Boeing Air Traffic Service (ATS) Data Link Perspectives and Capabilities

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Key points are highlighted
Purposes

- **ATS data link purposes**
  - At least from Boeing’s perspective...
  - **Primary:** Integrate avionics and ground automation to enable beneficial capabilities not possible with voice communications
    - For example, enable trajectory-based operations (TBO)
      - Departure Clearance (DCL) service now being deployed in domestic United States is an early form of TBO
  - **Secondary:** Supersede voice communications when and where appropriate
    - Enable communications via data link
      - For example, a climb clearance request and response
    - Enable surveillance via data link
      - For example, automated position reports
Benefits

- Increased capacity
  - Reduced controller workload in continental airspace
  - Reduced separation in oceanic, polar, and remote airspace
    - For example, “30/30” separation in Pacific, RLatSM in North Atlantic

- Improved efficiency
  - Decreased fuel consumption and/or time enroute
    - For example, increased availability of optimum altitudes, Dynamic Airborne Reroute Procedure (DARP) reroutes that take advantage of new winds and temperatures aloft forecasts
Benefits

- Enhanced safety
  - 787 operator in *Aviation Week*: “integration of [CPDLC] with the autoflight system... enhances safety”
  
- Navigation database validation avoids waypoint ambiguity

- Avionics route clearance loading prevents navigation errors caused by manual transcription
Architecture

- Data link may be divided into two parts
  - Applications
    - Functions which provide services to users
  - Infrastructure
    - Networks and subnetworks (links or media) which connect applications

- In other words, applications-over-infrastructure
  - Voice-over-IP (VoIP)
  - E-mail-over-WiFi
  - Facebook-over-4G LTE
  - FANS-over-Inmarsat Classic Aero SATCOM
Applications

- Application types
  - ATS Facilities Notification (AFN) / Context Management (CM)
    - Provides initial manual “log on” capability to flight crew, supports automated transfers of communications between ATS facilities
  - Automatic Dependent Surveillance – Contract (ADS-C)
    - Allows ATS providers to establish “contracts” with avionics for delivery of single, periodic, and/or event-based reports
    - Provides position reporting, separation assurance, route conformance monitoring, and trajectory synchronization capabilities
  - Controller-Pilot Data Link Communications (CPDLC)
    - Provides pre-defined message elements for request and delivery of clearances and reports, including free-text messages
    - Most beneficial when integrated with Flight Management Computer (FMC) or equivalent navigation avionics to enable route clearance loading, navigation database validation, and similar capabilities
Applications

- Application sets
  - Future Air Navigation System (FANS)
    - Consists of FANS AFN, CPDLC, and ADS-C applications
    - Initially operational in South Pacific in 1995, now operational or planned in many areas worldwide
    - Normally FMC-integrated – supports TBO and similar capabilities not possible with voice communications
    - Generic avionics implementation is called FANS-1/A
      - FANS-1 is Boeing’s implementation, FANS-A is Airbus’s implementation
      - “FANS-1/A+” adds CPDLC uplink message latency detection
  - LINK 2000+
    - Consists of LINK 2000+ CM and CPDLC applications
    - Initially operational in Europe in 2009, but deployment is facing both operational and technical obstacles
      - Technical problems led multiple airlines to stop using LINK 2000+
Applications

• **LINK 2000+ (continued)**
  - Normally not FMC-integrated – does not support TBO
    - Subset of Baseline 1 (B1) capability intended to reduce frequency congestion and controller workload, so limited CPDLC message set only replicates common voice phraseology
    - Low benefits (limited message set, no TBO) but high costs (large and complex requirements set and code base)

• **[future] Baseline 2 (B2)**
  - Consists of B2 CM, CPDLC, and ADS-C applications
    - CPDLC adds speed schedule and one-second required time of arrival (RTA) precision, ADS-C adds Extended Projected Profile (EPP) for trajectory synchronization
  - New services include 4-Dimensional Trajectory Data Link (4DTRAD) and Data Link Taxi (D-TAXI)
  - FMC-integrated – supports TBO and similar capabilities not possible with voice communications
Applications

- Capability comparison of application sets:

  ~175% (of FANS capability)
  Advanced 4D TBO

  ~150% (of FANS capability)
  4D TBO

  100% (of FANS capability)
  Initial TBO

  ~25% (of FANS capability)
  Basic communications

  **FANS**
  9 services (DO-352): DLIC, ACM, CRD, AMC, IER, PR, DCL, OCL, ITP

  **LINK 2000+**
  4 services (DO-353): DLIC, ACM, CRD, AMC

  **[future]**
  B2 “Initial”
  12 services (DO-351): DLIC, ACM, CRD, AMC, IER, PR, DCL, OCL, ITP, 4DTRAD, D-TAXI, IM

  **[future]**
  B2 Rev A
  14 services (draft DO-351A): DLIC, ACM, CRD, AMC, IER, PR, DCL, OCL, ITP, 4DTRAD, D-TAXI, A-IM, D-RNP, ATC Winds

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Flight Information Region (FIR) boundaries are provided by ICAO. Service availability is depicted to the best of Boeing’s knowledge. Service is not necessarily available throughout an indicated FIR.
Applications

- Boeing capabilities
  - FANS-1
    - Boeing has made “FANS-1/A+” CPDLC uplink message latency detection available on all its airplane models
  - LINK 2000+
    - LINK 2000+ implementation in Communications Management Unit (CMU) avionics is stand-alone solution
      - Not integrated with FMC or equivalent navigation avionics – no route clearance loading, navigation database validation, etc.
  - FANS-2
    - FANS-2 application ‘superset’ is integrated combination of FANS-1 and LINK 2000+ application sets
      - Enables seamless transfers between FANS and LINK 2000+ centers
      - Provides common flight crew interface
      - Integrated with FMC or equivalent navigation avionics
### Boeing capabilities (continued)

<table>
<thead>
<tr>
<th>Applications</th>
<th>737NG/737MAX&lt;sup&gt;1&lt;/sup&gt;</th>
<th>747-400&lt;sup&gt;2&lt;/sup&gt;</th>
<th>747-8</th>
<th>757/767&lt;sup&gt;1&lt;/sup&gt;</th>
<th>777&lt;sup&gt;4&lt;/sup&gt;</th>
<th>787/777X</th>
<th>MD-11</th>
</tr>
</thead>
<tbody>
<tr>
<td>FANS-1</td>
<td>Yes (&quot;+&quot;), Optional</td>
<td>Yes (&quot;+&quot;), Optional</td>
<td>Yes (&quot;+&quot;), Standard</td>
<td>Yes (&quot;+&quot;), Optional</td>
<td>Yes (&quot;+&quot;), Standard</td>
<td>Yes (&quot;+&quot;), Optional</td>
<td>Yes (&quot;+&quot;), Optional</td>
</tr>
<tr>
<td></td>
<td>or</td>
<td>and</td>
<td>or</td>
<td>and</td>
<td>and</td>
<td>Optional</td>
<td></td>
</tr>
<tr>
<td>LINK 2000+</td>
<td>Yes (CMU), Optional</td>
<td>No&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Yes (FANS-2), Standard</td>
<td>Yes (CMU), Optional</td>
<td>Yes (FANS-2), Optional</td>
<td>Yes (FANS-2), Optional</td>
<td>No&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

1 FMC-based FANS-1 and CMU-based LINK 2000+ capabilities on 737NG/737MAX and 757/767 are mutually exclusive due to host system and flight crew interface differences
2 747-400 may be upgraded with 747-8 FMC and CMU to gain “FANS-1/A+” and LINK 2000+ capabilities as part of FANS-2
3 Unless via third-party CMU Supplemental Type Certificate (STC)
4 777 offers concurrent FANS-1 and LINK 2000+ capabilities, but they are not sufficiently integrated to be called FANS-2

- Contact Boeing to discuss possible FANS interoperability testing opportunities with its avionics labs
747 Operation

- MCDU provides primary interface
  - ATC key provides access to ATS datalink functions
- EICAS provides ATC MESSAGE visual alerts
- MAWEA provides high-low chime aural alerts
- Older-design airplanes (737, 757, 767, and MD-11) are similar
787 Operation

- MFD, keypad, and cursor provide primary interface
- EICAS provides **ATC** visual alerts and high-low chime aural alerts
- Large-format displays automatically show CPDLC uplink messages in primary field of view
- ACCEPT, CANCEL, and REJECT glareshield buttons permit rapid responses to CPDLC uplink messages
- Newer-design airplanes (777) are similar
FANS-2 Displays

- Common displays for FANS and LINK 2000+
  - Options unavailable with the smaller LINK 2000+ CPDLC message set are disabled
Infrastructure

- Networks
  - Aircraft Communications Addressing and Reporting System (ACARS)
    - In use since late 1970s, now main network worldwide
    - Used by FANS ATS applications, also used by Aeronautical Operational Communications (AOC) applications
  - Aeronautical Telecommunication Network (ATN)
    - Based on Open Systems Interconnection (OSI) reference model
    - In use since early 2000s, but only in Europe and only by LINK 2000+
      - Technical problems are apparent in design and implementation of multiple layers of protocol stack
  - [future] Internet Protocol Suite (IPS)
    - IPS use is acknowledged as a strategic goal
      - Will move toward a simplified and cost-effective architecture
      - Will allow maximum flexibility and compatibility
Infrastructure

- **Subnetworks**
  - **Short-range, line-of-sight subnetworks**
    - VHF Digital Link (VDL) Mode 0/A
      - Uses original “Plain Old” ACARS (POA) protocol
    - VDL Mode 2
      - For ACARS messages, uses ACARS over Aviation VHF Link Control (AVLC) (AOA) protocol
      - For ATN messages, uses ISO 8208 (ITU X.25) protocol
    - *future* AeroMACS
      - Based on IEEE 802.16 WiMAX
      - Will provide high-speed IP-oriented link for aircraft on airport surface
Subnetworks (continued)

- Long-range, beyond line-of-sight subnetworks
  - Inmarsat Classic Aero SATCOM
  - Iridium SATCOM
    - Provides polar coverage
  - HF Data Link (HFDL)
    - Provides polar coverage
    - Generally a last-choice subnetwork due to performance challenges
  - Inmarsat SwiftBroadband SATCOM
    - High-speed, IP-oriented
    - FAA Performance-based operations Aviation Rulemaking Committee (PARC) Communications Working Group (CWG) is currently evaluating the viability of FANS-over-SwiftBroadband, with promising results so far
  - [future] Iridium Certus (using Iridium NEXT constellation)
    - Will provide high-speed, IP-oriented link and polar coverage
Infrastructure

- Boeing capabilities
  - Networks
    - All Boeing airplane models are capable of using the ACARS network
    - Most Boeing airplane models are capable of using the ATN network
  - Subnetworks
    - All Boeing airplane models are capable of using VHF, SATCOM, and HF subnetworks
      - Typical subnetwork preference order: VHF (VDL Mode 2 then VDL Mode 0/A), then SATCOM (Inmarsat or Iridium), then HFDL
      - Newer avionics offer customization of subnetwork preferences, geographic regions, POA frequencies, AOA service providers, etc.
  - Depending on the airplane model, some network and subnetwork capabilities are standard and some are optional
Performance-Based Communication and Surveillance (PBCS)

- PBCS is a concept for prescribing and complying with objective operational criteria for communication and surveillance performance
  - This modern performance-based approach is more effective than earlier technology-specific approaches
- PBCS includes Required Communication Performance (RCP) and Required Surveillance Performance (RSP) specifications
  - RCP and RSP specifications include availability, integrity, and continuity requirements
  - Continuity “overdue time” requirement provides name; for example, RSP180 requires that 99.9% of ADS-C reports be delivered to ATS provider within 180 seconds
PBCS (continued)

- PBCS also includes post-implementation monitoring to assess performance and investigate problem reports
  - Regional groups perform this function, including:
    - South Atlantic (SAT) FANS Interoperability Team (FIT)
    - North Atlantic (NAT) Technology and Interoperability Group (TIG)
      - Formerly the Communications, Navigation, and Surveillance Group (CNSG)
    - European Data Link Services (DLS) Central Reporting Office (CRO)
    - Informal Pacific ATC Coordinating Group (IPACG) FIT
    - Informal South Pacific ATS Coordinating Group (ISPACG) FIT
    - FIT Asia
PBCS

- PBCS post-implementation monitoring (continued)
  - ATS providers assess performance in their control areas
PBCS post-implementation monitoring (continued)

Regional sub-groups investigate problem reports, including:

- SAT Central FANS Reporting Agency (CFRA)
- NAT Data Link Monitoring Agency (DLMA)
- IPACG Central Reporting Agency (CRA)
- ISPACG CRA
- FIT Asia CRA

These sub-groups provide briefings at regional group meetings
• **PBCS post-implementation monitoring (continued)**
  - Boeing provides NAT DLMA, IPACG CRA (for US airspace), ISPACG CRA, and FIT Asia CRA problem report investigation services
  - In that role, Boeing would welcome coordination with the SAT CFRA
    - Especially for avionics and network problems that occur across regions
  - As Boeing itself, Boeing offers to support SAT CFRA problem report investigations that involve Boeing airplanes
    - Partial list of closed problem reports against Boeing airplane models:

<table>
<thead>
<tr>
<th>PR</th>
<th>System</th>
<th>Description</th>
<th>Status</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1358-MM</td>
<td>777</td>
<td>777 &quot;ack-n-toss&quot; issue (ACARS avionics acknowledge receipt of FANS uplinks but do not deliver them to the FANS avionics)</td>
<td>CLOSED</td>
<td>CLOSED with availability of 777 AIMS-2 BPV17.1 software</td>
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<tr>
<td>1405-GS</td>
<td>787</td>
<td>787 loses SATCOM link after losing VHF Cat B link</td>
<td>CLOSED</td>
<td>CLOSED with availability of 787 CMF BP2.5 software</td>
</tr>
<tr>
<td>1480-SN</td>
<td>MD-11</td>
<td>MD-11 sends unexpected ADS-C lateral deviation report</td>
<td>CLOSED</td>
<td>CLOSED with availability of MD-11 FMC -922 software</td>
</tr>
<tr>
<td>1534-GS</td>
<td>787</td>
<td>787 does not respond to AFN uplink messages</td>
<td>CLOSED</td>
<td>CLOSED with availability of 787 CMF BP2.5 software</td>
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<tr>
<td>1585-GS</td>
<td>787</td>
<td>787 does not respond to ADS-C uplink messages</td>
<td>CLOSED</td>
<td>CLOSED with availability of 787 CMF BP2.5 software</td>
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<tr>
<td>1726-RP</td>
<td>747-8</td>
<td>747-8 Inmarsat Classic Aero SATCOM avionics issues</td>
<td>CLOSED</td>
<td>CLOSED with availability of Rockwell Collins SDU-2200 part number 822-2556-103</td>
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<tr>
<td>1760-GS</td>
<td>787</td>
<td>787 SATCOM avionics issues</td>
<td>CLOSED</td>
<td>CLOSED with availability of 787 CMF BP3 software</td>
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<tr>
<td>1798-GS</td>
<td>787</td>
<td>787 fails to send armed MAINTAINING [altitude] reports</td>
<td>CLOSED</td>
<td>CLOSED with availability of 787 CMF BP3 software</td>
</tr>
<tr>
<td>1943-RP</td>
<td>747-8</td>
<td>747-8 (or 747-400 with 747-8 FMC) AFN protocol errors</td>
<td>CLOSED</td>
<td>CLOSED with availability of 747-8 FMC BP3.1 software</td>
</tr>
</tbody>
</table>
Conclusion

- Boeing is a strong supporter of ATS data link and the benefits it provides
- Boeing is working to improve existing ATS data link technologies and procedures and to develop new ones
- Both as the CRA/DLMA for other regions and as Boeing itself, Boeing offers its assistance to the SAT FIT and SAT CFRA

Thank you

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