Connected Aircraft Applications

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**Connected Aircraft 1.0**

**Connected operations**
- Business trajectory + airspace constraints
- AOC, CPDLC messages
- SWIM

**Challenges/opportunities**
- Performance
- Cost of change
- Connectivity/applications
- Timing

**Objectives**
- Evolved vision for connected aircraft
- Applications of interest
Connected Aircraft Ecosystem “2.0”

New users/use cases
- EFBs
- Trainers
- Maintenance crew
- OEM
- Digital twins
- Traveler

Timing
- Pre-flight
- During flight
- Post-flight

Key principles/needs
- Connectivity/connectedness
- Security
- Low-cost, rapid change
- Data and digital-twins
01

FMS Overview
Flight Management Civil pedigree … 3 generations; 14,000+ deliveries; 35+ years

**1st Generation**
- Introduction of first FMS
  - Lateral navigation functions
  - Vertical navigation functions
- Launch platform
  - 737

**2nd Generation**
- Advanced features
  - New approaches … GPS, LPV, RNP
  - New waypoint leg types
- Launch platforms
  - A320
  - A340
  - A330

**3rd Generation**
- Modular flight management application
  - Low-cost updates
  - Platform agnostic
- Targeted platforms
  - Civil air transport
  - eVTOL
  - Rotorcraft

@ General Electric Company 2023
Flight Management System Overview
Key functionality and interfaces

**Flight plan and trajectory management**
- Computes the intended aircraft trajectory – lateral, vertical, speed, fuel, and time
- Fuel optimal trajectory, economy speeds

**Flight guidance**
- Vertical navigation
- Lateral navigation

**Interfaces**
- CDU (Control Display Unit) for pilot input
- ND (Navigation Display) for geographic display of the plan and aeronautical data
- DataComm interface
Flight Management System Overview

Example: flight planning

Flight plan entry
- Manual entry
- Pre-loaded company routes
- Upload using ACARS (datalink)

Flight plan review and activation
- Check for constraints, discos, etc.
- Review the flight plan displayed on the ND – only displays a subset of published aeronautical information (ARINC 424 data)

Aeronautical charts
- Paper charts
- Digital charts stored on EFB
02

Electronic Flight Bag
Missing: connectivity between FMS and EFB

Other EFB use cases

- Filing flight plans
- Obtaining a complete view of aeronautical information content and a strategic view of the flight procedure
- Verifying FMS entered procedure/routes and constraints
- Off-line performance calculations (V-speeds, weights, temperatures, take-off thrust)

Double-entry reduces situational awareness, requires additional workload, and is prone to entry errors.
Connected Flight Management System

An environment where your tablet applications are seamlessly connected to the flight management system and your flight operation center.

• Improves situational awareness
• Enables flight optimization to reduce DOC, upload of custom performance parameters
• Reduces pilot workload
• Improves coordination with dispatch and ATC
• Enables capture of aircraft data to support post-flight maintenance and investigation
• Open interface enables BYO-devices/apps
Connected FMS – Safe, secure, open & connected

**Flight Management System**
Control Display Unit
- **New FMS options**
  - Enable data-out
  - Enable data-in

**Compute platform**
- Out
- ARINC 429

**Comm mgmt. unit**
- In
- ARINC 429

**Air Traffic Control**
- ACARS

**Airline Operations Centers**
- ACARS

**Aircraft interface device / network server**
- Other Avionic Systems
  - WiFi or wired connection
  - Synchronization

**EFB**

**Cloud**
- Traffic
- Maintenance
- Weather
- Scheduling

**Digital Twin**
- Trajectory
- What-iffing

**Data Link**
- ENROUTE
- Network
- Weather

**ARINC 429**
- Communication
- Data exchange

**WiFi or wired connection**
- Network communication

**Scheduling**
- Flight
- Data
Software Development Kit (SDK) – Airline / 3rd Party App Integration
Combination of test equipment and software libraries to support the application developer

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<tr>
<th>FMS</th>
<th>Real FMS running on COTS hardware platform</th>
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<tr>
<th>Aircraft Simulation</th>
<th>Full aircraft level simulation environment provided on user PC</th>
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<th>Example Apps</th>
<th>Hello World, basic startup Data parsing examples Networking Example</th>
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<tr>
<th>Documentation</th>
<th>Setup / Connectivity Aircraft Simulation Libraries for C, C++, SWIFT, ObjC Top Level and Detailed Functional Calls Release Notes</th>
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<th>Support</th>
<th>GE technical support</th>
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<tr>
<th>App Libraries</th>
<th>iOS &amp; Surface Pro Support C# / C++ / Objective C / Swift Wrapper Communication Security Data Encode/Decode</th>
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Trajectory-Based Operations
Trajectory-based Operations use cases enabled by Trajectory Synchronization

**Time-Based Management**
- Flow management
- Arrival/Extended Arrival/Departure Management

**Advanced Air Mobility and UAS Traffic Management**
- Strategic coordination
- Demand Capacity Balance
- Integration of new operations into airspace
Cloud Flight Management System
Cloud FMS synchronizes with the airborne FMS/EFB and enables enhanced decision making and awareness.

- Streamline coordination: pilot, ATC, and AOC
- Model alternate routes with the most accurate information possible
- Enables “what-if” capability for ground applications
- Extend FMS SW with minimal certification impact
- Arrival Management: potential to reduce DOC, workload, CO2 emissions, and noise
Overview: Cloud FMS

System components

- Secure, air-ground network
- Public internet
- Safety-critical functions on the flight deck
- Non-safety critical functions
  - *Optional* EFB (i.e., Connected FMS) for enhanced pilot interface, negotiation
  - Cloud-based FMS (digital twin) for synchronization
NASA SBIR Cloud FMS project

Team
- Mosaic ATM, SmartSky Networks, and GE Aerospace

Objectives
- Assess impact on flight plan negotiation
- Assess impact on air-ground datalink disruption
- Demonstrate data exchange and key function in lab and flight-test environment

Outcomes observed
- Reduction in flight plan negotiation time
- Secure in-flight connectivity (IFC) service can provide the required functional performance in the connection between the aircraft and Cloud FMS

Next steps
- Support NASA Digital Flight research
- Potentially support FAA connected aircraft and Info-centric NAS research
- Implementation in the NAS

Demonstration components: (1) non-safety critical airborne FMS, (2) Aircraft, and (3) laboratory environment.
04

– FMS Trainer
Virtual FMS environment - Training & Development

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<tr>
<th>Feature</th>
<th>FMS Cockpit Trainer</th>
<th>FMS Training Center</th>
<th>FMS Anywhere</th>
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<tbody>
<tr>
<td>Free play FMS</td>
<td>✓</td>
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<tr>
<td>Actual aircraft software</td>
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<tr>
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