Internet Protocol Suite (IPS) ecoDemonstrator Validation and Development Update

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Boeing Research & Technology
Airspace Operational Efficiency

IP06 of ACSICG/9
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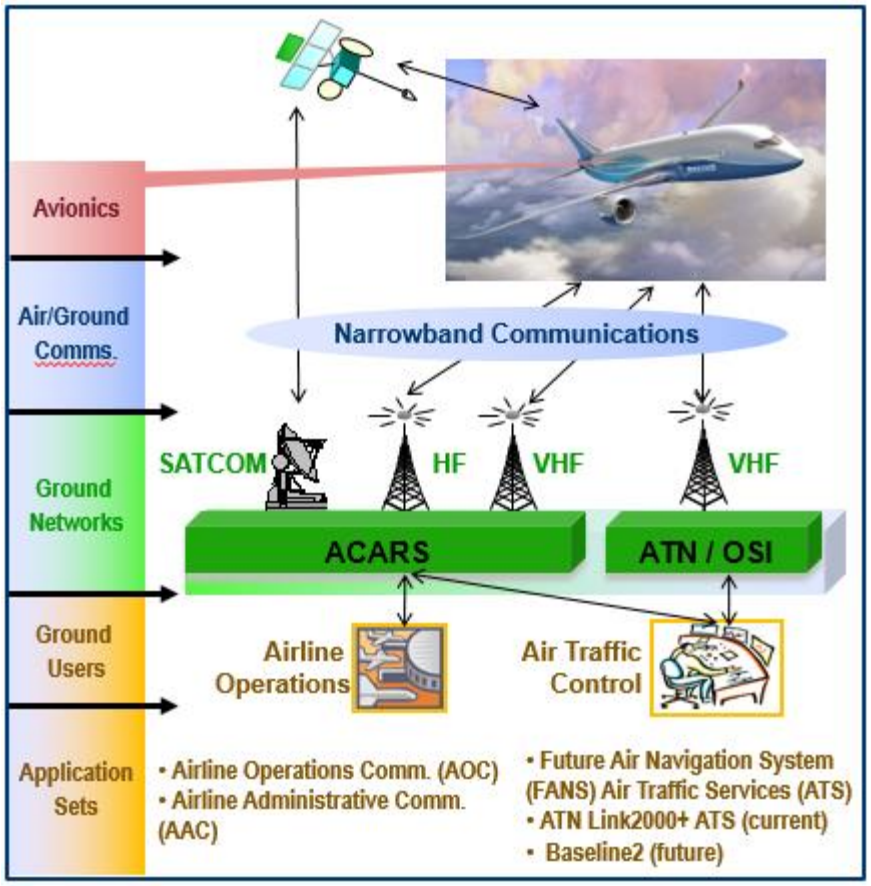
With thanks: Aloke Roy and Mike Olive, Honeywell

Agenda

- Current Air-Ground Environment Overview
- Internet Protocol Suite (IPS) Approach and Benefits
- Evolution of the technology
- Standardization activities
- Validation and testing

Infrastructure: Existing Networks – ACARS and ATN



Source: "Internet Protocol Suite for Safety Services: Progress Towards a Validated Standard", ICNS 2017

- **Aircraft Communications Addressing and Reporting System (ACARS)**
  - Character-oriented, in use since late 1970s
  - Defined by ARINC Specifications 618 and 620
  - In use in domestic/oceanic/remote airspaces
- **Aeronautical Telecommunications Network (ATN)**
  - Based on Open Systems Interconnection (OSI) reference model
  - Bit-oriented, in use since early 2000s
  - Defined by ICAO Doc 9705 and Doc 9880
  - Only used in European domestic airspace

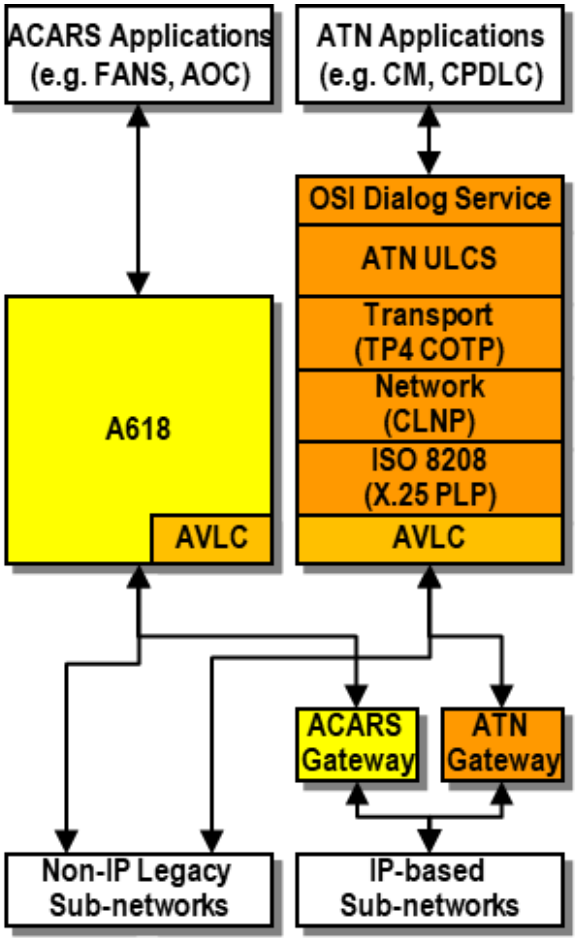
Current Air Traffic Services Datalink Situation

- **Two Air Traffic Control (ATC) datalink standards in use causes issues for airframers on many levels:**
  - Communication and application protocols for the two standards are technically incompatible with each other
  - OSI is a complex protocol to implement
  - OSI is not widely supported in the marketplace (supplanted many years ago by TCP/IP), so it is also very expensive to implement and maintain
  - B1 (using OSI) is *mandated* in continental Europe, and only used in Europe
    - As of 2018 for ground systems, 2020 for aircraft (slipped 5 years from original date due to technical issues – still not all ground systems are ready as of 2022)
    - Cannot fly above FL285 in Europe if not equipped
  - FANS-1/A ATC services are *mandated* in the North Atlantic
  - US uses FANS-1/A in domestic and oceanic airspace
  - FANS-1/A usage continues to grow around the world
- **Aircraft that operate in Europe and North Atlantic (or other parts of the world) have to implement both protocols**

What this means from a conceptual standpoint

- **Forced architecture support – two protocol stacks, two sets of applications**

FANS = Future Air Navigation System, includes Controller Pilot Data Link Communications (CPDLC) and Automatic Dependent Surveillance Contract (ADS-C)
AOC = Airline Operations Communications



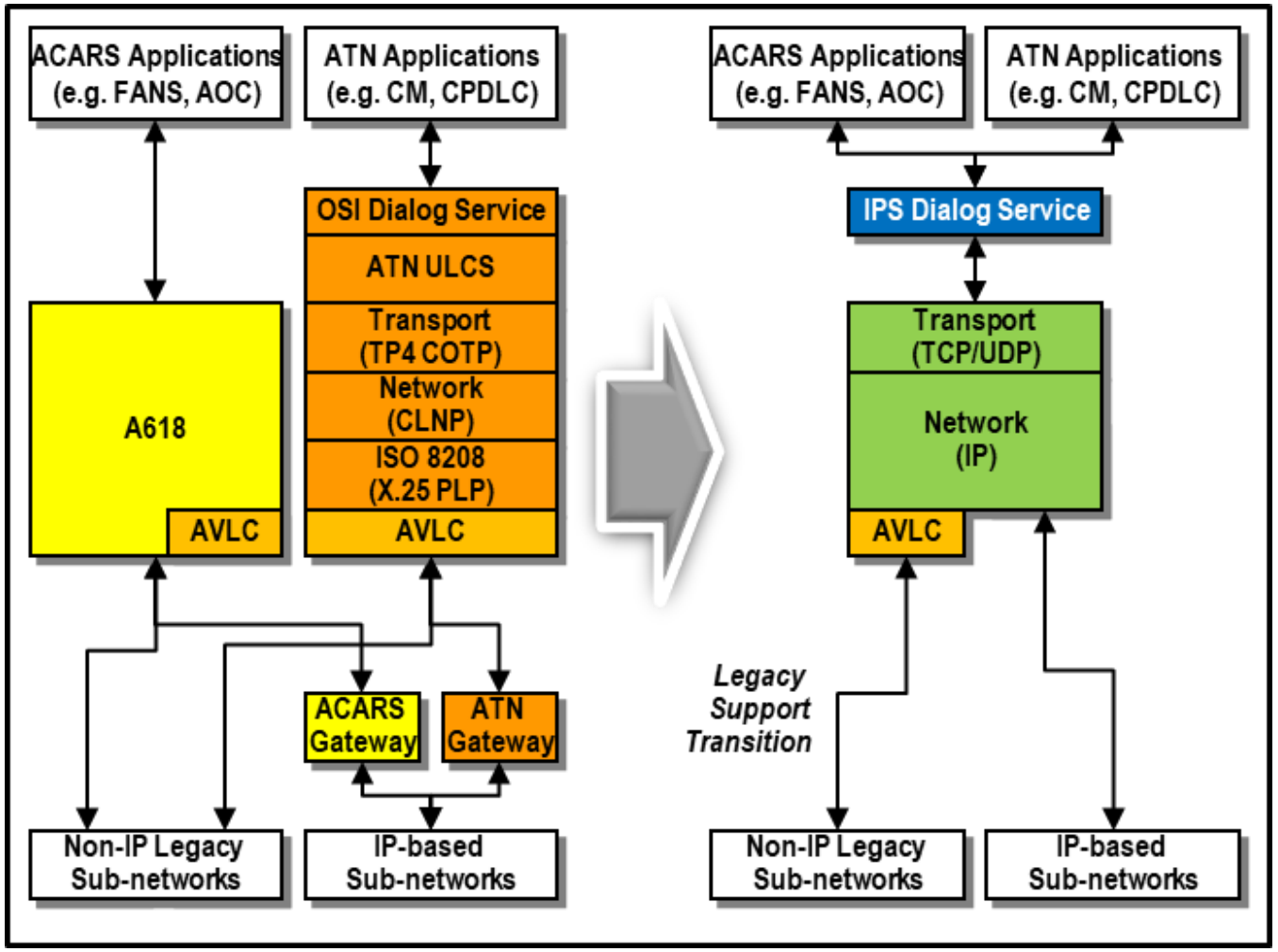
CM = Context Management application
CPDLC = Controller Pilot Data Link Communications application

Source: "Internet Protocol Suite for Safety Services: Progress Towards a Validated Standard", ICNS 2017

IPS Approach

- **IPS is intended to provide a migration from legacy ATN and ACARS to IP-based protocols**
- **Ground rule is to have no changes to the existing applications (e.g. CPDLC) while moving away from legacy protocols**
  - Avoids having to re-do flight decks, aircraft applications and ground systems
  - Removes dependency on applications from OSI protocols
  - Starts to provide real IP-based routing as opposed to ACARS character-oriented routing
  - Creates a logical transition path to future IP-based communication links
  - Can support AOC, FANS-1/A, B1 and B2 applications
  - Can provide a common security framework (e.g. Datagram Transport Layer Security, DTLS)
- **IPS is being specified to support extensibility for other uses (e.g. UAS/UAM)**
  - Acceptable means of compliance for UAS C2 per DO-377A

IPS Protocol Transition



Source: "Internet Protocol Suite for Safety Services: Progress Towards a Validated Standard", ICNS 2017

Benefits of moving to IPS

- Commonality with mainstream communication protocols
  - Greater availability of commercial off-the-shelf (COTS) solutions
  - Greater access to technical expertise
- Protocol stack simplification, which supports movement toward simplified, unified aircraft architectures
- Compatibility with broadband IP-based sub-networks for safety services
  - Inmarsat Swift Broadband (SBB)
  - Iridium NEXT
  - Aeronautical Mobile Airport Communications System (AeroMACS)
  - L-band Digital Aeronautical Communication System (LDACS) – *future*
- Cybersecurity features absent from existing ACARS and ATN

Source: "Internet Protocol Suite for Safety Services: Progress Towards a Validated Standard", ICNS 2017

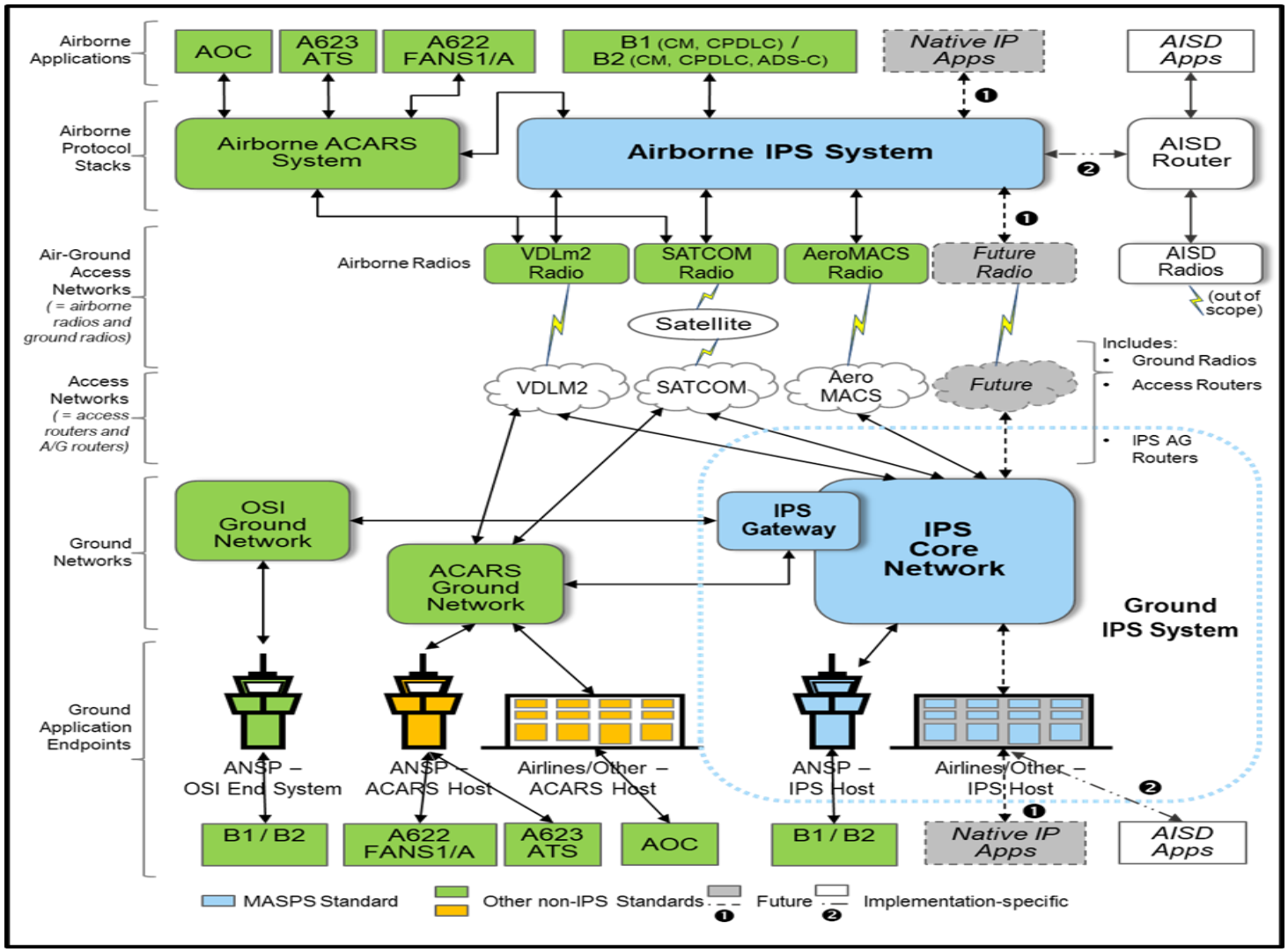
IPS enables cost, performance, and security improvements

What is IPS?

- Commercial Internet is already on the aircraft!! Is that good enough?
  - **NO,** because it has too many security vulnerabilities and options that will affect performance & interoperability required for Safety Services
    - Internet is not secure. Why?
      - Is the protocol deficient? – **Yes,** leaves too many penetration points, if not implemented carefully
      - Is commercial software not adequate permitting exploitation? – **Possible.** Same rational why DO-178B process is needed
      - Open Internet: **Anyone can reach anything on aircraft** – addressing, web-crawler, bored kids, terrorists!!
- Is IPS so unique (like OSI) that OEMs and vendors must build it from scratch, which adds Complexity, cost, obsolescence, maintainability….
  - **NO**. Commercial IP stack available for DO-178B implementation
- **Internet Protocol Suite (IPS) for aviation**
  - **Characteristics:**
    - Commercial IP RFCs, Profiled and architected correctly to protect flight-safety equipment, applications and services from intentional AND unintentional unauthorized access
    - IETF RFCs are Profiled to restrict protocol elements that introduces vulnerabilities while maintains lower cost, upgrade flexibility, compatibility with commercial Internet
    - Strong Security – Meets all C2 SERs plus offers Domain isolation, interface control, firewall, port filtering, etc. to prevent exploitation
    - Meets requirements for safety services and accommodates use of commercial data links
      - Meets operator goals for flexibility, growth, agility, maintainability
    - Assures performance through effective and consistent use of QoS through intermediate public/private networks

Honeywell

IPS System Architecture
End-End Perspective



Source: Draft IPS MASPS

IPS Harmonization & Industry Standardization

US-EU Harmonization Efforts

- The US and Europe are developing a joint data communications strategy to align respective implementations to facilitate interoperability
- While still a work in progress, there is agreement on IPS as the end-state network technology

ICAO

- Completion and evolution of IPS technical provisions and guidance material
- Deliverables
  - Doc 9896 IPS Manual
  - Docs 10090, 10094, 10095, 10145 - Security

RTCA / EUROCAE

- IPS Protocol Profiles
  - RFCs per Doc 9896 plus RFCs that address mobility, security, etc.
- MASPS
  - Allocate performance / QoS requirements from SC-214 / SC-206
  - Define test scenarios

AEEC

- Phase 1: Aircraft architecture & roadmap
  - Completed A658
- Phase 2: Specifications
  - Core IPS protocol stack
  - Domain isolation, port filtering, firewall
  - System & security Mgmt.
  - First ed A858 published, 2021

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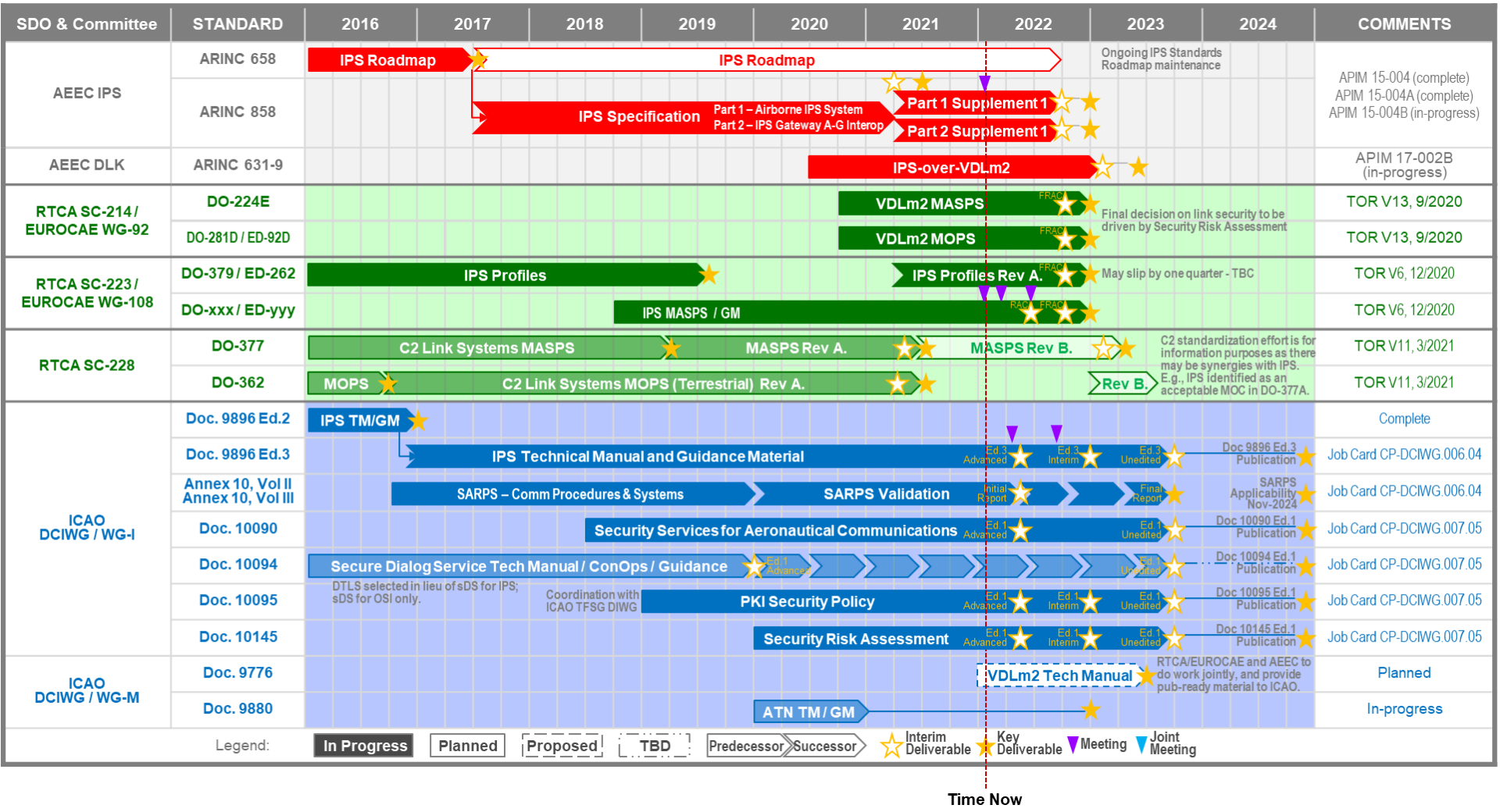
Recognized need for globally harmonized IPS standards

ATN/IPS A/G Standardization Roadmap
(rev. 2021-11-12)



Source: ARINC Specification 658

IPS Lab and Flight Test Activities

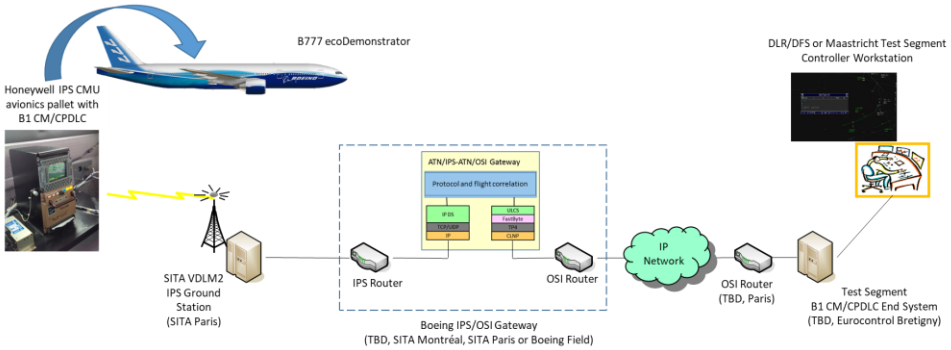
- **Initial application-level compatibility proven with Honeywell prototype IPS CMU**
  - Inmarsat and SITA provided SATCOM and VHF connectivity, respectively
  - Tested in a standard Boeing 737 avionics bench at Boeing lab facilities
  - No changes to ATS functionality from the flight crew and avionics perspective
  - B1 and FANS-1/A exchanges over IPS using VDLM2, SwiftBroadband
- **Initial flight trials in Honeywell KingAir test aircraft**
- **Lots of lessons learned**
- **Additional partners Airtel ATN and Collins Aerospace added**

Validation of IPS specifications and interoperability demonstrated

2019 ecoDemonstrator IPS Activities

- **Test FANS-1/A messaging over IPS using VDLM2 on continental US flights, connected to FANS-1/A over IPS ground end system**
- **Test B1 messaging over IPS using VDLM2 on continental US flights, connected to B1 over IPS ground end system**
- **Test B1 messaging over IPS using VDLM2 on European continental flight, using an OSI/IPS Gateway connected to B1 over ATN/OSI ground end system**

B1/IPS aircraft connected to OSI End System
via VDLM2 and IPS/OSI gateway



Further validation and testing of IPS viability in a live flight environment along with the IPS Gateway concept

2021 ecoDemonstrator IPS Activities

- **Two suppliers provided CMUs:**
  - Collins red label IPS CMU, including security, multilink
  - Honeywell soft CMU and IPS router, including mobility and multilink
- **ARINC (Collins) and SITA provided VHF Ground Stations**
  - Collins also provided IPS-ACARS Gateway
- **Inmarsat and Cobham provided SATCOM broadband IPS connectivity service and hardware**
- **Boeing and Collins provided FANS-1/A, B1, and AOC ground end systems**

- **FAA FANS/CPDLC Ground Test Tool inclusion from the FAA Tech Center via IPS-ACARS Gateway**
  - Typical FANS-1/A Messaging scenarios
- **Alaska Airlines AOC center inclusion for AOC messaging via IPS-ACARS Gateway**

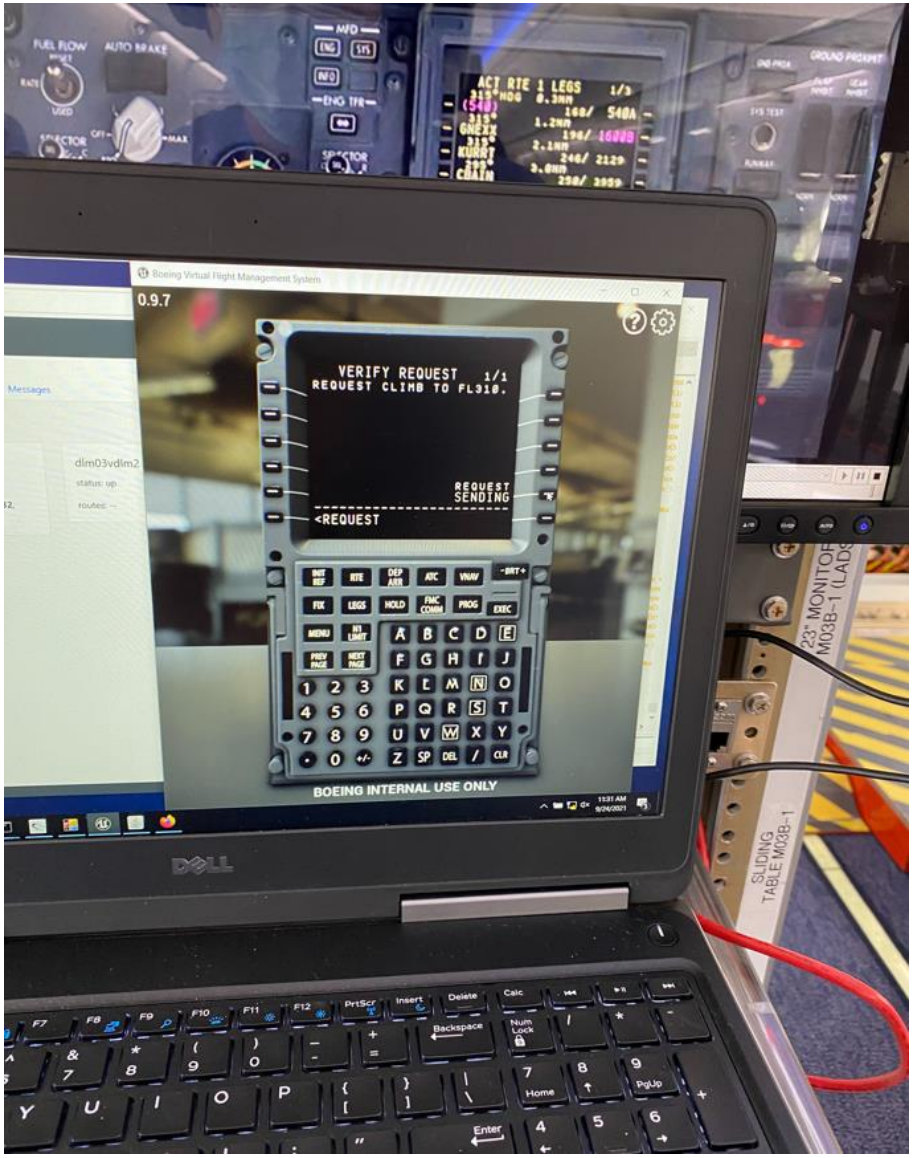
All results and lessons learned fed back into standards and validation reports

Collins Flight Test Summary

- Two flights total within CONUS using both SATCOM and VDLM2
- Datagram Transport Layer Security (DTLS) authentication, protecting VDLM2 communications.
- FAA Test Facility and crew exchanged FANS 1/A CPDLC messages over UI connectionless VDLM2 via IPS Gateway
- ADS-C periodic and waypoint contracts established with aircraft; reports downlinked via IPS throughout the flights
- Using connectionless VDLM2, Baseline 1 (B1) CM logon and CPDLC messages were exchanged over IPS between aircraft crew and a Collins IPS end system.
- AOC messages over IPS were exchanged between the aircraft and Alaska Airline OPS center as well as AOC host in the Collins lab
- Still crunching performance data, but initial results very good

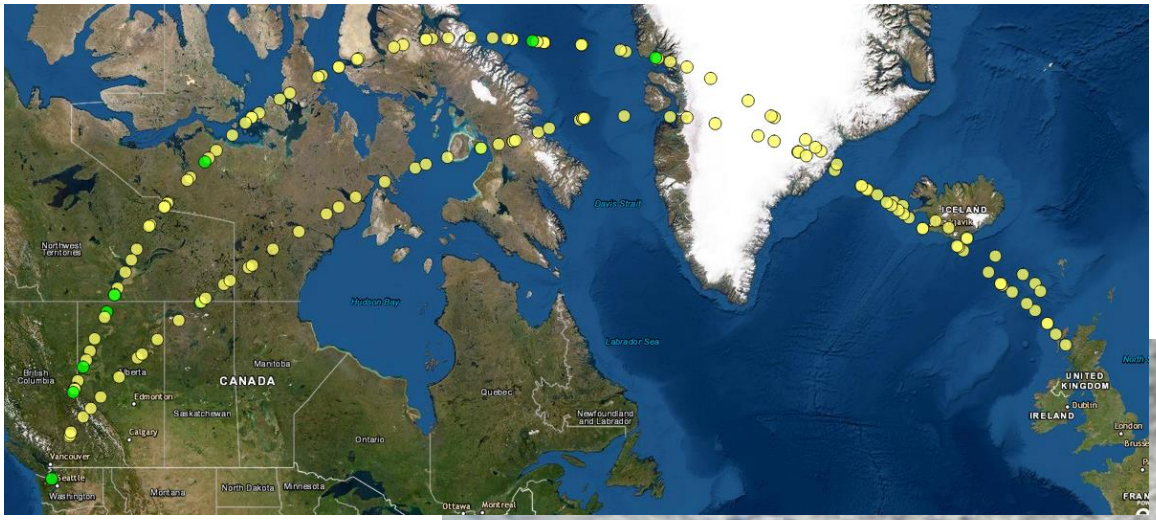
Honeywell Flight Test Summary

- **Four flights total**
  - Two CONUS, VHF and SATCOM
  - Two Europe, SATCOM only
- **Messaging controlled by simulated FMS at the instrumentation rack**
  - Both FANS-1/A and B1 messaging
  - Scripting technology employed
- **Very good performance for IPS**
  - Mobility tested; quick switchover
  - End-end times similar to existing technologies
  - SATCOM interface worked well; proposing as potential standard
- **Still crunching data**



Next Steps

- **Attended Glasgow Innovation/Sustainability Event**
  - Lots of positive press for IPS as enabler for advanced ATM
- **In discussions with partners for follow-on with future ecoDemonstrators**



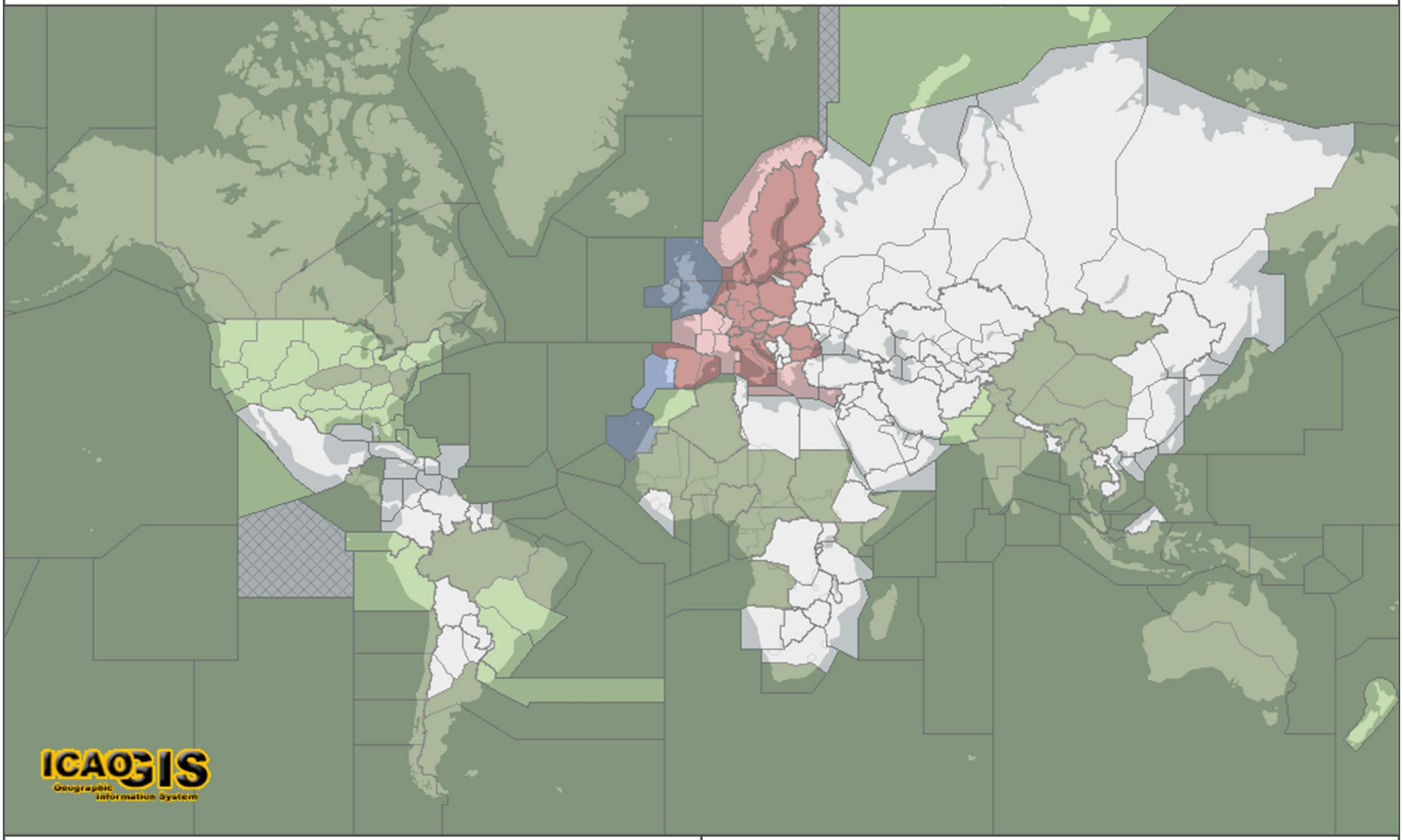
Questions?

Thank you!

Backup

Air Traffic Services (ATS) Data Link Map

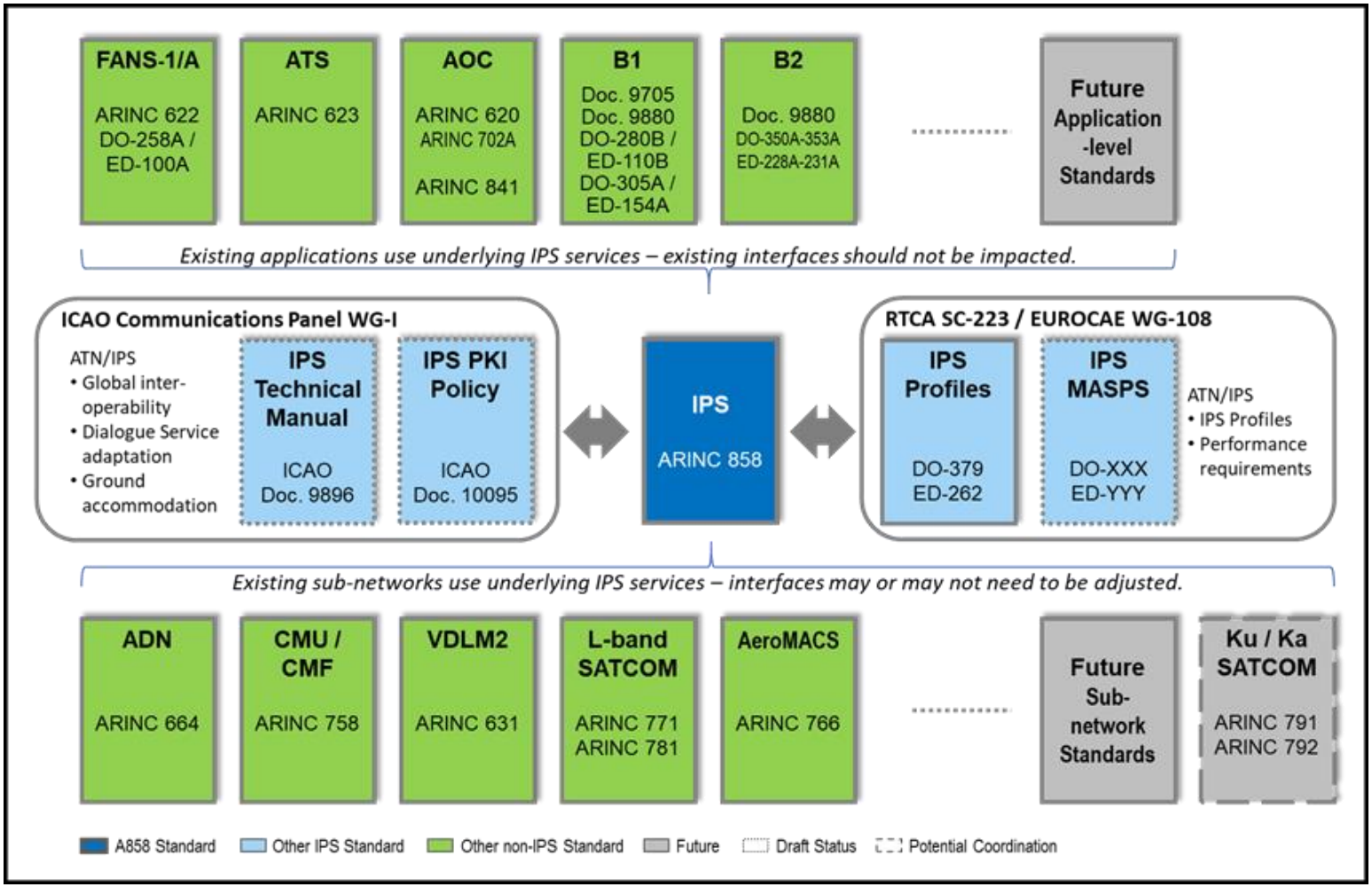
September 2021



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.

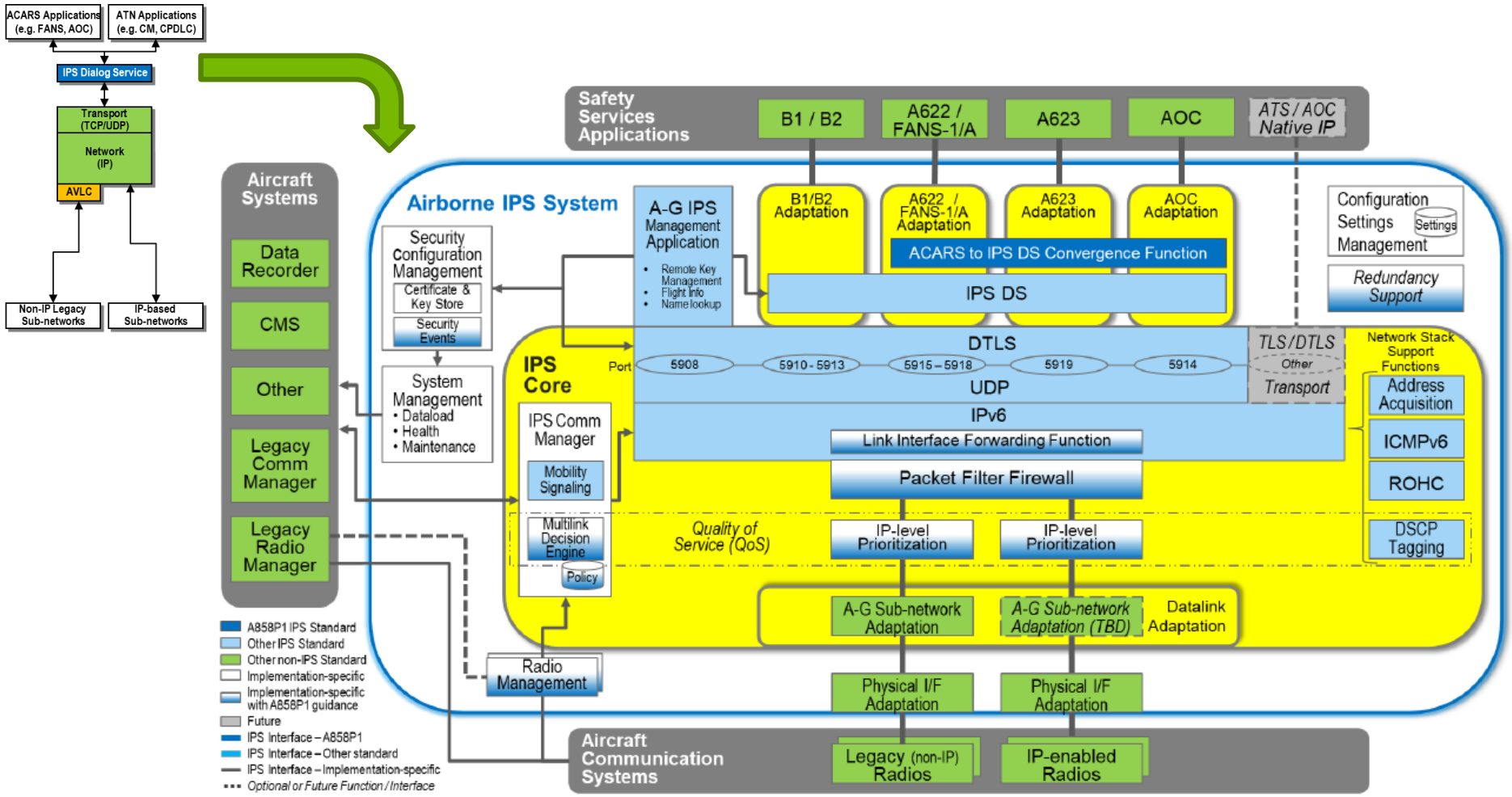
- FANS operational
- FANS planned
- FANS and Baseline 1 operational
- FANS and Baseline 1 planned
- Baseline 1 operational
- Baseline 1 planned
- No services operational or planned
- FIR not delegated by ICAO

IPS Relationship to other Standards Bodies



Source: ARINC Specification 858, Part 1

Diving into more detail…IPS architecture



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