Communications System Architectures for Autonomous Formation Flight

16.886

Air Transportation Systems Architecting

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Agenda

- General Communications System Architecture
- Intership Communications
  - Network Architectures
  - Communication Mediums
    - Tested
    - Other Possibilities
  - Management of Communications Failures
- Selected References

Intership Communications

- Different information required for different types of control:
- Leader-Following
  - Relative position of leader
- Follow Preceding Aircraft
  - Relative position of preceding aircraft
- Positioning relative to imaginary point in formation determined by location of all aircraft (FGC = Formation Geometry Center)
  - Follow a virtual leader
  - Shape of formation (location and flight plan pre-determined)
- Wake Sensing
  - No intership communication needed

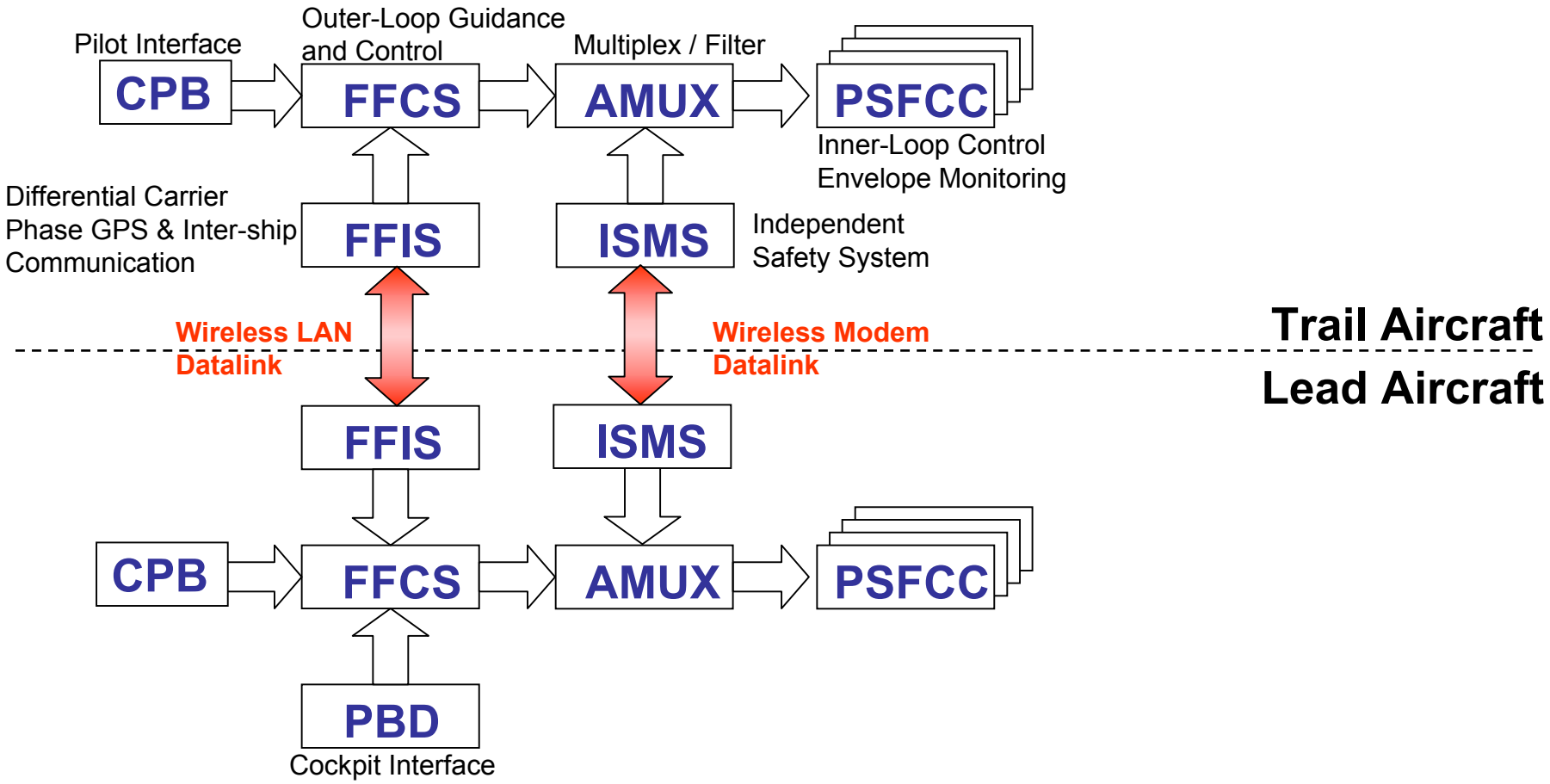
Network Architectures

- Network Topologies
  - Star, Bus, Ring (EMFF), Tree, Star-Bus, Star-Ring, Mesh, etc.
- Logical Topologies
  - Ethernet, Token Ring (EMFF), FDDI, ATM, LocalTalk, etc.
- Protocols used in Aviation Comm. Architectures
  - ATN, Internet (UDP, TCP/IP), VDL-2/IP, AMSS/IP, Mode S/IP, etc.

Communications Mediums Existing Systems

- NASA Dryden AFF
  - Wireless LAN Datalink for primary communications
    - Each aircraft determines it's own position via GPS/INS and sends to others
  - Wireless Modem Datalink to determine if aircraft is within range for formation
- EMFF (SPHERES)
  - RF link for data transfer
    - Each satellite sends its states to others
  - Combination of Ultrasonic and Infrared transmitters and receivers used to calculate distance to other vehicles

AFF System Architecture



Source: Larson, G., “Autonomous Formation Flight"

Communications Mediums
Other Possibilities

- Laser Communications (Lasercom)
  - GalliumArsenide (GaAs) Laser; Data Rate 10Gbps
  - Generally used for long-distance communication for inter-satellite links and space-ground communications to replace Ka-band radio.

- Mode S, VHF, SATCOM
  - Standard channels used to send and receive data on existing aircraft
  - Update rate for Mode S may not be high enough to be useful, but could be used in combination with wake sensing

Management of Communications Failures

- Addressed by Innocenti et al. in “Management of Communication Failures in Formation Flight”, Journal of Aerospace Computing, Information, and Communication, 2004.
- If an aircraft loses Rx, configuration repositions aircraft to be closer to leader if pre-stored trajectory can still be updated via ground link
- If complete Rx lost, aircraft must leave formation
- If an aircraft loses Tx, configuration repositions aircraft to back of formation as it can no longer be a reference to others
- If leader loses Rx, can still be leader
- Reconfiguration accomplished through predefined reconfiguration maps

Selected References

- Cobleigh, B., "Capabilities and Future Applications of the NASA Autonomous Formation Flight (AFF) Aircraft", AIAA's 1st Technical Conference and Workshop on Unmanned Aerospace Vehicles, Portsmouth, VA, May 20-23, 2002.

- Giulietti, F., Pollini, L., and Innocenti, M., "Formation Flight Control: A Behavioral Approach", AIAA Guidance, Navigation & Control Conference, Montreal, Canada, August 6-9, 2001. AIAA-2001-4239.

- Grappel, R., D., “Open System Protocols for Aviation Data Link Applications”, AIAA Guidance, Navigation & Control Conference, Monterey, California, August 5-8, 2002. AIAA-2002-4931.

- Innocenti, M., Pollini, L., Giulietti, F., "Management of Communication Failures in Formation Flight", Journal of Aerospace Computing, Information, and Communication, Vol. 1, Jan. 2004.