

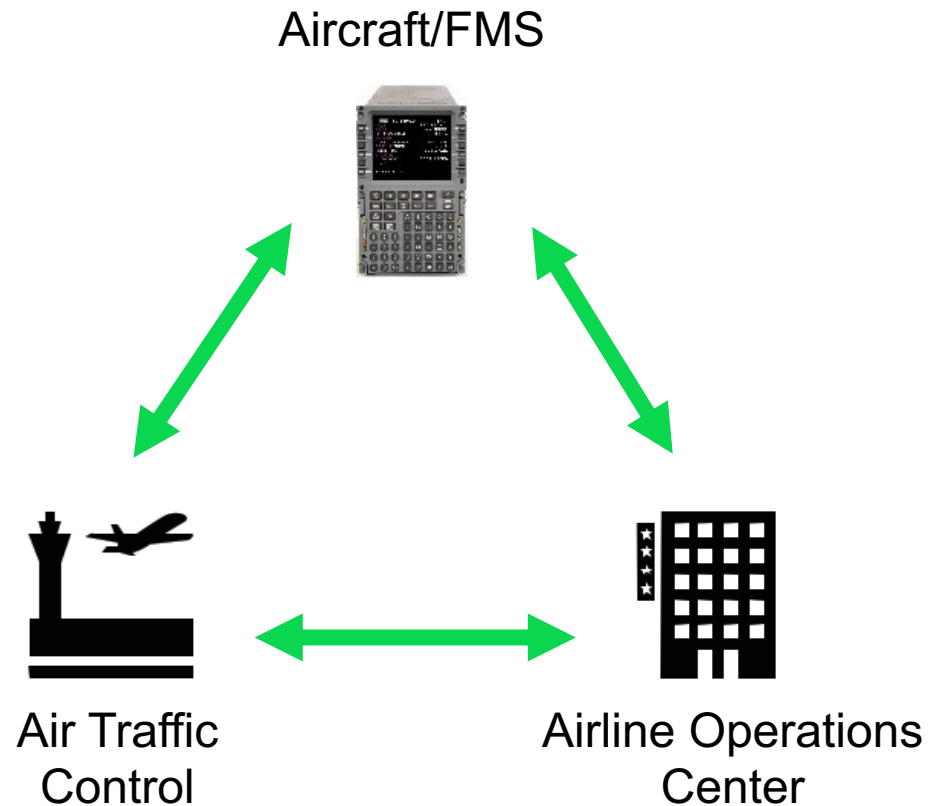


Connected Aircraft Applications

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Connected Aviation Intelligence Summit, September 8, 2023

Connected Aircraft 1.0



Connected operations

- Business trajectory + airspace constraints
- AOC, CPDLC messages
- SWIM

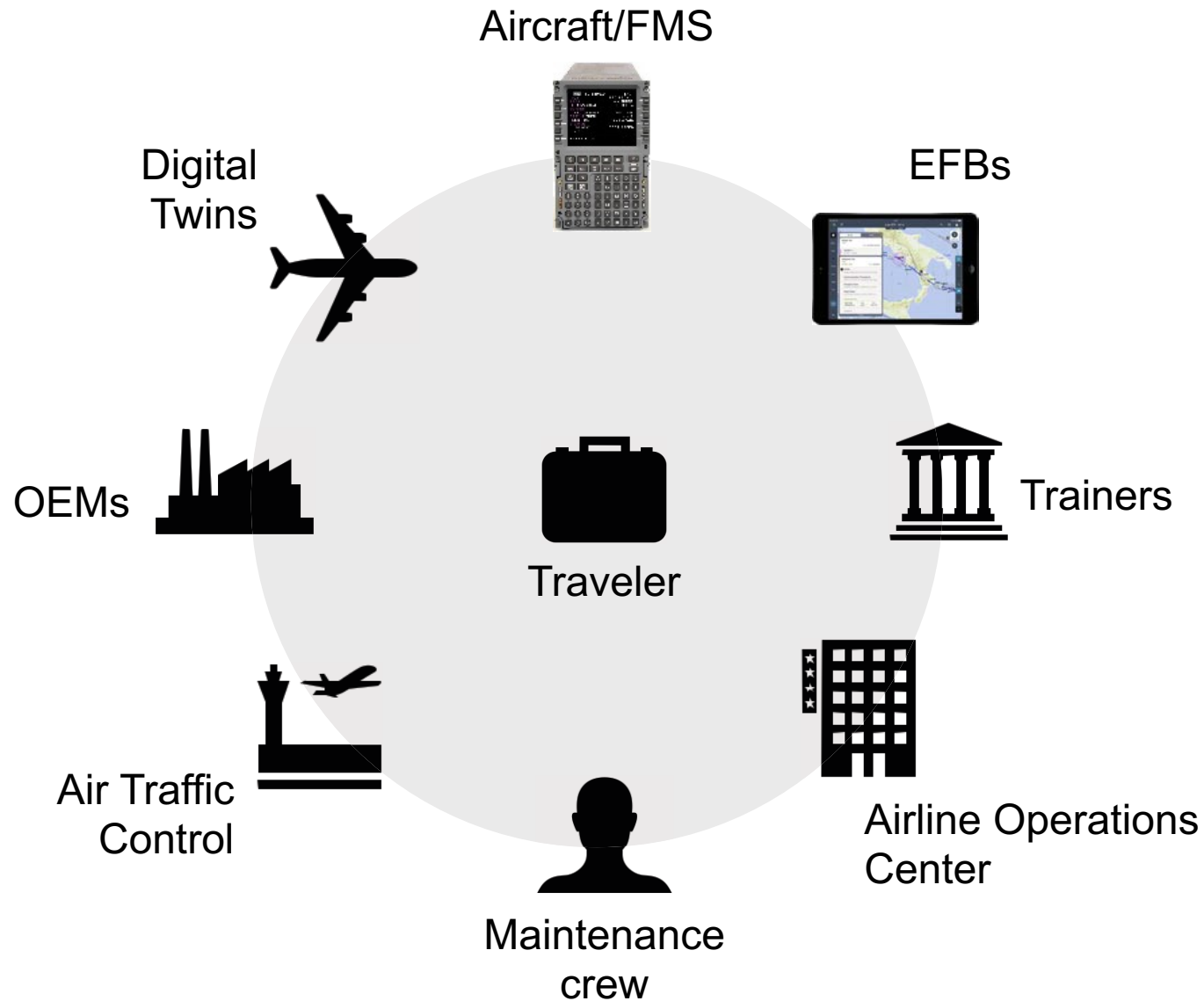
Challenges/opportunities

- 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

1985

Introduction of first FMS

- Lateral navigation functions
- Vertical navigation functions

Launch platform



737



2nd Generation

2010

Advanced features

- New approaches ... GPS, LPV, RNP
- New waypoint leg types

Launch platforms



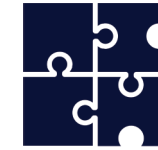
A320



A340



A330



3rd Generation

2022+

Modular flight management application

- Low-cost updates
- Platform agnostic

Targeted platforms



Civil air transport

eVTOL



Rotorcraft

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



Cockpit interfaces to the FMS

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

Example Operational Flight Plan (OFP)

```
ATC C/S EDU321 21MAY2018 OFP 2 ISSUED AT 1401Z
NAIROBI/JOMO KENYATTA - AMSTERDAM/SCHIPHOL CRZ SYS CI100
HKJK/NBO EHAM/AMS GND DIST 3924
STD 2000Z STA 1200Z AIR DIST 4036
2H773 BOEING 777-320ER AVG WIND 276/024
MTOW 351.5 MLAW 251.3 MZFW 237.7 DOW 175.0 AVG FF KG/HR 7403
ETOW 285.6 ELAW 222.8 EZFW 215.0 FUEL BIAS P00.0
-----
ROUTE ID:MCT
WX PROG 2118 2121 2200 2203 2206 OBS 2106 2106 2106 2106 2106
-----
HKJK/06 NAVEX1D LOTAS UM308 ETKET UG650 DULAB DCT 2000N03830E DCT
MIPOL DCT KAROX DCT 22N038E DCT DEDLI DCT XL300 DCT ABIMR DCT XB418
DCT SHM DCT RASDA UA16 YAA DCT FENER UA16 VADEN DCT APROB DCT BUDOP
DCT PATAK DCT LALES L602 BABUS DCT VARIK DCT TAMEB DCT KEMAD UL602
REBGU L602 RELBI UL602 TENLI L602 FLEVO UL602 SPY EHAM/18R
-----
DEP ATC CLRN:
-----
DEP ATIS
-----
PLANNED FUEL GRND / COMPY - FREQ
-----
RMKS NO
-----
TOBT / TSAT / CTOT
... / ... / ...
-----
ADDITIONAL IMPACTS
AVAILABLE
-----
/330/ETKET/350/
B/340/MIPOL/360/
B/380/
-----
Time> ENG START: .....
-----
..... - .....
```



Crew entry of the flight plan

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)



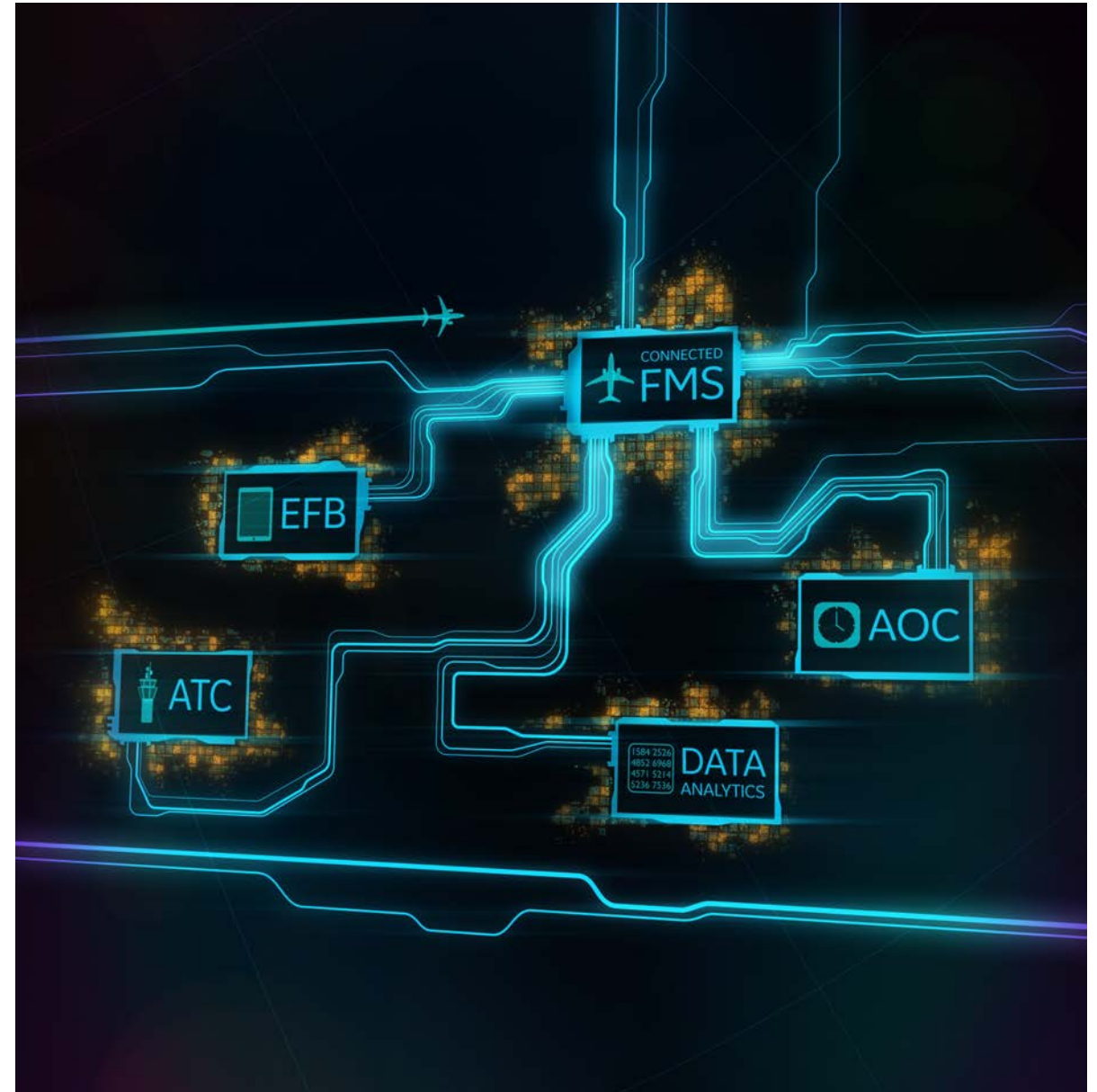
EFB and FMS lack a two-way connectivity in the cockpit, today.

Double-entry reduces situational awareness, requires additional workload, and is prone to entry errors

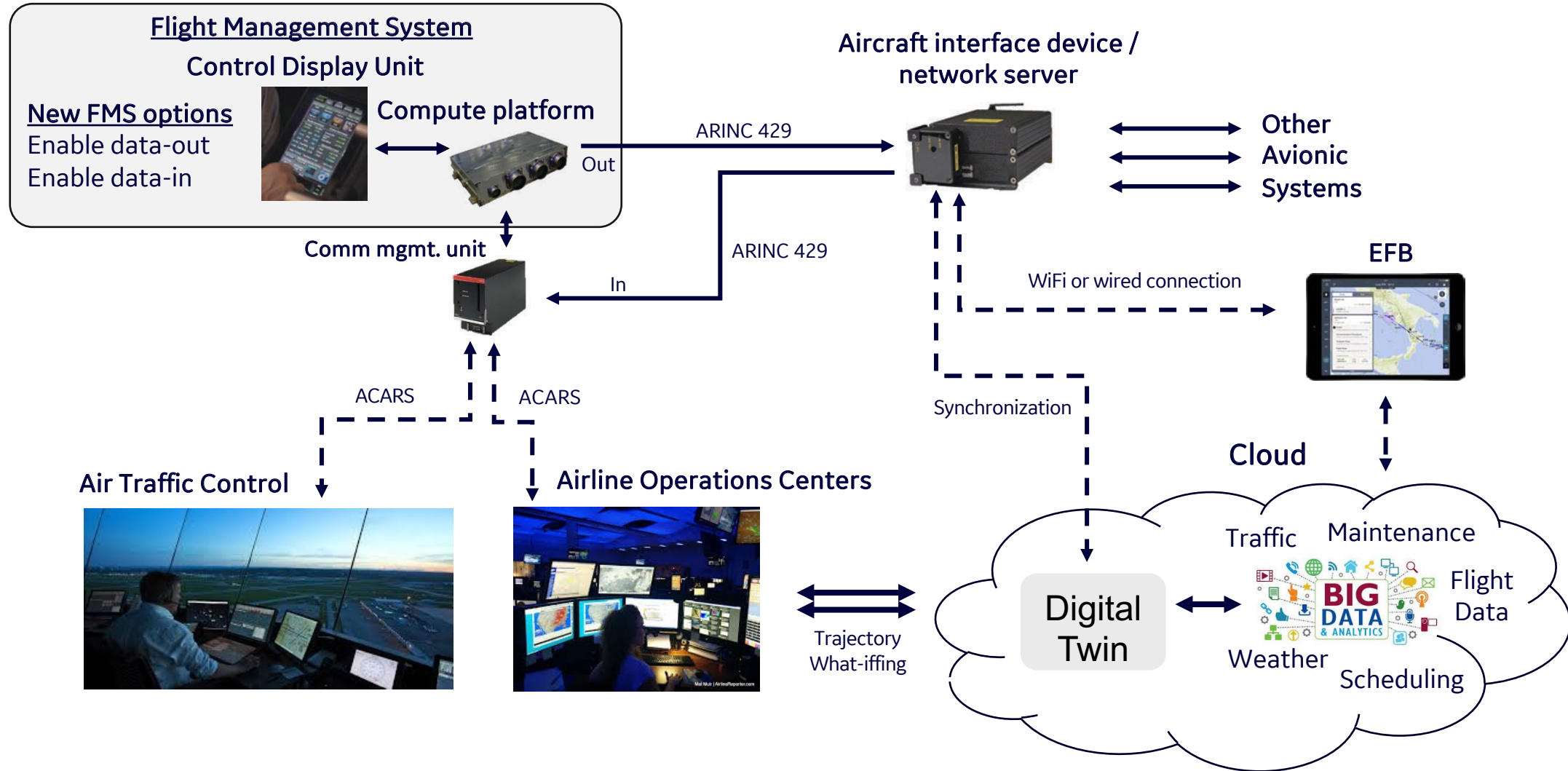
Connected Flight Management System

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





Connected FMS SDK



ACTUAL --- .733/FL380
<RTE 2 LEGS
EFB UPLINK AVAILABLE
RTE DATA

Software Development Kit (SDK) – Airline / 3rd Party App Integration

Combination of test equipment and software libraries to support the application developer

FMS



Real FMS running on COTS hardware platform

Example Apps

```
template<class InputString, class OutputString>
bool unhexlify(const InputString& input, OutputString& output) {
    if (input.size() % 2 != 0) {
        return false;
    }
    output.resize(input.size() / 2);
    int i = 0;
    while (i < input.size()) {
        return c = input[i] <= '9' ? c - '0' :
            c == 'A' || c == 'a' ? c - 'A' + 10 :
            c == 'B' || c == 'b' ? c - 'A' + 11 :
            c == 'C' || c == 'c' ? c - 'A' + 12 :
            c == 'D' || c == 'd' ? c - 'A' + 13 :
            c == 'E' || c == 'e' ? c - 'A' + 14 :
            c == 'F' || c == 'f' ? c - 'A' + 15 :
            -1;
    }
    for (uint8_t i = 0; i < output.size(); i++) {
        int highbits = unhexlify(input[i]);
        int lowbits = unhexlify(input[i + 1]);
        if (highbits < 0 || lowbits < 0) {
            return false;
        }
        output[i] = (highbits << 4) + lowbits;
    }
    return true;
}
```

Hello World, basic startup
Data parsing examples
Networking Example

Aircraft Simulation



Full aircraft level simulation environment provided on user PC

Documentation



Setup / Connectivity
Aircraft Simulation
Libraries for C, C++, SWIFT, ObjC
Top Level and Detailed Functional Calls
Release Notes

App Libraries



iOS & Surface Pro Support
C# / C++ / Objective C / Swift Wrapper
Communication
Security
Data Encode/Decode

Support



GE technical support

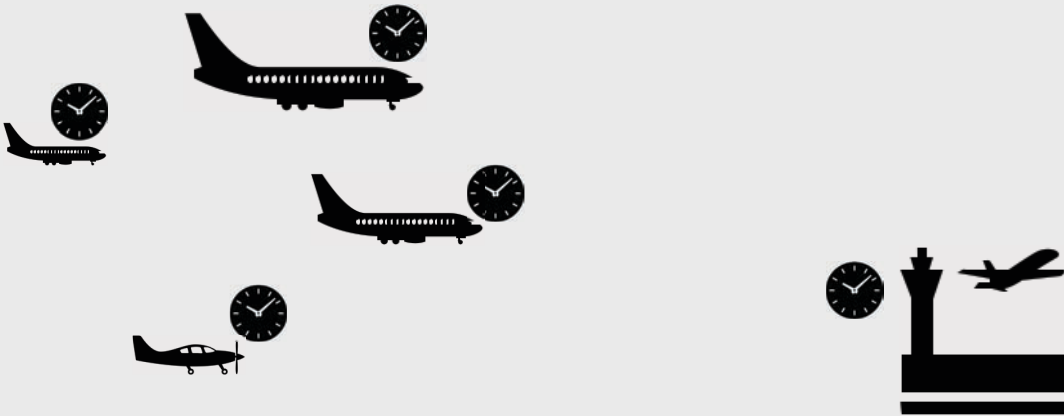
03

– Trajectory-Based Operations

Trajectory-based Operations use cases enabled by Trajectory Synchronization

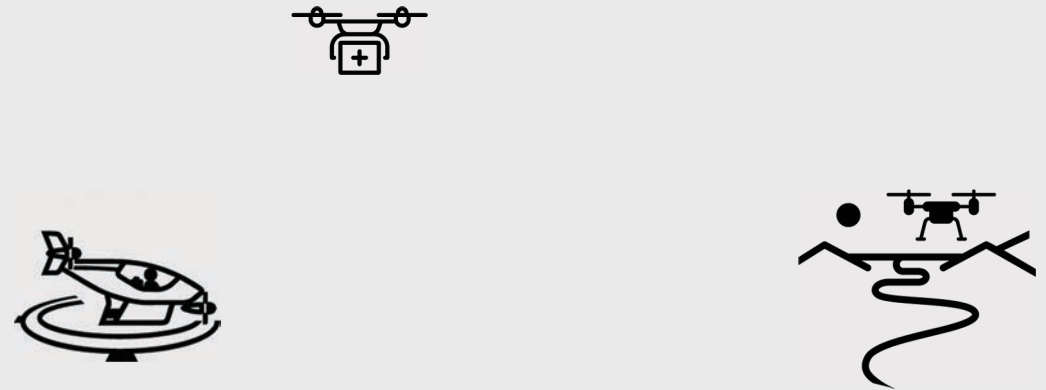
Time-Based Management

- Flow management
- Arrival/Extended Arrival/Departure Management



Advanced Air Mobility and UAS Traffic Management

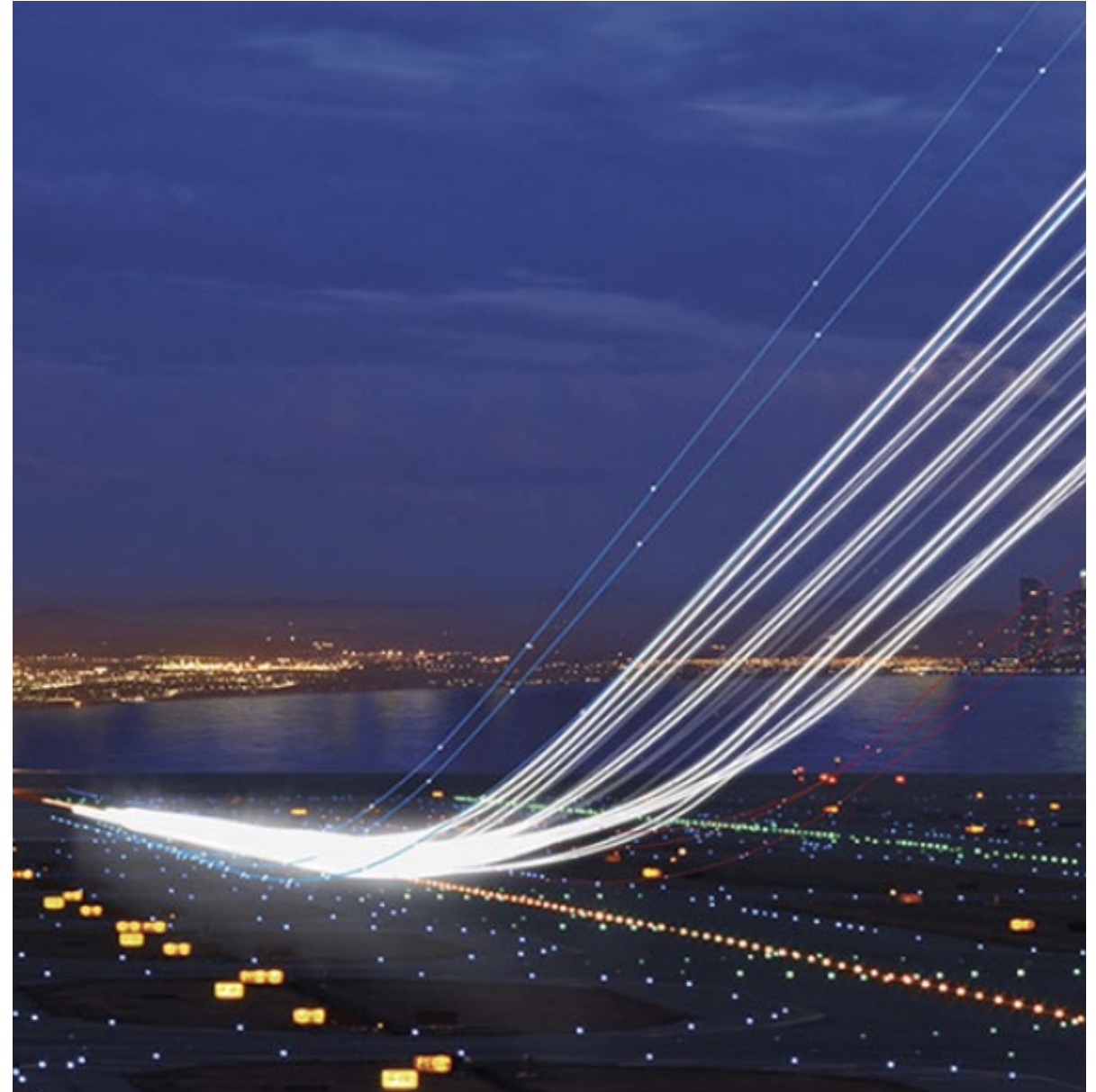
- Strategic coordination
- Demand Capacity Balance
- Integration of new operations into airspace



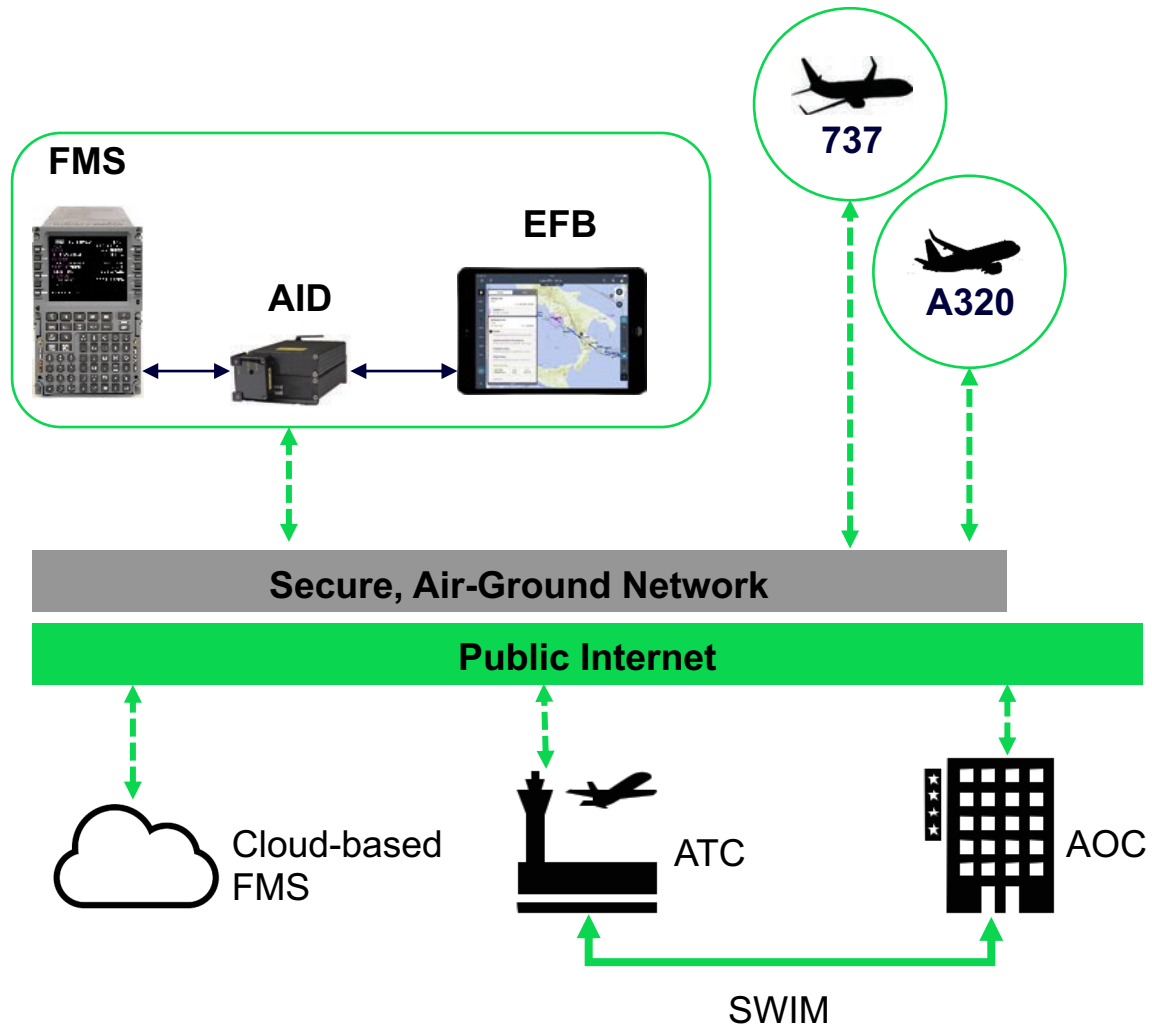
Cloud Flight Management System

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



FMS Cockpit Trainer



FMS Training Center



FMS Anywhere

Free play FMS	✓	✓	✓
Actual aircraft software	✓	✓	✓
Actual aircraft hardware	✓		
Standalone workstation	✓	✓	
Flight training device/sim integration	✓		
Mini-computer hosted		✓	
Cloud-based			✓
Device-agnostic			✓
Customized training modules	✓	✓	✓



GE Aerospace