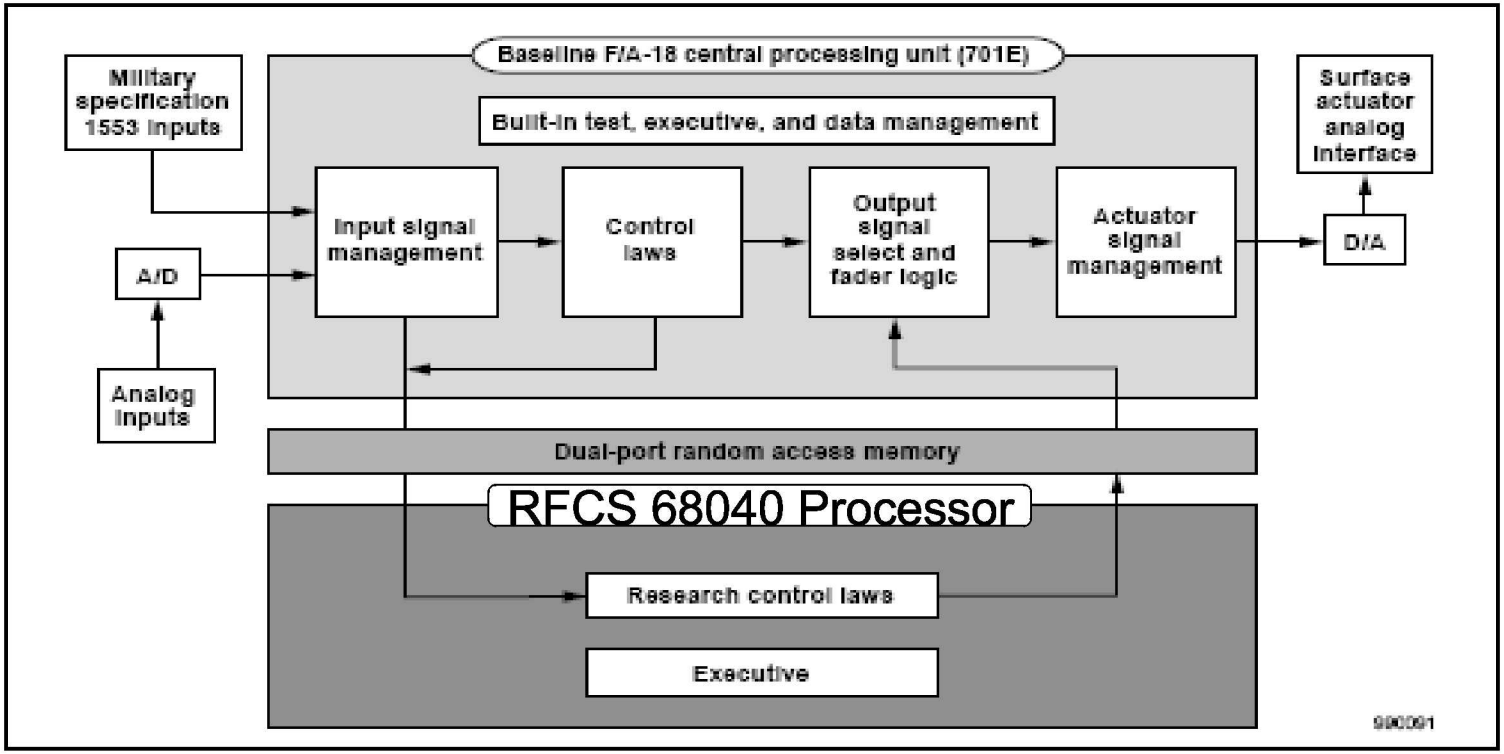
EMPENNAGE PARAMETERS-14

4 – POSITIONS SENSORS
10 – ACCELEROMETERS

RFCS and ARTS IV Architecture



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

Portable test computer

Lab unit

ARTS IV Capabilities

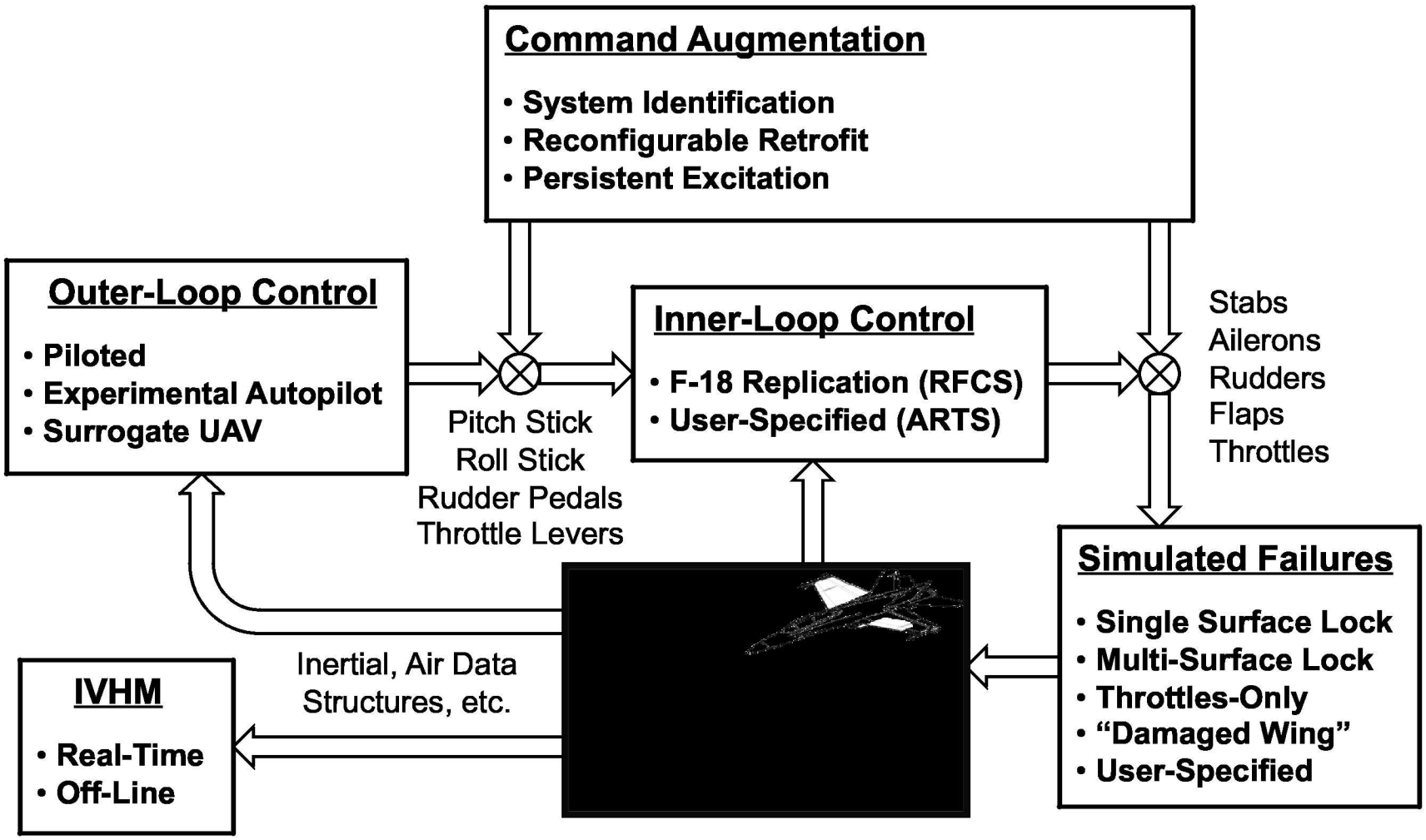
- The ARTS IV can be given full control of the aircraft's control surfaces and engines via the RFCS.
- It is time-synchronized with the RFCS and designed to minimize time delays in the control path.
- The ARTS IV experiment software is mission-critical for rapid prototyping capability. The quad-redundant 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

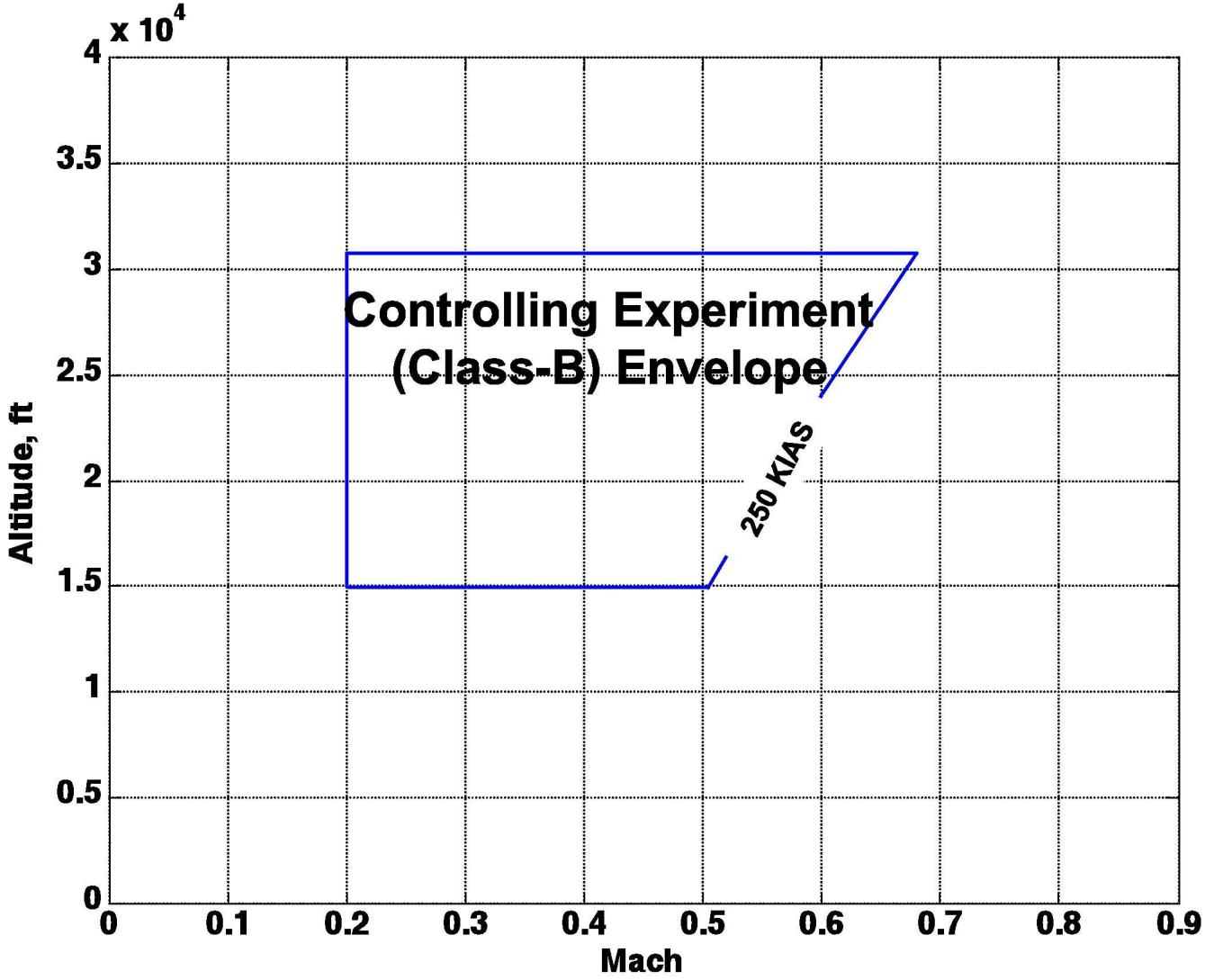
Controls-Centric Capabilities



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



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

IRAC Full-Scale Flight Testbed
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Questions?