Considerations for a Wireless Primary Flight Control System in a commercial aircraft

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Agenda

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- Wireless Primary Flight Control application - consideration and rationale
- Impediments to a completely Wireless Flight Control System
- Architecture for the Wireless network
- Benefits of a Wireless Flight Control application
- Tradeoff with wired digital Flight Control system
- Experiment at the University of Minho in Portugal

Introduction

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- **This presentation is not focused on the Wireless technology itself, but on how a Wireless network can be used to address a peculiar problem in the design of Electronic Flight Control systems for particular types of passenger-carrying aircraft**

- **Wireless Flight Controls could be viewed as an invention in search of a problem as in, there is no obvious valid rationale for completely replacing a wired Electronic Flight Control system in an aircraft**
  - Certification Authorities and the OEMs would lose interest very quickly (need for alternate hardware interface)
  - No comprehensive method of mitigation for Wireless network electromagnetic interference
  - Wireless Flight Controls may however provide a means of improving system availability for certain types of failures

- **Adaptation of University of Minho (Portugal) proof-of-concept Wireless aircraft controls experiment**

Abbreviations

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- **ACE** Actuation Control Electronics
- **COTS** Commercial Off the Shelf
- **FBW** Fly-By-Wire
- **FCM** Flight Control Module
- **FCS** Flight Control System
- **LRU** Line Replaceable Unit
- **OEM** Original Equipment Manufacturer
- **PFC** Primary Flight Controls
- **PFCS** Primary Flight Control System
- **RAT** Ram Air Turbine

Wireless PFC consideration & rationale

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- **Electronic Flight Control systems used in the commercial arena are typically layered with Redundant computing engines which**
  - Provide complex control functions
  - Interface with basic Stick-to-Surface electronic control of the actuation system

- **The Stick-to-surface actuation electronics provide an inherent backup mechanism in the event of failures resulting in loss of higher level control**

Wireless PFC consideration & rationale

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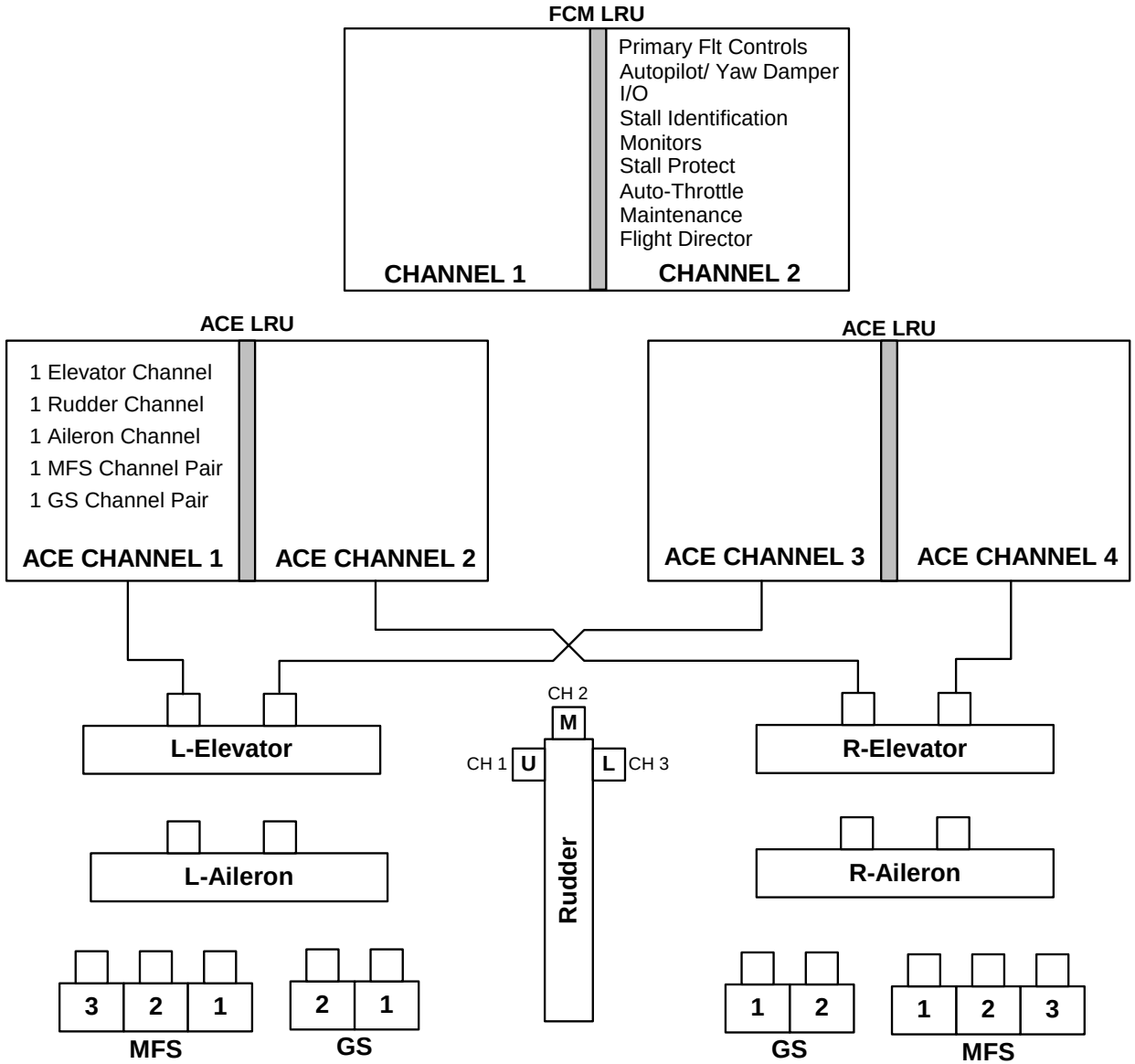

Wireless PFC consideration & rationale

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- **Why Wireless consideration for a PFC system?**
- **Wired Electronic Flight Control systems already in use in transport category aircraft are now being introduced into Business aircraft**
- **Some of these aircraft platforms have only two hydraulic systems and are not readily conducive to the installation of the FBW systems without special considerations**
  - Some do not have a Ram Air Turbine (RAT) for auxiliary electrical power
  - Some have rear fuselage-mounted engines where catastrophic engine failures resulting in rotor-burst could potentially disable critical portions of the PFC system communications network

Wireless PFC consideration & rationale

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- Equipment bays in which the critical control electronic components are housed are located in the forward and/or middle section of aircraft and interface with the actuation by means of wiring
- Position Control sensors used to signal the flight crew commands are located in the forward section of the aircraft below the flight deck
- Actuators located at the control surfaces interface to the electronics by wiring
- Potential for severing of the interconnect wiring between these critical control subsystem over the length of the aircraft

Wireless PFC consideration & rationale

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- **Wireless controls could potentially be used as a redundant means of communicating in order to maintain full functionality**

- **Reversions to Wireless controls would be ‘control system reconfiguration’ in the event of failures that result in loss of wired communications**

- **Wireless could solve intractable problems such as corner cases in the system safety assessment relating to ‘loss of control’ of critical control surfaces**

Wireless PFC consideration & rationale

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- **Fly-By-Wire Electro-hydraulic Flight Controls systems undergo a higher degree of scrutiny by the Certification Authorities than tradition hydro-mechanical systems**
  - Complexity of software
  - Electronics design instead of mechanical controls
  - Development processes
  - High Integrity requirements
  - High Availability requirements

- **Every effort is made to maintain system operation with maximum functionality in the presence of failures**
  - Complete propulsion system failure
  - Complete electrical system failure
  - Complete hydraulic system failure

Impediments to a completely Wireless PFCS

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- **Impractical as primary control communications in a PFC system**
  - Susceptibility to external interference
  - Increased cost differential from current wired digital systems
  - Increased system complexity with multiple Wireless networks that would be required to meet the High Availability requirements
  - Certification hurdles in addressing Wireless networks in critical control systems
  - Extreme conservatism in all aspects of Flight Control system design
  - Electrical power distribution to actuators cannot be eliminated

Impediments to a completely Wireless PFCS

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- **A completely Wireless control system would require a dissimilar backup system**
  - FCS are designed to inherently protect against single, combined, and in special cases, multiple simultaneous failure events from disabling the entire control system

Architecture for the Wireless network

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- The simplest Wireless network would be a ‘single string’ Backup Wireless network
- Basic overlay of the wired communication system with the wireless network to provide continuation of high-level control functions throughout the flight envelope
- At least one Wireless node must be forward and one aft of the rotor-burst (or other critical) zones for interfacing flight deck controls with wing and tail section actuation systems
- Emergency electrical power sources would be co-located with the Wireless and Flight Controls electronics

Architecture for the Wireless network

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- **Wireless would allow for continued safe flight and landing in the event of catastrophic failures that render inoperative, the wired signaling and communications network from flight deck controls and forward E-bay to wing and empennage areas**

- **Provide control to maintain aircraft safety with regard to structure and handling qualities commensurate with the flight conditions**
  - Primary flight control system would maintain full high level functionality
  - Pilot workload with regard to aircraft control would not change in the presence of failures
  - Auto-flight functions would continue to operate and aid workload mitigation

Architecture for the Wireless network

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- **There are many ways of mechanizing the Wireless network**
  - Each FCS electronic unit being able to communicate wireless
  - Wireless Nodes wired to electronic units deemed critical to flight in each aircraft control zones (wing and empennage)

- **With the exception of the Wireless nodes hardware and interfaces, no additional complexity would be added to the FCS**
  - FCS electronic units would process Wireless data in lieu of wired data
  - System integrity would be maintained by Wireless network

Benefits of a Wireless FC application

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- **Would be great if Wireless can be complete solution**
  - Comprehensive solution for communications
  - Removal of all FCS aircraft wiring
  - Less weight
  - Higher bandwidth
  - Less software
  - Less maintenance
  - Retrofit and future upgrades
  - Backward compatibility without changing the aircraft
  - Cost less
  - A great value proposition

Benefits of a Wireless FC application

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- Provides a dissimilar means of high-integrity communications in the event of loss of the primary communications and could improve safety
- Potential for full-functionality control in the case of catastrophic failures that render the primary wired communication or signaling to critical components inoperative
- Backup controls in the event of catastrophic failure such as rotor burst, fire, structural failure or other unforeseen failure events that would cause severing of the wired communication system

Tradeoff with wired digital FCS

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- **With the highly efficient current designs, the benefit gap with regard to ‘removal of wiring’ has narrowed significantly such that the disadvantages come into balance with the benefits**
  - Virtually all communications between system components is by means of 2-wire high speed digital buses
  - Actuators, although analog interfaces, have co-located electronic units that interface with the control electronics by means of digital buses
  - Wire weight, which was once a significant concern, is now mitigated by means of digital communications

- **2-LRUs controlling at least one channel of each control surface is a significant improvement in efficiency**
  - Includes both primary and secondary control surfaces

Experiment - University of Minho in Portugal

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- Commercialized off-the-shelf (COTS) technologies exist that would allow a Wireless network to be used for a high-criticality function such as Flight Controls
- In the commercial Flight Control industry however, COTS parts are not typically used for communications without mitigation to ensure protocol integrity
- The Bluetooth technology employed was used only as prototyping tool for the Wireless network which is the focus of the experiment
- Equipment used in the AIVA demonstration is a remotely piloted air vehicle