IRAC F/A-18 RFCS on NASA 853

IRAC F/A-18
February 2009
Scope

2008: F-15 IFCS
Stability
MS IRAC 4.1.1

Adaptive Flight Control

2009: F/A-18 TN853 IRAC

2010: ACFS Simulation
Stability + Maneuverability
MS IRAC 4.1.2.1

Flight Planning and Guidance
Adaptive Flight Control
Airframe and Structural

2011: F/A-18 IFS
Stability + Maneuverability
MS IRAC 4.1.2.2

Engine Control
IVHM Data Mining Lab
Airframe and Structural

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F/A-18 Testbed Development⇐⇐⇐⇐⇐⇐F/A-18 Flight Research⇐⇐⇐⇐⇐⇐

3.3.1.2 3.3.2.2 3.2.2.1 (Option A) IVHM 4.3.1

IVHM Data Mining Lab
IPP DASP or IVHM 3.4.1 Successor

3.3.1.2
3.3.2.2
V&V Methods

Engine Control
Adaptive Flight Control
Flight Planning and Guidance
Airframe and Structural

Baseline
IVHM
Option A
F/A-18 RFCS History

• Quad 1750A RFCS addition to F/A-18 production FCS allowed by 701B to 701E upgrade (1987-1989)
  – Almost all I/O routed through production Input and Actuator Signal Management
    • (1) analog channel to RFCS I/O
  – Addition of TVCS ASM (6 aileron actuators), later added Forebody Strakes (2)
  – RFCS integrated with F/A-18 version 10.1 Control laws
  – Production Mission Computer (MC) modified to provide additional inputs to RFCS, increased rate (80 Hz)
  – Class-B RFCS S/W environment and envelope
  – System design stressed flexibility and testability (validated by 20 year legacy)
  – Shared S/W development and testing (NASA, BAE (GE), Boeing (McAIR))

• Programs that utilized 1750A RFCS
  – PSFCC (1997-1999) [demod TVCS and FBS actuation, include RFCS CCDL]
  – AARD (2006-2007)

Pace 1750A : 16 bit
Speed: 40 Mhz
Memory available for control laws: 32K
F/A-18 RFCS History (cont.)

• Quad 68040 RFCS upgrade to allow more capable Claws for AAW
  
  (1995-1999)
  – All I/O routed through production Input and Actuator Signal Management
  – RFCS integrated with 10.1 Claw (same as 1750A)
  – Addition of OutBoard Leading Edge Flap Actuator Signal Management
  – First RFCS Class-A S/W environment and envelope
  – Boeing RFCS S/W development, shared S/W testing (NASA, Boeing, BAE)

• Programs that utilized 68040 RFCS
  – AAW

68040: 32 bit
Speed: 40 Mhz (?)
Memory available for control laws: 2Mb
Next Generation RFCS
Next generation RFCS Assumptions

- Useful system lifespan between 5 and 10 years
- Most time-critical flight control processing done within RFCS
- Maximize use of Matlab/Simulink and features such as RTW, autotest, etc.
- Bulk of RFCS S/W testing done at NASA or NRA partners
- RFCS interface to each engine
- External high-speed datalink (Ethernet to ARTS) for eventual instrumentation feedback (structural, IVHM, etc.) into flight control
- Incorporate lessons learned from past RFCS programs and other research flight systems (ARTS II (IFCS on 837), ARTS III, AAW, etc.)
Requirements Framework

• RFCS and ARTS H/W
  – Provide throughput, memory, and computational resources to support current and future research control laws (2x to 10x the memory and complexity/computation of F/A-18 replication control laws)
  – Provide external I/O to RFCS/701E with external high-speed datalink (minimize time delay)

• RFCS and ARTS S/W
  – Design for level B and the potential for Level A
RFCS/ARTS “use cases”
How may this architecture be used

- Mini-stick, AFF, AARD – RFCS/ARTS
  - External stick or sensor inputs into ARTS, F/A-18 claws in RFCS

- PSFCC – RFCS primary or RFCS/ARTS
  - F/A-18 replication control law mods
  - Also USN reconfigurable retrofit

- IFCS Gen II (837) - RFCS/ARTS or ARTS primary
  - Claws in RFCS or ARTS, Adaptive control law elements in ARTS

- FADS, IVHM – RFCS primary or RFCS/ARTS
  - External I/O processed in ARTS

- HARV, AAW not represented
  - Not possible without significant FCS modifications (level A)
### One Set of Potential RFCS Upgrade Options

<table>
<thead>
<tr>
<th>Baseline</th>
<th>701e</th>
<th>1750A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Already exists</strong> 10.1 CLAWS in the 701E (used for HARV, PSFCC, mini-stick, AFF, AARD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Limited throughput and memory</td>
<td></td>
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<tr>
<td>• Very limited external I/O (2 analog A/D channels)</td>
<td></td>
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<tr>
<td>• Ancient TLD Ada compiler and no/limited S/W support</td>
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<table>
<thead>
<tr>
<th>68040 Demod</th>
<th>701e</th>
<th>68040</th>
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</thead>
<tbody>
<tr>
<td><strong>Already exists</strong>, 10.1 CLAWS in the 701E (modified for AAW)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Better throughput and memory than 1750A</td>
<td></td>
<td></td>
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<tr>
<td>• Very limited external I/O</td>
<td></td>
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<tr>
<td>• No flight qualified compiler at DFRC and limited S/W support. Tartan compiler at Boeing?</td>
<td></td>
<td></td>
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<tr>
<td>• Requires mod to 701E to remove additional AAW LEF commands</td>
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<table>
<thead>
<tr>
<th>68040 upgrade</th>
<th>701e</th>
<th>68040</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1553</strong></td>
<td></td>
<td></td>
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<tr>
<td>• 1553 on 68040 already exists but not activated, 10.1 CLAWS in the 701E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Better throughput and memory than 1750A</td>
<td></td>
<td></td>
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<tr>
<td>• Untested compiler at DFRC and limited S/W support</td>
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<tr>
<td>• Requires mod to 701E to remove additional AAW LEF commands</td>
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<table>
<thead>
<tr>
<th>RFCS upgrade</th>
<th>701E or upgrade</th>
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<tbody>
<tr>
<td><strong>10.7 CLAWS in the 701E</strong></td>
<td></td>
</tr>
<tr>
<td>• Best throughput and memory within the RFCS</td>
<td></td>
</tr>
<tr>
<td>• No compiler yet at DFRC, S/W support likely available</td>
<td></td>
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<tr>
<td>• Very limited external I/O</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>RFCS+HSDL upgrade</th>
<th>701e</th>
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<tbody>
<tr>
<td><strong>HSDL</strong></td>
<td></td>
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<tr>
<td>• 10.7 CLAWS in the 701E</td>
<td></td>
</tr>
<tr>
<td>• Best throughput and memory within the RFCS and ARTS</td>
<td></td>
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<tr>
<td>• No compiler yet at DFRC, S/W support likely available</td>
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<tr>
<td>• Extensive external I/O using the ARTS</td>
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<tr>
<td>• Potential for sharing IFCs computation within the ARTS and PPC/RFCS</td>
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701E and RFCS integration

- Military specification 1553 inputs
- A/D
- Analog inputs
- 68040 Research Processor
- Research control laws
- Executive
- Dual-port random access memory
- Baseline F/A-18 central processing unit (701E)
- Built-in test, executive, and data management
- Input signal management
- Control laws
- Output signal select and fader logic
- Actuator signal management
- Surface actuator analog interface
- D/A
Notional RFCS and ARTS Timing

One of 16 subframes (0 to 15)

<table>
<thead>
<tr>
<th>Basic F-18</th>
<th>Executive</th>
<th>Preprocessing routine</th>
<th>ISM, discrete</th>
<th>Basic F/A-18 control law</th>
<th>Remaining processes, actuator signal management, and background</th>
<th>Next frame preprocessing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hardware discrete</td>
<td>Data ready discrete</td>
<td></td>
<td></td>
<td>Note: B + C &lt; 2.2 msec</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A 1.30 to 1.98 msec</td>
<td>B 0.65 to 1.55 msec</td>
<td>C 0.65 to 1.55 msec</td>
<td></td>
<td>Research control law data ready</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exec</td>
<td>Research control law</td>
<td>Exec</td>
<td>PBIT</td>
<td>Exec</td>
<td></td>
</tr>
</tbody>
</table>

6.25 msec

Exec ISM Application CCDL OSM

Feb 2009
701E/RFCS and ARTS Timing
ARTS IV

• Curtiss-Wright 183 PowerPC
• 3 SBCs per unit (2 units)
  – SBC 2 and SBC 3 are dedicated to research.
  – SBC1 performs critical I/O and host safety critical software.
• Specifications:
  – 6U VME based computer
  – 512 MB RAM
  – 1 Gigahertz PowerPC CPU
  – Discovery III System Controller
• On board I/O:
  – Ethernet, USB, RS-232
  – 2 PCI Mezzanine Card (PMC) Sites
RFCS/ARTS IV integration
F/A-18 Research System Components

- Displays
- Arm/engage
- OBES sel

Mission computer

1553

853 instrumentation system

1553

701E baseline
F/A-18 FCC

68040 RFCS

Adaptive algorithms contained here

F-18 actuators

ARTS IV computer

TM to ground

Feb 2009
Current IRAC Schedule

- FCCs (with 68040) and ARTS IV to DFRC in April/May ‘09
- Integration on the DFRC Test Bench in Aug ‘09
- Testing on the DFRC Bench with F-18 Sim Aug-Nov ‘09
- Install RFCS and ARTS IV in F-18 TN 853 Jul-Aug ’09
- Peer review of IRAC controls experiment Sept ‘09
- Ground Tests Sept-Nov ‘09
- FRR for 1st Flight (RFCS & ARTS w/o Research S/W) Nov ‘09
- 1st Flight (RFCS & ARTS w/o Research S/W) Feb ‘10
- Select Adaptive Research Control Laws Sept ‘10
- IRAC Milestone 4.1.2.2 Mar ’11 (adaptive integrated flight/propulsion control experiment)
Potential IRAC Experiments

- Integrated aero/propulsion control
- Integrated adaptive structural control
- Adaptive aeroservoelastic experiments
- Adaptive guidance / mission management
- Adaptive algorithm validation
- Upset recovery control validation
- Pilot interaction with adaptive system